A&D PLM Action Group Digital Thread Collaborative Research Report

General Availability Edition

Release 1.0

August 2023

AEROSPACE & DEFENSE PLM ACTION GROUP

Co-sponsors

aras

eurostep

jama software

ptc

SIEMENS

Abstract

CIMdata, on behalf of the Aerospace & Defense PLM Action Group (AD PAG), has conducted a collaborative research effort with multiple PLM solution providers to gain an understanding of needs and opportunities within the industry on the topic of digital thread. The shared objective of the participants was to align perspectives on the topic and have a meaningful impact on the providers' solution strategies and roadmaps. CIMdata was responsible for project management and creation of project artifacts. The project used two methods to gather information: subject matter expert (a.k.a. domain expert) interviews and an online survey. The primary information source for analysis and reporting was the set of responses to the web-based survey. These responses represent a broad community and, as answers to a set of closed-ended questions, lend themselves to statistical analysis. The responses to each question are summarized in charts or graphs. The range of survey responses to each question are compared to the interview responses to that question and any significant differences are noted. At the end of the report, CIMdata offers summary observations for consideration by the AD PAG members and the PLM solution provider sponsors.

Table of Contents

Table of Figures

Revision Record

Revision	Date	Description
1.0	January 2023	Initial Release of the *A&D PLM Action Group Digital Thread Collaborative Research Report*, which is based on subject matter expert (a.k.a. domain expert) interviews and a detailed online survey

A&D PLM Action Group Digital Thread Collaborative Research Report

Executive Summary

This report presents the results, analysis, and summary observations from a research effort on the topic of digital thread conducted by CIMdata on behalf of the Aerospace & Defense PLM Action Group (AD PAG) in collaboration with multiple PLM solution providers. For this research effort, CIMdata and the AD PAG partnered with Aras, Eurostep, Jama Software, PTC, and Siemens Digital Industries Software, all solution providers committed to addressing the digital thread challenges of industrial companies.

The project used two methods to gather information: subject matter expert (SME) interviews and an online survey. Interviews were conducted by CIMdata with three communities: the participating PLM solution providers, key A&D customers nominated by the participating solution providers, and the AD PAG member companies. The second method of information gathering was through a web-based survey targeted toward a broader community of PLM practitioners in industry. The learnings from the interviews were applied to develop the line of inquiry in the web-based survey.

CIMdata conducted a total of 15 interviews: 5 with our solution provider sponsors, 5 with key customers recommended by our solution provider sponsors, and 5 with AD PAG members. A total of 90 complete and validated survey responses were received and have been analyzed. The survey was open to all industries, but it was targeted toward and most heavily promoted within aerospace and defense and nearly 60% of responses were from that industry. Review of the names of companies represented and the positions held by the interviewees and survey respondents confirms that the information received is representative of the most influential companies and leading thinkers within the aerospace and defense industry.

Significant Findings

The following key findings were derived from analyzing the interview and survey results:

- CIMdata's analysis clearly indicates that digital thread investment within the ecosystem of industrial users, their customers, suppliers, and solution providers is poised for rapid growth. Initial implementations of targeted digital thread solutions have provided proof points of value and essential learnings. New rounds of investment are ramping up, guided by these early achievements and with expectations driven by the value potential revealed.

The What and Why of the Digital Thread

- The conceptual understanding of digital thread within industry is very immature. Nearly half of companies surveyed do not have a commonly accepted definition of digital thread. However, there is a broadly shared perception of what a digital thread **does** and what a digital thread **is**. The most prominent characteristics of what a digital thread is and what it does relate to "establishing traceability of product information."

