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Digital Twin

Its Role and Structure within a Modern Systems Engineering Approach

SMSWG Meeting

March 12, 2019

SMS_ThinkTank™

Digital Twin
Its Role and Structure within a Modern Systems Engineering Approach

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Content *

- Digital Twin as part of Engineering Trends
- Digital Twin
  - Definition and Architecture
  - The Digital Twin and the Engineering “V”
  - How does a Digital Twin evolve?
  - What are various aspects of the Digital Twin in terms of applications?
  - What is the Role of the Digital Twin?
    - In terms of the engineering lifecycle
    - In terms of business maturity
  - Examples
- Future Considerations

* Based on Publication: Edward A Ladzinski, Frank W Popielas, Don Tolle - SMS_ThinkTank™ white paper: “Digital Twin - *Its Role and structure within a modern Systems Engineering Approach”;* February 20, 2019
* Presented at the COExperience 2019; New Orleans, LA, US, February 25-27, 2019

Digital Twin as part of Engineering Trends

Market Challenges and Engineering Trends

Market:

- Global Economy
- Faster than ever changing / evolving technology
- The age of data and information
- Digitalization, visualization, and collaboration
- The complexity issue

Engineering:

- Increased complexity
- Demand for more flexibility and choices
- Improved product quality and robustness guarantee
- Digitalization
- Sustainable innovation

More complex technologies are challenging the ability for middle and upper management to understand the emerging needs of the business

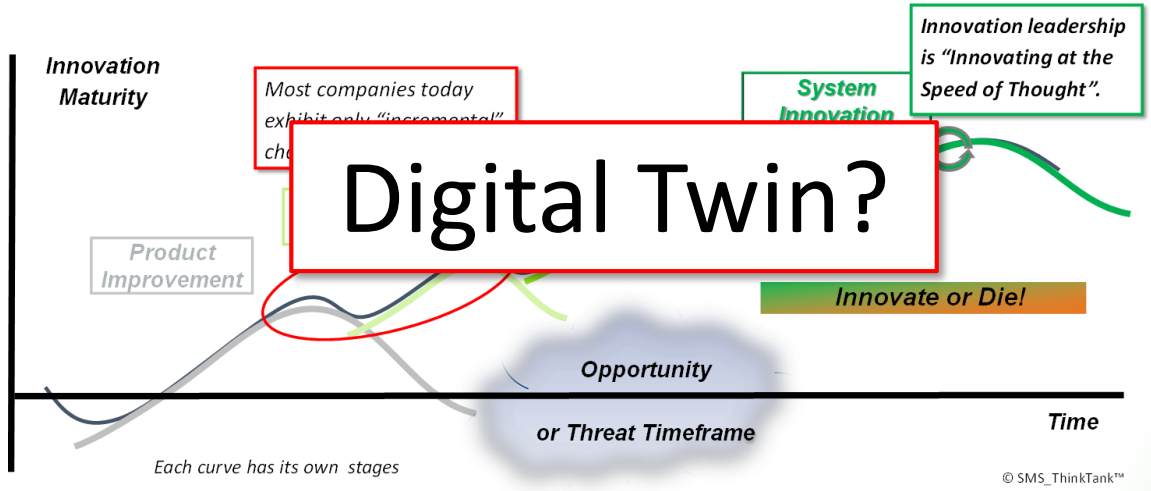
- *Companies are operating in an ever leaner environment*
- *Ever growing demand for accountability*

Achieving Sustainable Innovation

SMS is the use of interdisciplinary functional, architectural, and behavioral models (with physical, mathematical, and logical representations) in performing ***MBSE (Model-Based Systems Engineering)*** to specify, conceptualize, design, analyze, verify and validate an organized set of components, subsystems, systems, and processes….. *

- System modeling and simulation
- IIoT and Industry 4.0
  - New era in manufacturing
- Big Data and IoT
  - The way we collect and distribute data is changing rapidly
  - New infrastructure needed
- Iterative and collaborative approaches
  - Closed-loop
  - Across domains and organizations
- Cognitive engineering
  - Predictive analytics
  - Deep learning
  - **Digital twin**

Innovating at the Speed of Thought



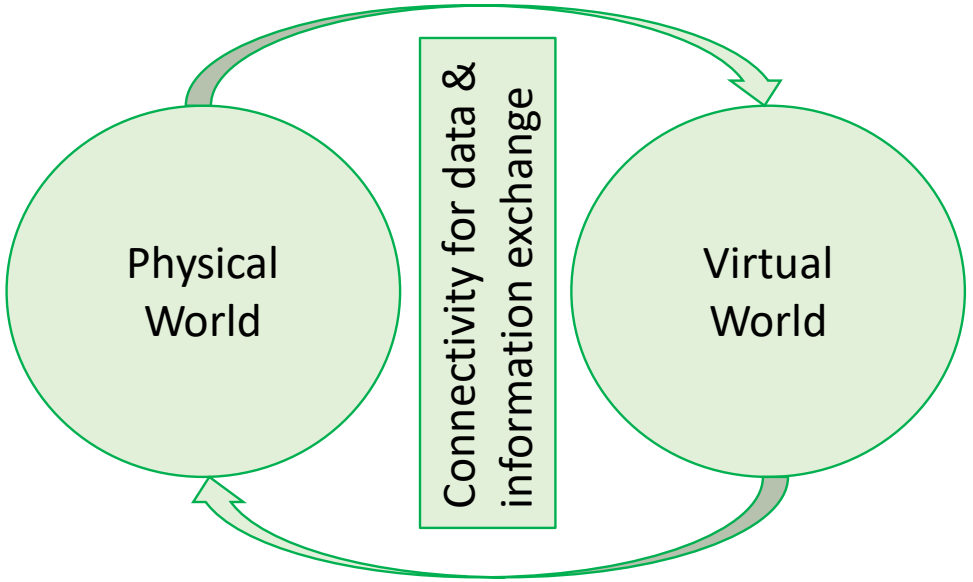
*SMSWG – Terms & Definitions: https://www.nafems.org/about/technical-working-groups/systems_modeling/smstermsdefinitions/s-u/

Digital Twin

Digital Twin Definition and Basic Architecture

Digital Twin* refers to a digital surrogate that is a dynamic physics-based description of physical assets, processes and / or systems that can be used for various purposes.