The Current Reality of Digital Thread in Industry

- As would be expected, digital thread implementations are most prevalent in the Concept and Development product lifecycle stages. They are also significant in Production but are rare in later lifecycle stages of Utilization, Support and Retirement.
- The most prevalent digital thread linkages currently are between design-related data categories, i.e., needs and requirements data, mechanical design data, electrical/electronic design data, software design data, and engineering bill of materials (BOM) data.
- The most striking indicator that digital thread investment is in its very early days is the contrast between importance assigned to digital thread use cases and the prevalence of current implementations. For example, lifecycle BOM management is considered essential by 62% and important by 26% of respondents but is currently implemented as a digital thread within only 25% of respondents' companies.
- The technologies used to link product lifecycle data segregate into three tiers. The top tier, which has the longest history, includes PLM and PDM, followed by ERP and custom applications. The middle tier consists of application and data integration tools. These are followed by newer specialty technologies for combining data from multiple sources and establishing linkages and traceability. We can expect the ranking of these specialty technologies to rise significantly over the next few years.
- Respondents' self-assessment of the maturity of the digital thread within their companies is very good news for solution providers. A majority of respondents assigned a rating of mature or industry-leading to their company's vision and level of planning and funding. This suggests that they are ready to invest in implementations which the majority rate as immature.
- For the respondents, the number 1 inhibitor to formulating and executing a digital thread strategy is "lack of interoperability between different vendors' tools and systems." The number 1 proposed means for mitigation is to "increase support of standards," which is followed closely by "increase management support."

Planning Investment for Digital Thread Expansion in Industry

- Looking to the future, interviewees are taking a broader view of the digital thread's value potential, with more investment in production and service use cases. They view the next stage as more complex and transformative to their companies. Several have been successful in establishing programs that enjoy strong support from a well-informed and motivated senior management. However, many others have not.
- The top six pain points being targeted in future implementations all relate to accessibility and traceability across data elements, especially traceability of requirements throughout the product lifecycle.
- Systems engineering was featured prominently in many responses, including ranking as the top new value opportunity being targeted in future digital thread implementations.
- Investment, which has been concentrated in the Concept and Development product lifecycle stages, will shift in the near term to Development and Production while ramping up

significantly in the later lifecycle stages. In the longer term, investment will shift substantially to the later lifecycle stages.

- It is notable that in the near term the heavy investment emphasis is in three areas:
  - Systems engineering, design optimization, validation, and traceability
  - Lifecycle BOM management and change impact assessment
  - Manufacturing engineering

Solution Capability and Provider Alignment

- Results from industry interviews on the topic of solution capability and provider alignment were mixed. Some interviewees were quite critical, especially regarding data model accessibility and flexibility to comply with a corporate data governance strategy. Another criticism was that PLM providers do not appear to be leveraging open, modular, event-driven architectures, calling into question their longer-term viability as core components of a digital thread.
- Other interviewees were neutral or slightly positive on this topic. They feel that some providers are moving in the right direction; some are not. Several felt that solution capabilities have improved significantly overall in the last 5 to 10 years and that, despite some remaining gaps, are these solutions are now fully capable. Some expressed satisfaction that “good partnering” is happening.
- A nearly universal concern is lack of openness and dependence on 3rd party connectors for connectivity and data interchange with the PLM solutions. The perception is that interoperability and openness have improved but are fragile and there are emerging signs of potential backsliding.
- Respondents were split on the question of whether their chosen PLM solution providers are aligned with their perspectives and strategies for digital thread investment, with the majority feeling that they are moderately or well aligned. A significant minority felt there were some or major gaps.

Introduction

CIMdata, on behalf of the Aerospace & Defense PLM Action Group (AD PAG), has conducted a collaborative research effort with multiple PLM solution providers to gain an understanding of needs and opportunities within the industry on the topic of digital thread. The shared objective of the participants was to align perspectives on the topic and have a meaningful impact on the providers’ solution strategies and roadmaps. CIMdata was responsible for project management and creation of the project artifacts.