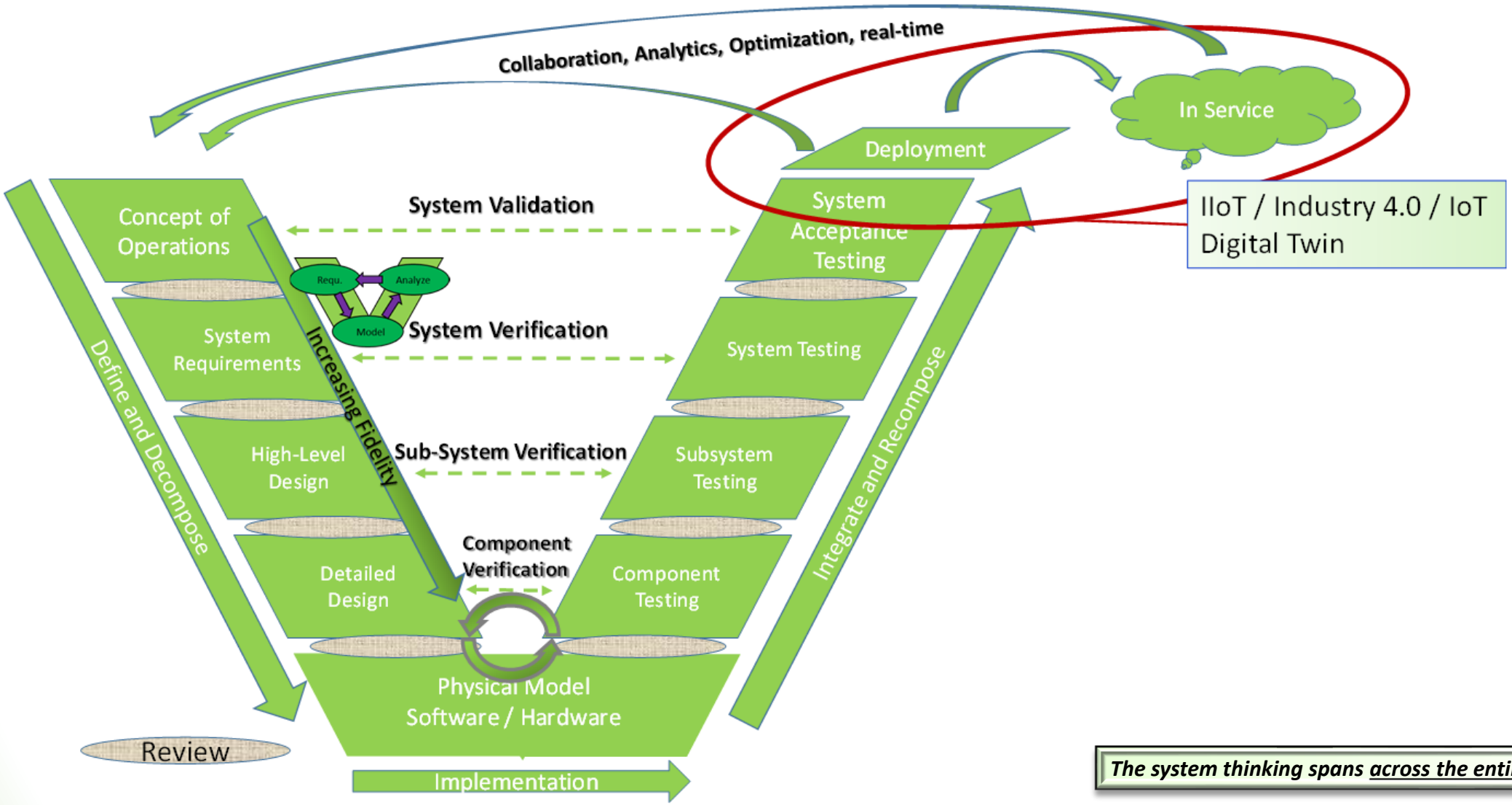
The twin accompanies its real-world companion throughout its lifecycle—being changed in tandem with the physical version.



Simplified Architecture

* adapted from https://en.wikipedia.org/wiki/Digital_twin, and https://www.dodmantech.com/ManTechPrograms/Files/AirForce/Cleared_DT_for_Website.pdf

Digital Twin – The engineering “V” and Lifecycle



The system thinking spans <u>across the entire</u> life cycle, ……

How does the Digital Twin evolves?

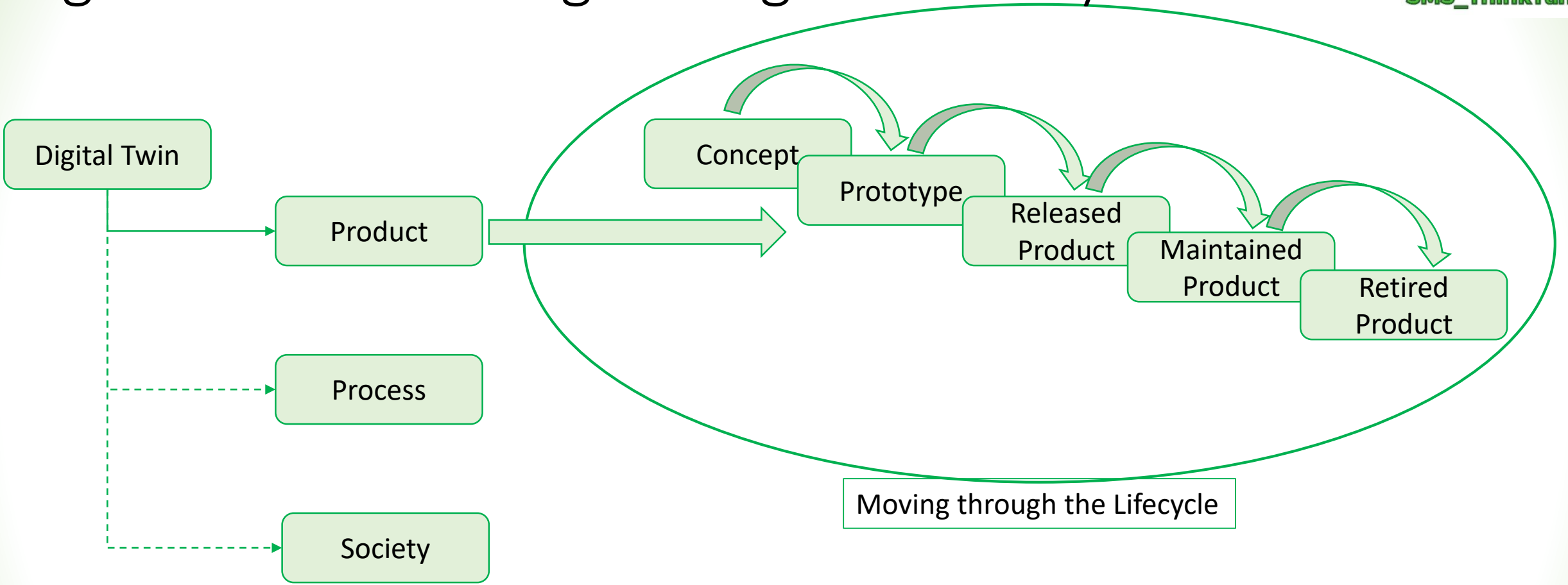
Innovation	Pioneering	Growth	Maturation	Decline	Retirement

Traditional fundamental lifecycle stages

When can we first talk about the Digital Twin?

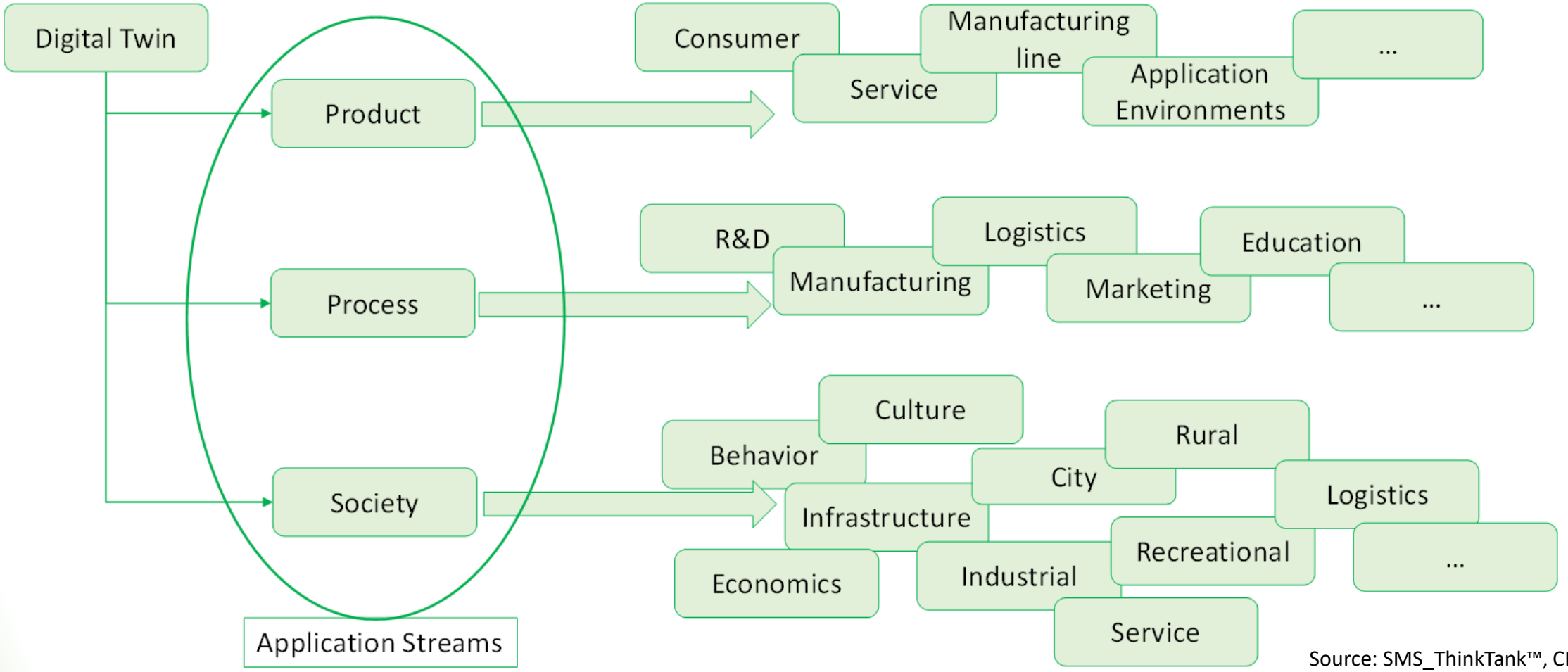
- At the point when a product or process is released into the real world and is associated with its “as released” virtual model this virtual model becomes the Digital Twin of the real-world asset.

Digital Twin – Moving through the Lifecycle



Source: SMS_ThinkTank™, CIMdata

Digital Twin – Application streams



Source: SMS_ThinkTank™, CIMdata

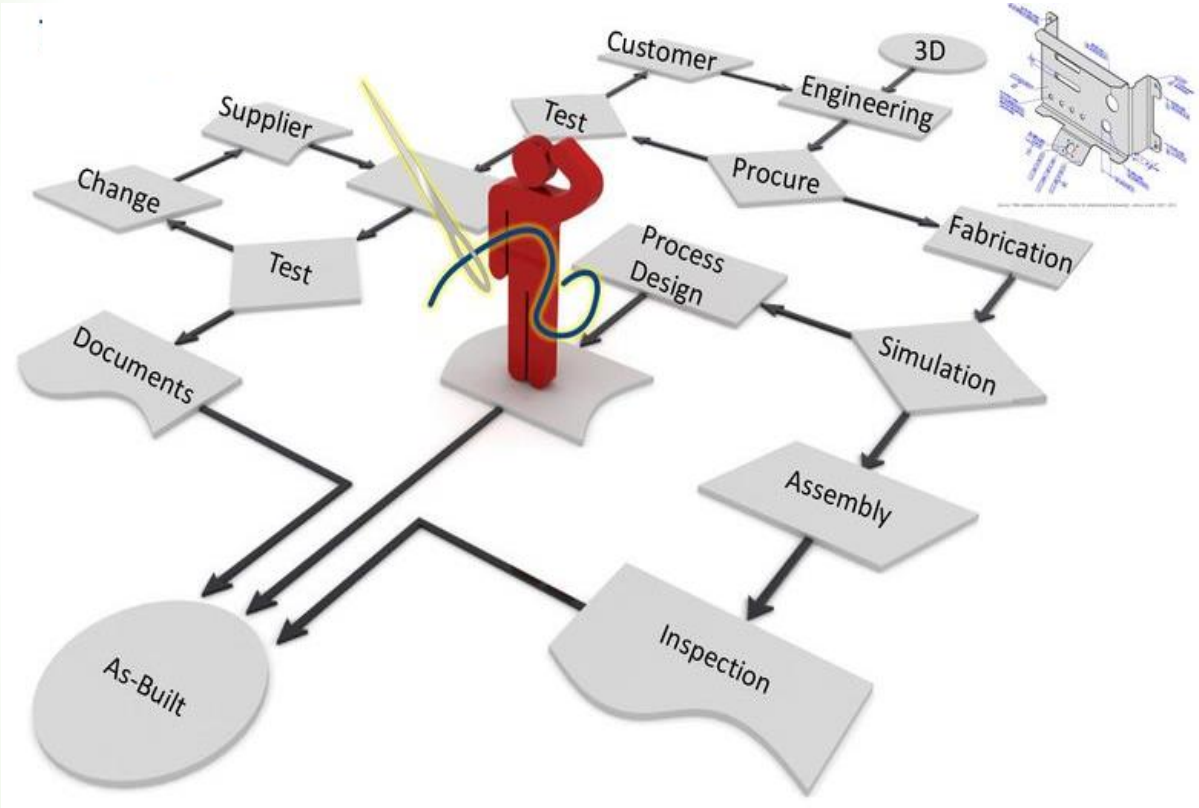
The Role of Platforms and the Digital Thread

- The Digital Twin lives and grows based on more and better operations data
- That data can come from the physical product or process operating in the real world as well as from the virtual world
- Per the previous discussion around the graphic “Innovating at the Speed of Thought” it shows the importance for a proper data backbone
- In today’s enterprise application environments, the **Product Innovation Platform** not only takes on the role of such a backbone but, at the same time connects all users and their information in a single environment to cultivate continuous creativity, yielding improvements in products and processes, plus inspiring new and better innovations throughout full lifecycles and across generations of products