Since its founding in 2014, the CIMdata-administered AD PAG has sponsored research and jointly staffed projects on topics such as Model-Based Definition, Multiple-View Bill of Materials, PLM Technology Obsolescence Management, Global Collaboration, Model-Based Systems Engineering, and Digital Twin/Digital Thread. The members regularly interact with the principal PLM solution providers in project collaborations and executive-level strategic discussions. Current AD PAG membership includes Airbus, Boeing, GE Aerospace, Gulfstream, Pratt & Whitney, Rolls-Royce, and Safran.

The Group's leadership recently decided to expand its reach into the PLM solution provider community and engage in collaborative research and dialogue on strategic topics. For this research effort, CIMdata and the AD PAG partnered with Aras, Eurostep, Jama Software, PTC, and Siemens Digital Industries Software, all solution providers committed to addressing the digital thread challenges of industrial companies.

Information Gathering

The project used two methods to gather information: subject matter expert (SME) interviews and an online survey.

Interviews

CIMdata conducted interviews with three communities: participating PLM solution providers, key A&D customers nominated by the participating solution providers, and the AD PAG member companies. All interviewees received a written questionnaire prior to the interview and were requested to return a completed copy before the scheduled call. Using this method, the interview could focus on asking questions of clarification and requesting additional detail.

The desired sequence for the interviews was to first query the sponsors, then the sponsors' recommended key clients, and lastly the AD PAG members. This sequence was intended to provide a layering of perspectives, giving heaviest weighting to the solution provider sponsors. This desired sequence was generally followed.

Web-Based Survey

The second method of information gathering was through a web-based survey targeted toward a broader community of PLM practitioners in industry. CIMdata developed the survey based on initial findings from the SME interviews and promoted it through their usual channels, e.g., a press release, Webinar, social media promotion, targeted emailings, etc. Each research sponsor was given a survey that duplicated the CIMdata survey questions for promotion using their own internal processes and methods. This was to help increase the number of industrial responses and ensure the data and results would be representative of the overall population of interest to the sponsors.

The learnings from the interviews were applied to develop the line of inquiry in the web-based survey. The line of questioning was similar, but whereas the interview questionnaire was open-ended, those questions were converted to closed-ended pick lists for the survey. The pick list choices were derived primarily from the interview responses. The richness of inquiry achieved in the interviews could not be replicated in the online survey, but the questions were crafted based on the interview results to provide useful insights into current state and future trends across a broader industrial community.

Analysis and Reporting

The primary information source for analysis and reporting is the set of responses to the web-based survey. These responses represent a broad community and, as answers to a set of closed-ended questions, lend themselves to statistical analysis.

The sections that follow summarize the responses to each question in charts or graphs. The range of survey responses to each question are compared to the interview responses to that question and any significant differences or additional insights from the interviews are noted.

At the end of the report, CIMdata offers summary observations for consideration by AD PAG members and the solution provider sponsors.

In addition to this report, CIMdata will create an abbreviated version for distribution to those who participated in the interviews and the web-based survey. Also, from time to time, CIMdata may extract content from this report for presentations or articles.

Respondent Demographics

Interviews

CIMdata conducted a total of 15 interviews: 5 with our PLM solution provider sponsors, 5 with key customers recommended by our solution provider sponsors, and 5 with AD PAG members.

The 10 industrial companies interviewed included 9 of the Top 40 (23%), 7 of the Top 20 (35%) and 5 of the Top 10 (50%) companies in the global aerospace & defense industry.

All interviewees completed the interview questionnaire in advance and all interviews were of high quality. Several interviews involved multiple SMEs. The participants were very open during the discussion and provided solid insights to their situations, as well as to more general issues and challenges facing companies implementing a digital thread.

Online Survey

A total of 90 complete and validated online survey responses were received and analyzed.