CIMdata®

CIMdata’s Product Innovation Platform

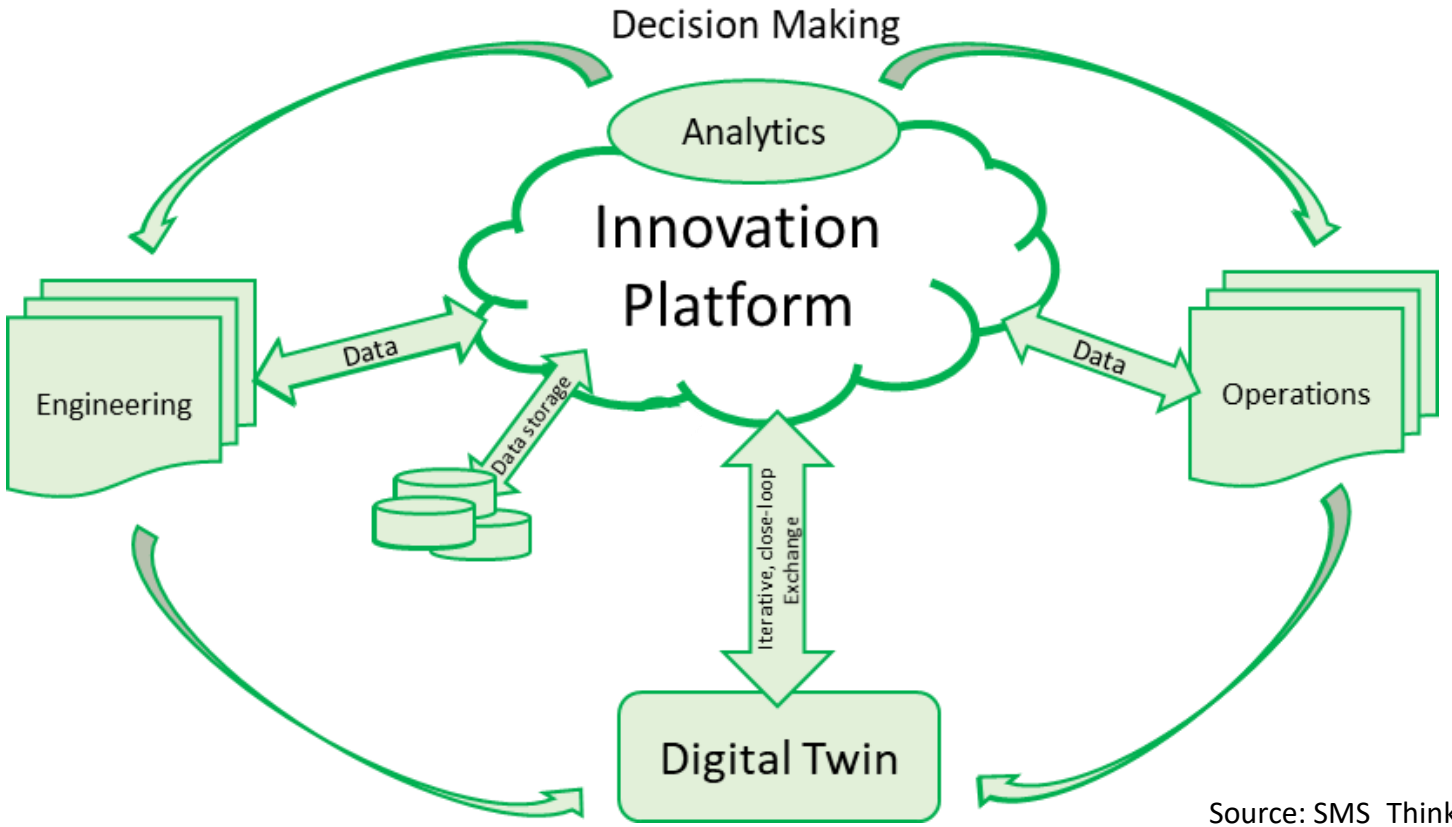
The Role of Platforms and the Digital Thread *



- Such platforms are the prerequisites to enable the **Digital Thread.**
- The digital thread is the foundational requirement to enable the Digital Twin.
- The Digital Twin needs to have access to the entire history and the current state of a product (or process) to help improve future designs (or processes) or optimize the performance of such while in operation.
- This highlights the importance of an **iterative, agile, and closed-loop <u>end-to-end</u> approach.**

* http://www.manufacturing-operations-management.com/manufacturing/2016/04/what-is-the-digital-thread-and-digital-twin-definition.html

Going Beyond the “V”

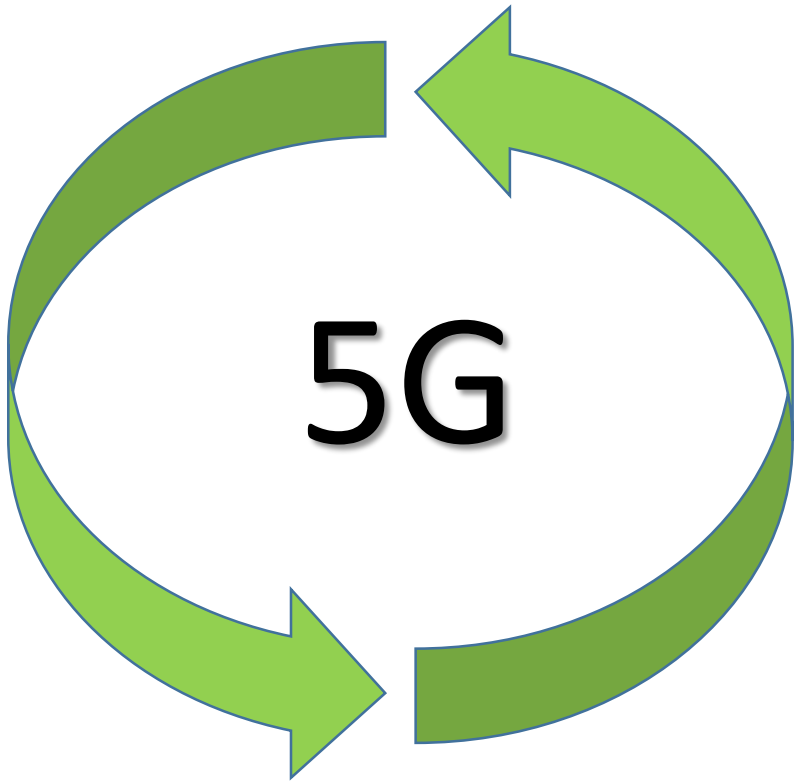


Source: SMS_ThinkTank™, CIMdata

Typically, there are several platforms involved to realize all the benefits of having a Digital Twin available. The underlying Product Innovation Platform needs to be able to bring the threads of all those platforms together to ensure that data and information is consistent and not duplicated.

Cognitive Engineering / Ecosystem

- IoT
- **Digital twin**
- Deep learning
- Predictive analytics



Innovating at the Speed of Thought

- Close-looped systems
- Edge computing
- **Scalable infrastructure**

IIoT / Industry 4.0: Model from Ideation to Utilization

Millions / Billions of devices are interconnected

Courtesy of GE Digital (GE.com)

- Digital prototypes (Models) will be followed by Physical Prototypes
- This creates the linked Digital Twin

Example: IBM Watson IoT for Automotive

the platform for connected vehicles

Driver behavior – identify risky behavior and help improve efficiency	Context for your location-based applications	Smarter resource and optimization
Understanding of the individual driving patterns of a vehicle operator to identify risky behavior, and violation of policies.	Highly accurate map matching foundation capabilities to locate the geospatial data to the road network geometry	Utilize cognitive ability to learn who the driver is, personality in the moment, environment inside and outside the vehicle, natural language interactions between the people and the vehicle
Drivers are 10 times more likely to get into an accident if they're distracted, emotional, or upset	Quickly create navigation that updates based on live information	Auto companies intend to increase their digital interaction with consumers 76% in the next 5 years

10 Watson IoT / IoT Platform

Watson IoT

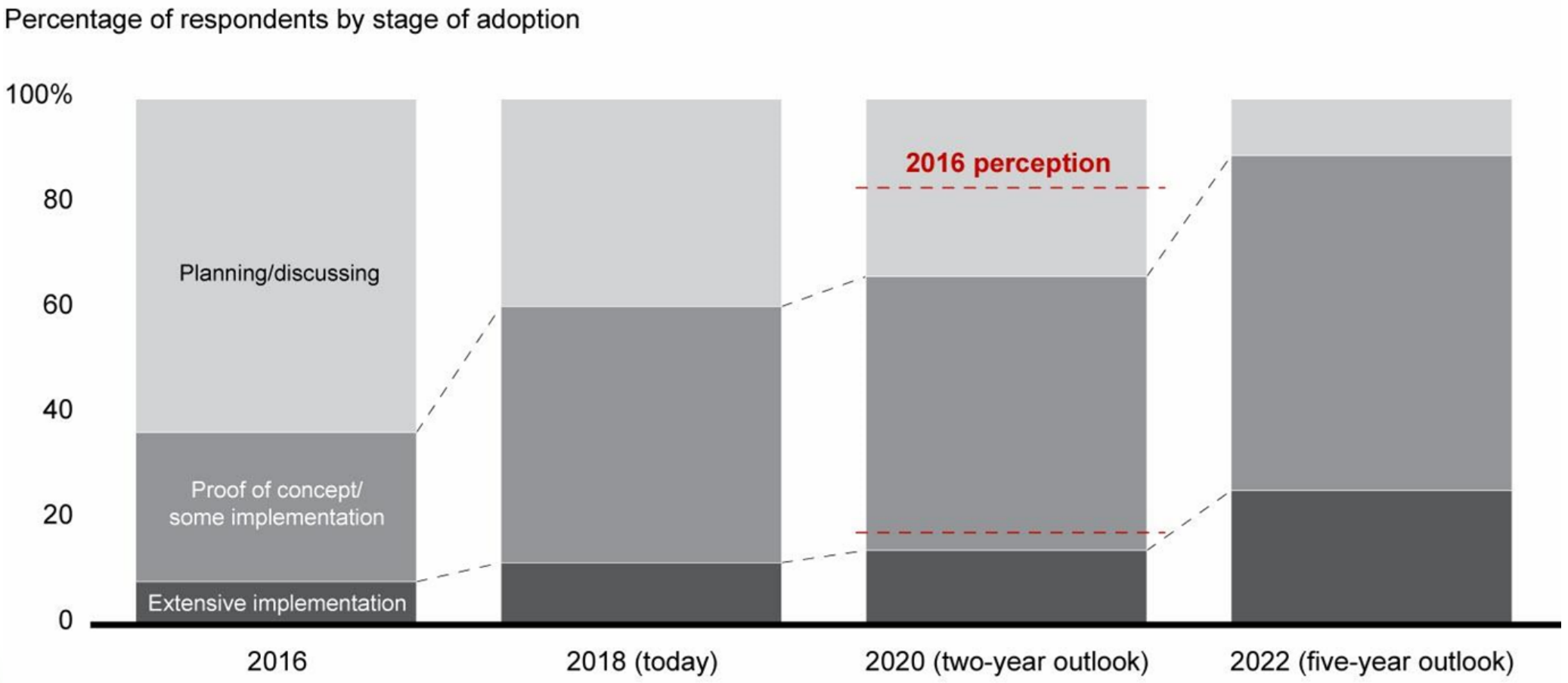
*Source: IBM Watson IoT Connected_Products_Presentation_July 2017

Honda R&D is using IBM IoT for Automotive to understand vehicle sensor data and identify safety situations.

Honda R&D is developing future capabilities leveraging IBM's IoT for Automotive offering. In the future, Honda cars will be able to understand data from vehicle sensors, their surroundings, and share that data with others drivers enabling Honda drivers and vehicles to take preventative actions in real time. The goal is to have this on the road by the 2020 Olympic Games.

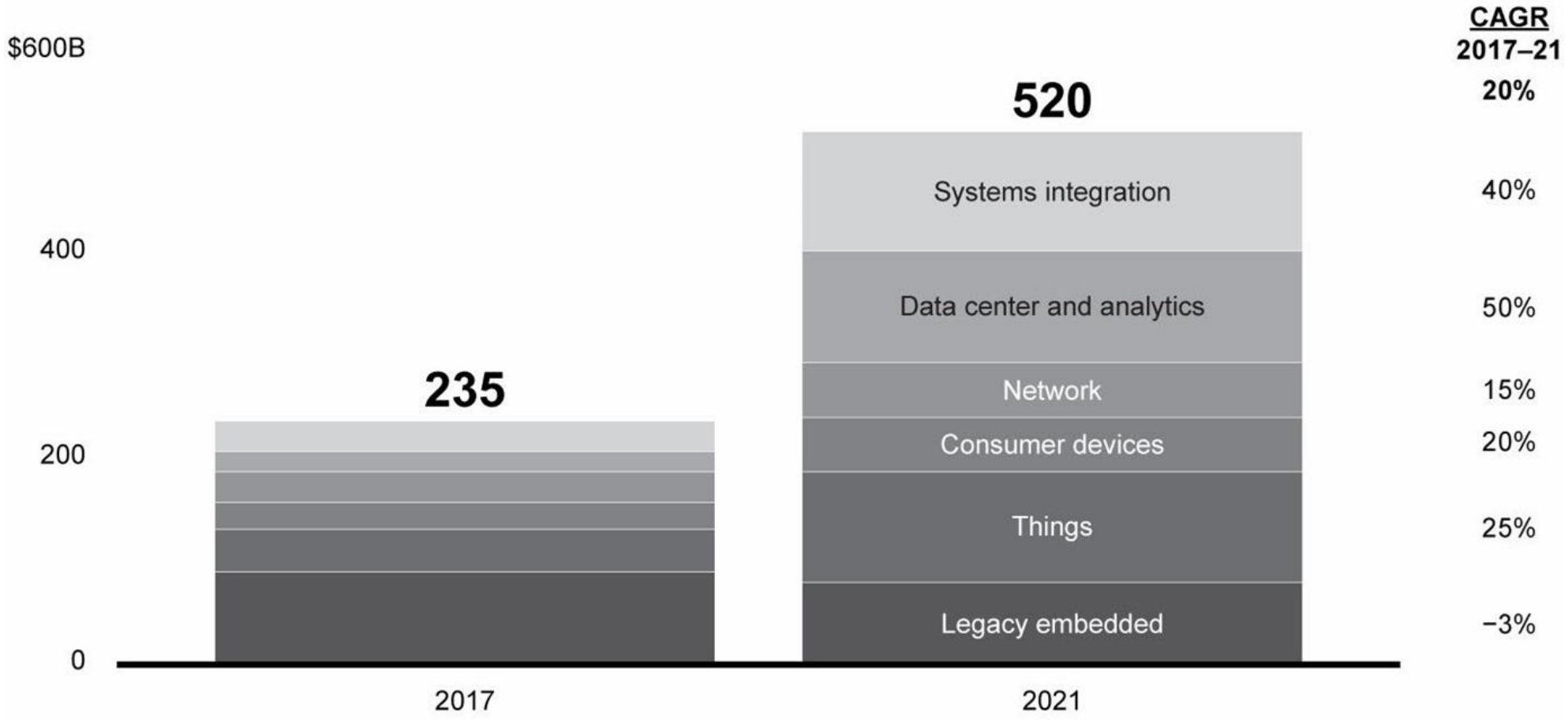
*Source: IBM Watson IoT Connected_Products_Presentation_July 2017