The survey was intentionally designed to be a challenge for the respondent. Answering the questions required a deep understanding of the current status and future plans for digital thread realization within the respondent's company. The average time to complete the survey was approximately 30 minutes. Consequently, it is fair to assume that only those with a serious interest in the topic of digital thread would invest the time and effort needed to complete the survey. This hypothesis may be confirmed by reviewing the respondents' self-selected role titles as shown in Figure 1 and by reviewing the respondent's job titles, which we were able to research based on the names and email addresses provided.[1]

[1] A partial list of respondents' job titles is provided in Appendix A.

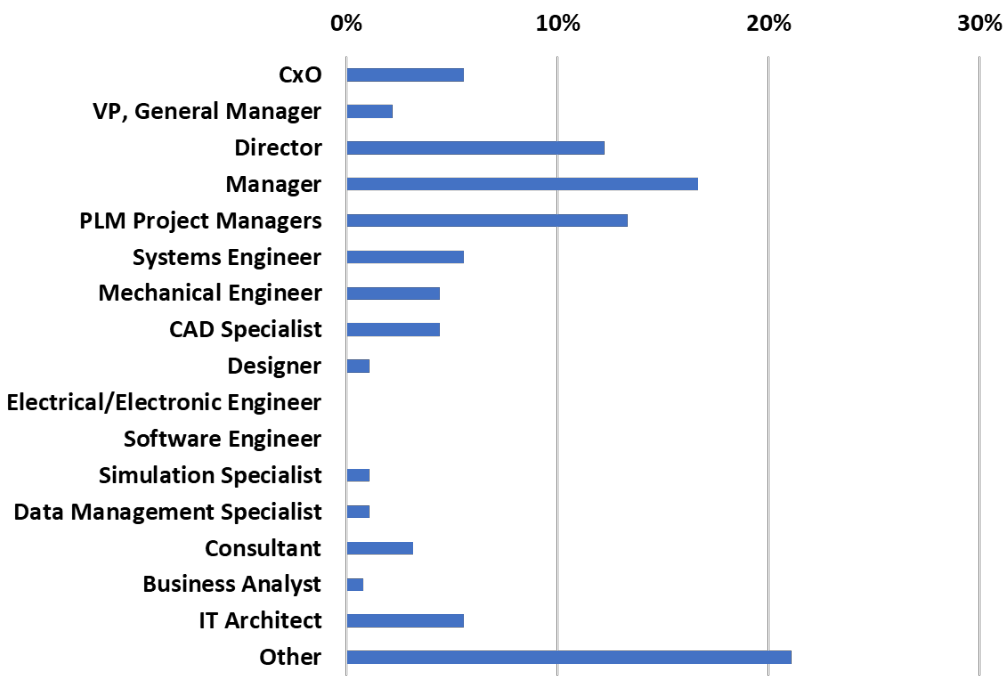

Figure 1 — Survey Respondents' Role Titles (% of respondents)

Respondents were almost exclusively from North America and EMEA, and evenly distributed across small, medium, and large revenue enterprises as shown in Figure 2 and Figure 3.