The Hype of Digital Twin and IoT *



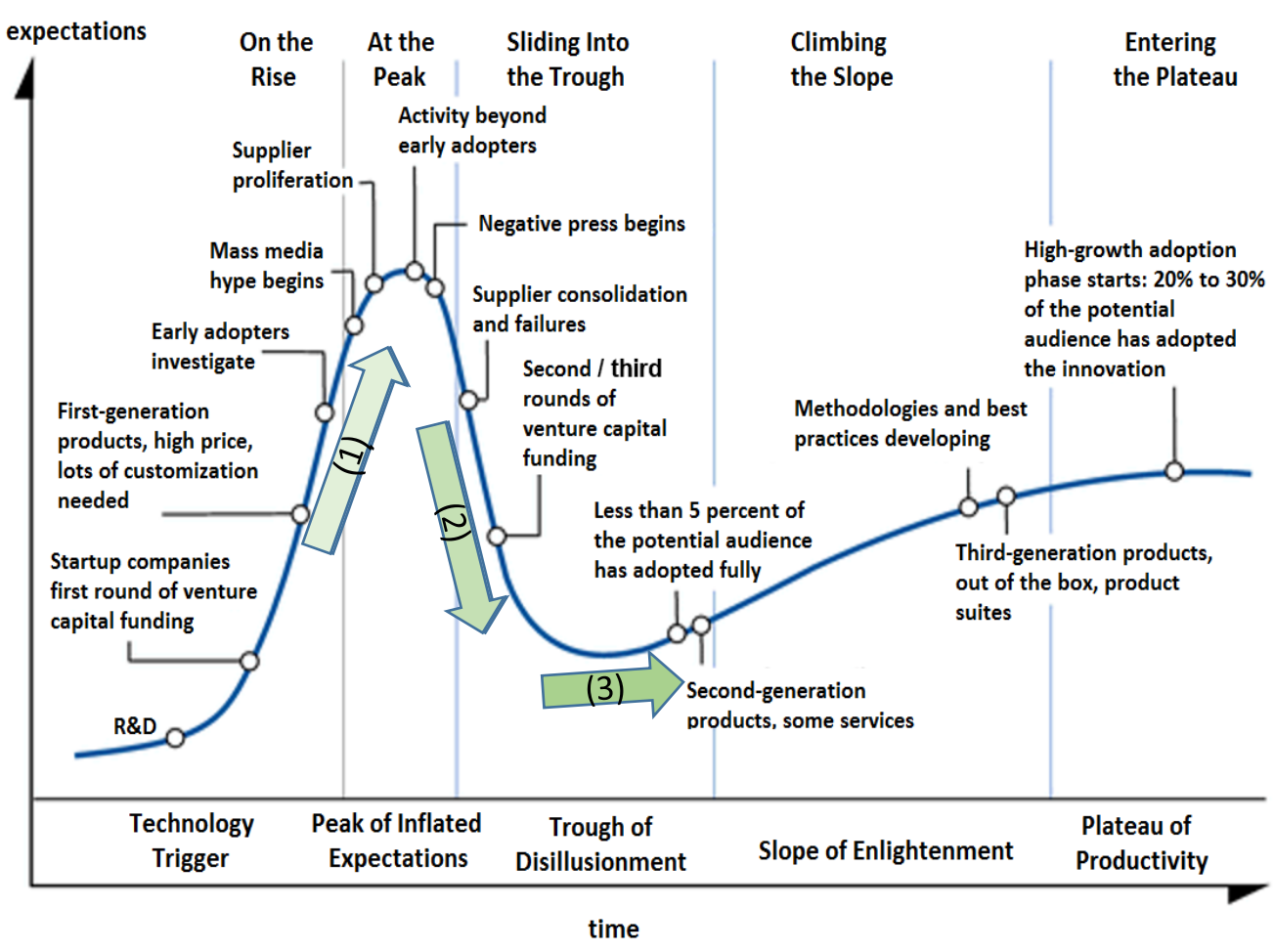
Source: https://www.forbes.com/sites/louiscolumbus/2018/08/16/iot-market-predicted-to-double-by-2021-reaching-520b/#7f10e0fd1f94

The Hype of Digital Twin and IoT *



Source: https://www.forbes.com/sites/louiscolumbus/2018/08/16/iot-market-predicted-to-double-by-2021-reaching-520b/#7f10e0fd1f94

Digital Twin – Maturity *

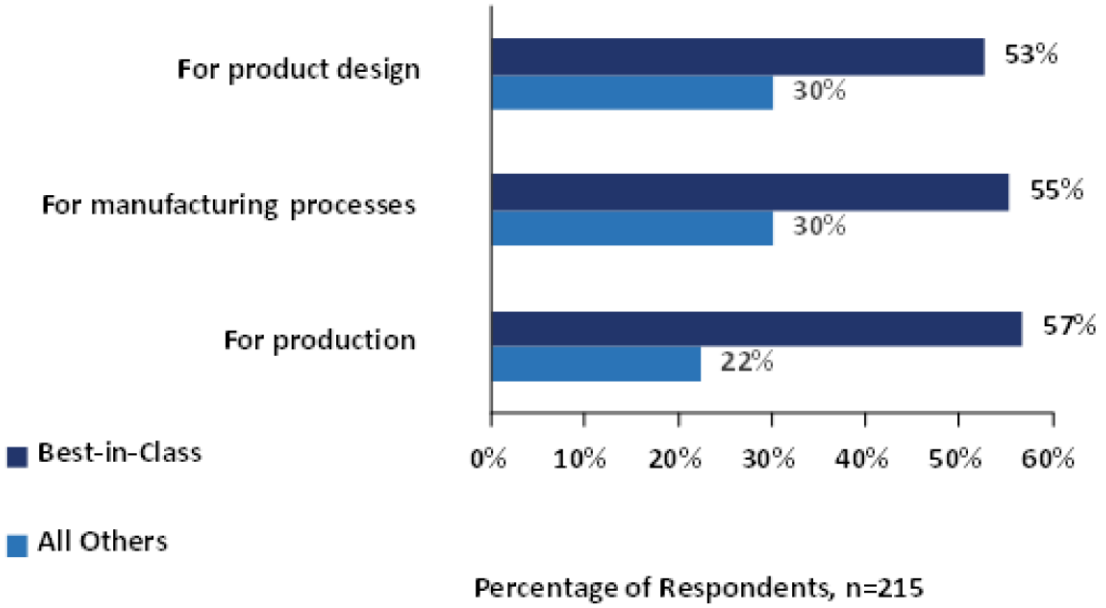


1. The majority of industry is still at the first up-slope
2. Companies that are typically focused on the machinery and equipment industries utilizing IIoT functionality as well as certain aspects of social media utilizing artificial intelligence (AI) capabilities
3. Thought leaders utilizing IIoT and focusing on Industry 4.0, as well as application of social media using the latest AI capabilities

Here we are not just talking about the level of Digital Twin maturity from a technology perspective but from an organizational and process point of view:

Is the business or organization ready for the Digital Twin?

The Centrality of the Digital Twin in Product Development



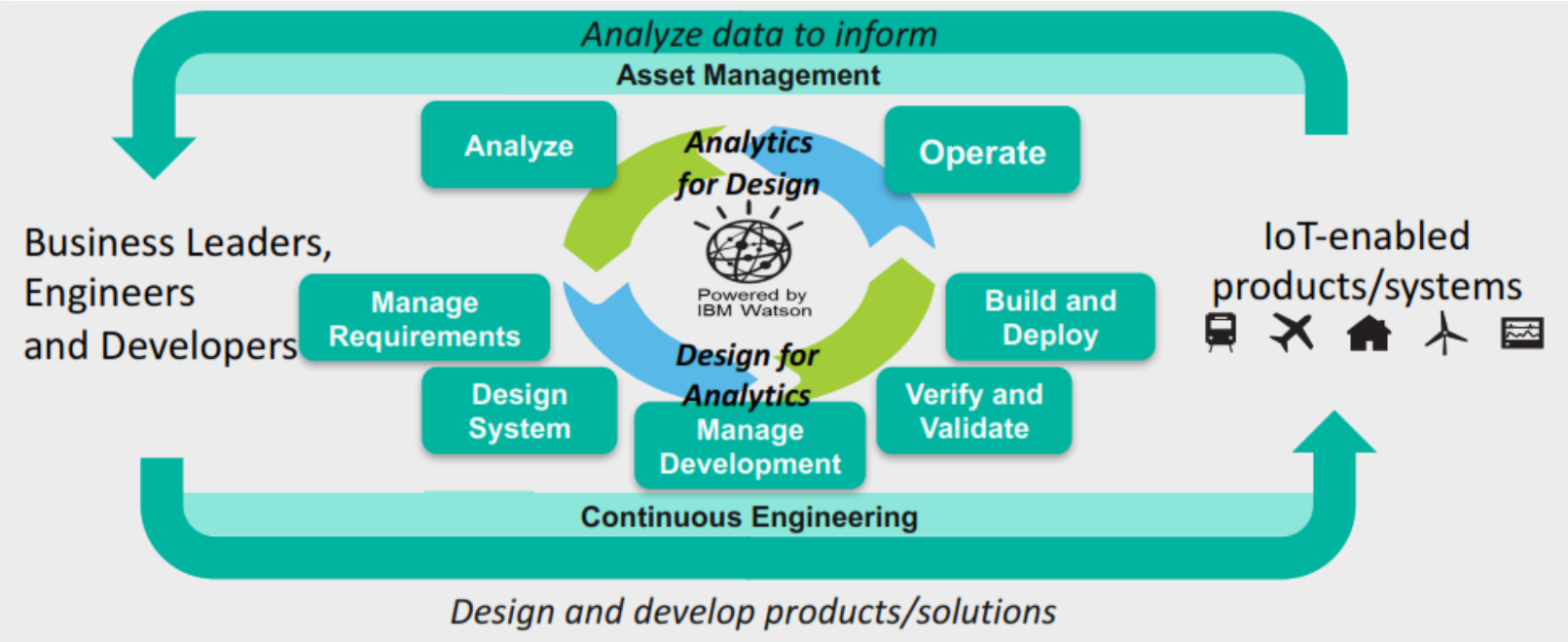
Best-in-Class firms are 1.8 times more likely than All Others to deploy the digital twin in designing products and in their manufacturing processes. In product production, the Best-in-Class edge jumps to 2.6 times more deployment of the digital twin than All Others.

- The Digital Twin is central to the digital transformation of product development among leaders
- Best-in-Class firms also recognized its transformational potential in major stages of product development

* Source: Aberdeen Group "Product Development and the Centrality of the Digital Twin"; July 2017

Cognitive Digital Twin Maturity *

The top-level maturity for the Digital Twin the "**Cognitive Digital Twin.**"

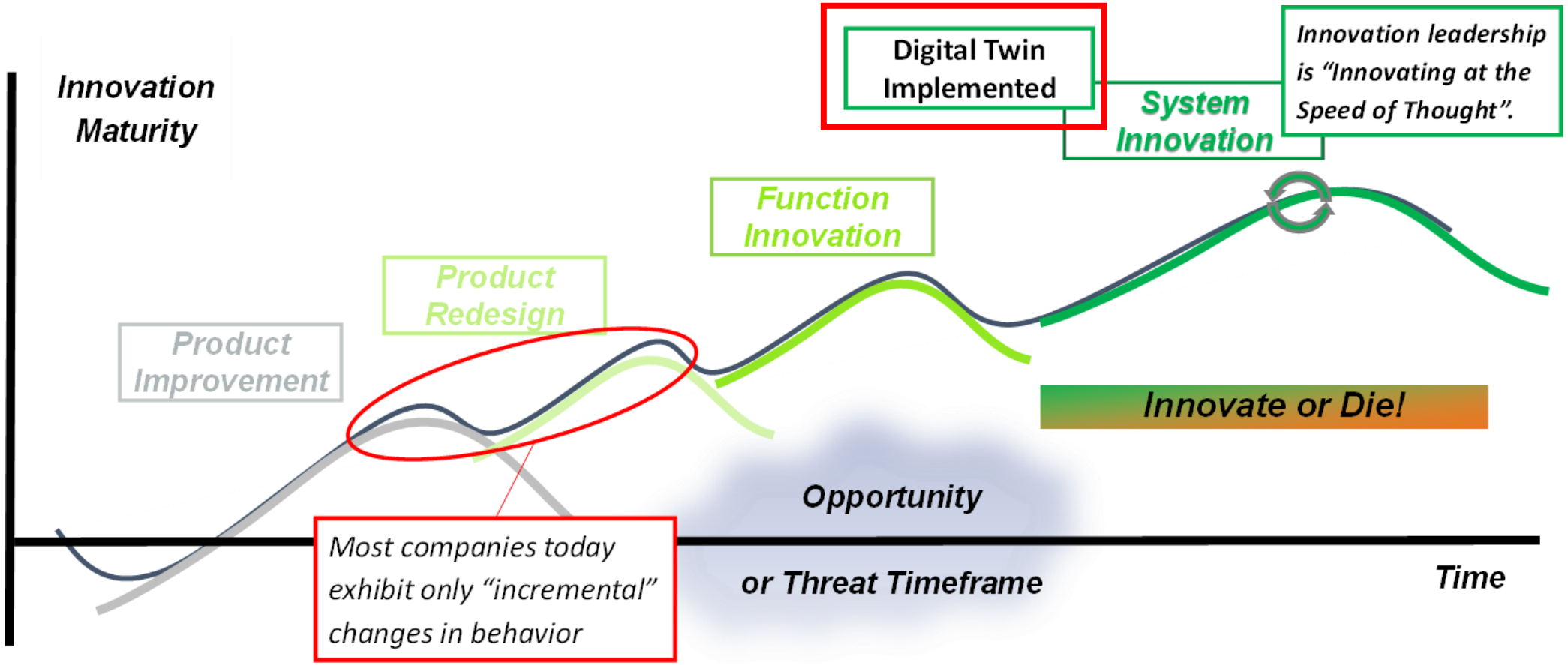


With the understanding of the word "cognitive" in conjunction with the top innovation maturity the major behaviors can be highlighted:

- Learn faster
- Adapt faster
- Innovate faster

*Source: IBM Watson IoT Connected_Products_Presentation_July 2017

Achieving Sustainable Innovation



With the enablement of Product Innovation Platform, IIoT, and IoT the Digital Twin can become reality and companies that are beginning to achieve the desired level of System Innovation will be the leaders in their segment.