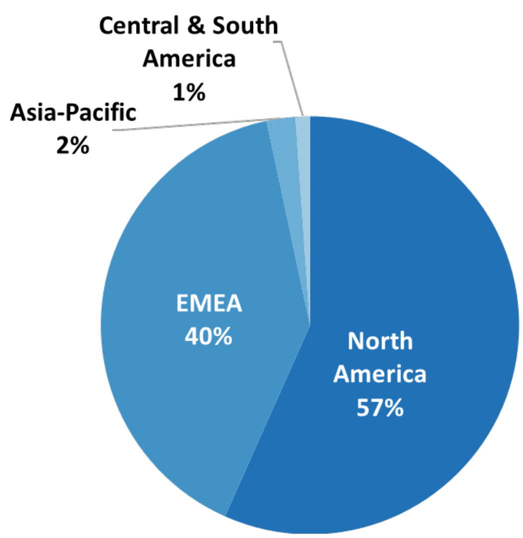

Figure 2 — Distribution of Survey Respondents by Geographic Region

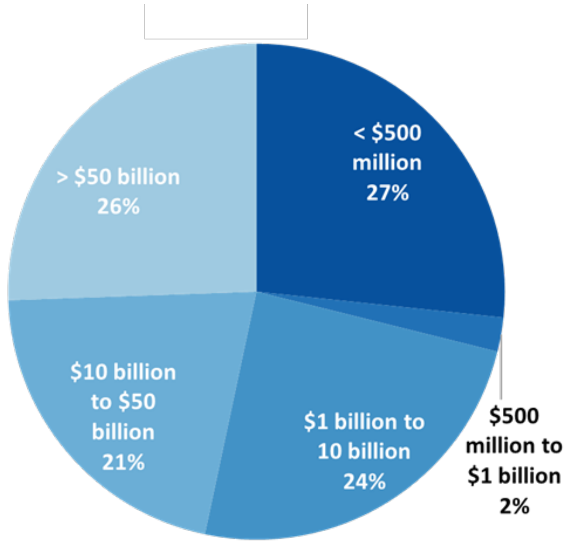

Figure 3 — Distribution of Survey Respondents by Company Revenue

While the survey was open to all industries, it was targeted toward and most heavily promoted within aerospace and defense. Consequently, nearly 60% of responses were from that industry. As shown in Figure 4, a total of 55 individuals from 46 A&D companies responded to the survey, and those companies included 15 of the Top 50 and 7 of the Top 10 in the global A&D industry.

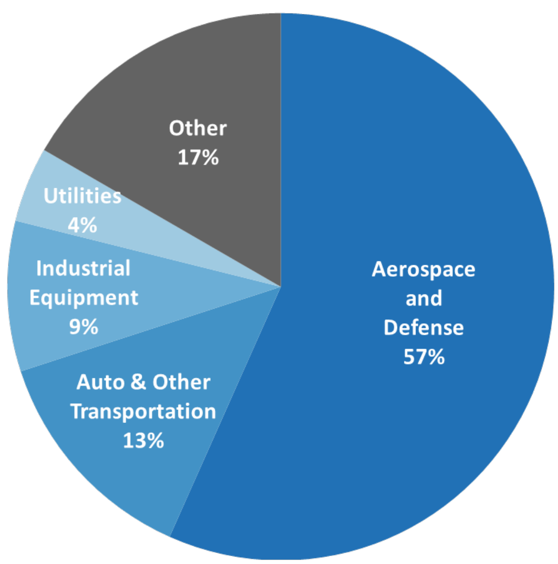

Figure 4 — Distribution of Survey Respondents by Industry

The What and Why of the Digital Thread

Interviews

Each interview began with the question "What is your definition of the digital thread?" Not surprisingly, this yielded 15 different definitions, one for each respondent. Some were long, others brief. Two were based on definitions published by respected external authorities.

There were observable patterns across these definitions: a consistent set of descriptors that characterize what a digital thread ***does*** and what a digital thread ***is***. These became the check list items in the web-based survey.

Survey

The first positioning question asked was "Does your organization have a commonly agreed-to definition of the digital thread?" Reviewing Figure 5, one may be surprised that nearly half of respondents do not have an agreed to definition within their company, or that slightly more than half do.

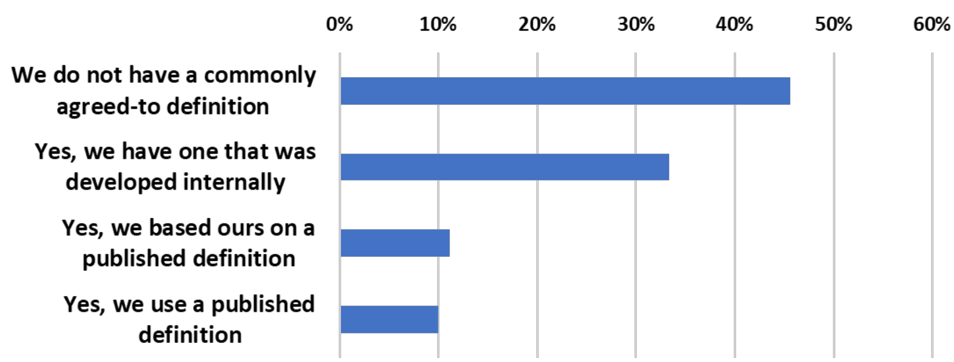

Figure 5 — Source of Digital Thread Definition Commonly Agreed to Within Respondent's Company (% 0f respondents)