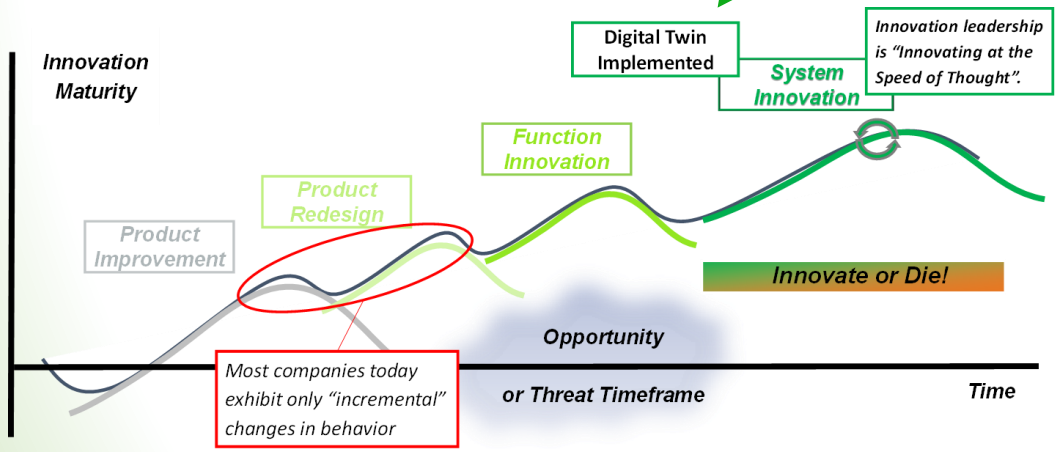
Achieving Sustainable Innovation

- Each S-curve typically has its own life cycle as traditionally defined

Innovation | Pioneering | Growth | Maturation | Decline | Retirement

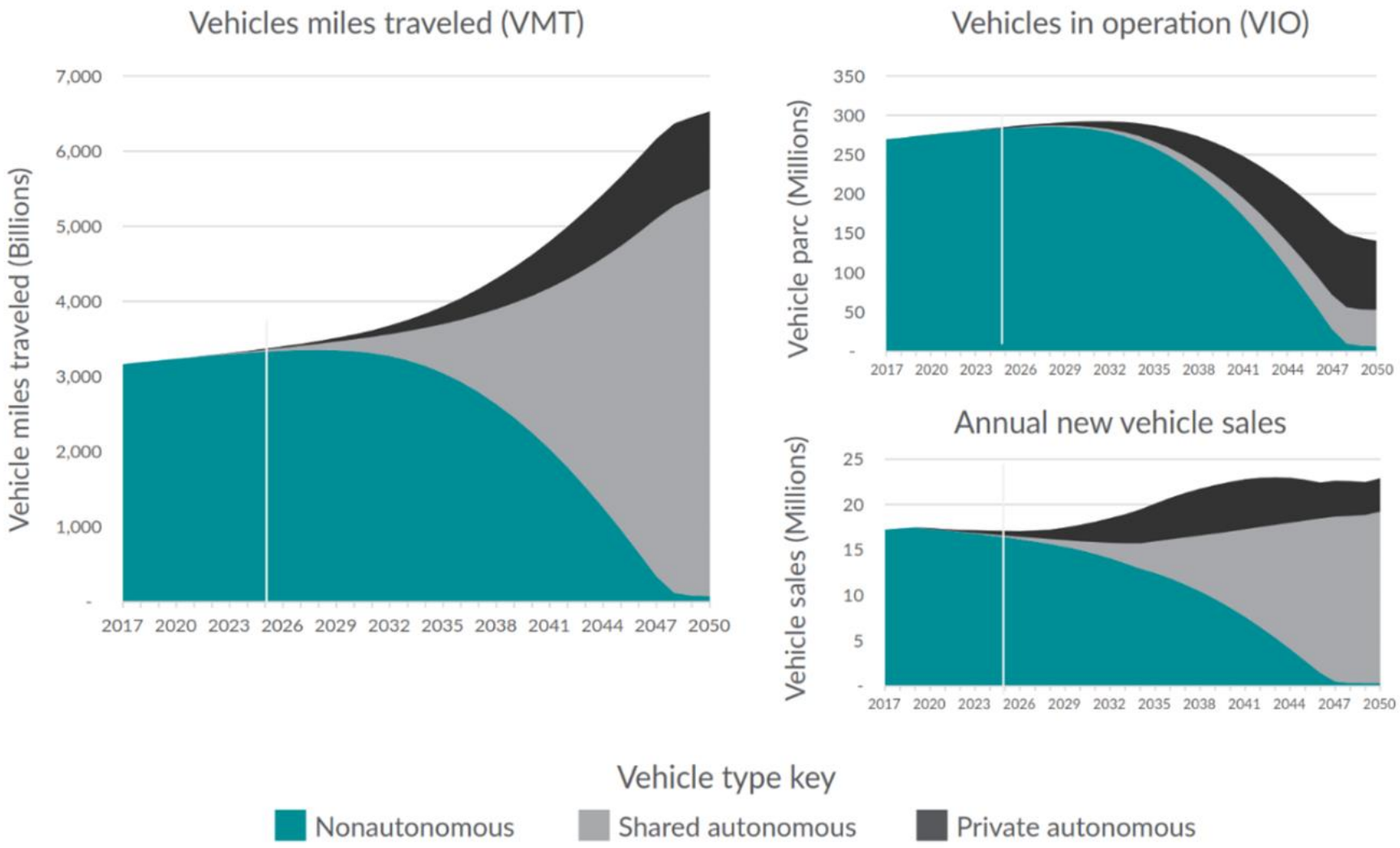
- Higher Levels of Innovation Maturity require a new Understanding

Concept | Design | Build | Produce | Launch | Service



- With the enablement of IIoT, IoT, Digital Twin there is additional huge untapped potential for a product and its related IP while in service
  - Only mechanical life and user acceptance decide the remaining life of a product

Future Considerations



Source: Plante Moran; "The future of mobility: Reinventing the auto industry"; February 2019; www.plantemoran.com

Future Consideration

Additional publications on the topic of “Digital Twin” focusing on:

- Digital Twin – its Maturity Levels and therefore Impact on Business Maturity and Competitive Position
- Digital Twin – Foundational Elements that enable a required Infrastructure and Ecosystem

Enabling Sustainable Innovation

New Frontiers

New Cultures

New Thinking

SMS_ThinkTank™

Appendix: References

1. Frank Popielas, Edward A. Ladzinski – SMS_ThinkTank™: “Achieving Sustainable Innovation – *Business Challenges in the Age of Digitalization and the Path forward*”; COE 2017 Annual Experience & TechniFair; April 23-27, 2018; Orlando, FL, USA
2. CIMdata eBook: “Digital Twins – *Changing the Way We Engineer, Validate, Market and Operate our Products”;* 03/13/2918 – Developed in partnership with SMS_ThinkTank™
3. Frank Popielas, Edward A. Ladzinski – SMS_ThinkTank™: “Systems Engineering – *Challenges for Management*”; COE 2018 Annual Experience & TechniFair; April 15-18, 2018; San Diego, CA, USA
4. Edward A. Ladzinski, Frank Popielas – SMS_ThinkTank™: “Model Based Systems Engineering – *Deeper Dive”;* COE 2018 Annual Experience & TechniFair; April 15-18, 2018; San Diego, CA, USA
5. Donald Tolle – CIMdata white paper: “Evolving from Digital Prototypes to Physics-Based Digital Twins: *The Key Role of Modeling & Simulation in Enabling Closed-Loop Lifecycle Performance Engineering”.* December 2018 - Developed in partnership with SMS_ThinkTank™
6. Edward A Ladzinski, Frank W Popielas, Don Tolle - SMS_ThinkTank™ white paper: “Digital Twin - *Its Role and structure within a modern Systems Engineering Approach”;* February 20, 2019