Respondents were asked to choose the most significant characteristics that describe what the digital thread ***does***. Their selections are shown in Figure 6.

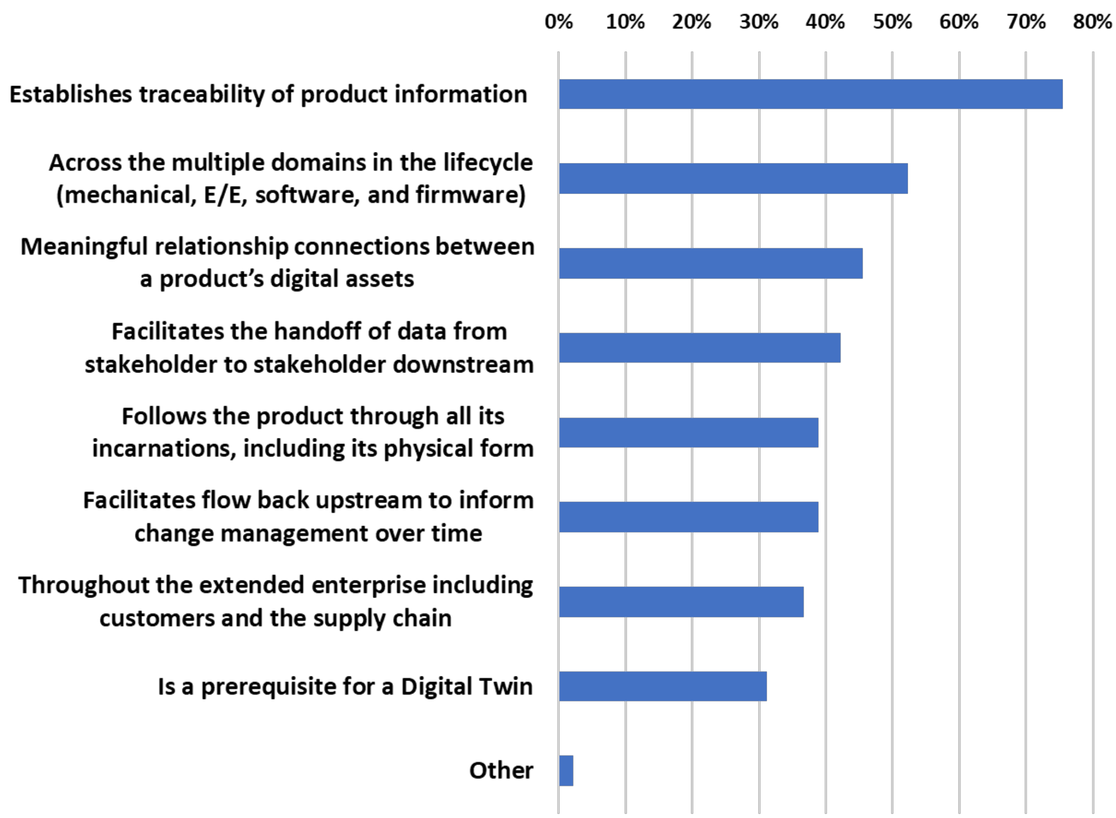

Figure 6 — Most Significant Characteristics that Describe What a Digital Thread Does (% of respondents)

Respondents were then asked to choose the most significant characteristics that describe what the digital thread ***is***. Their selections are shown in Figure 7.

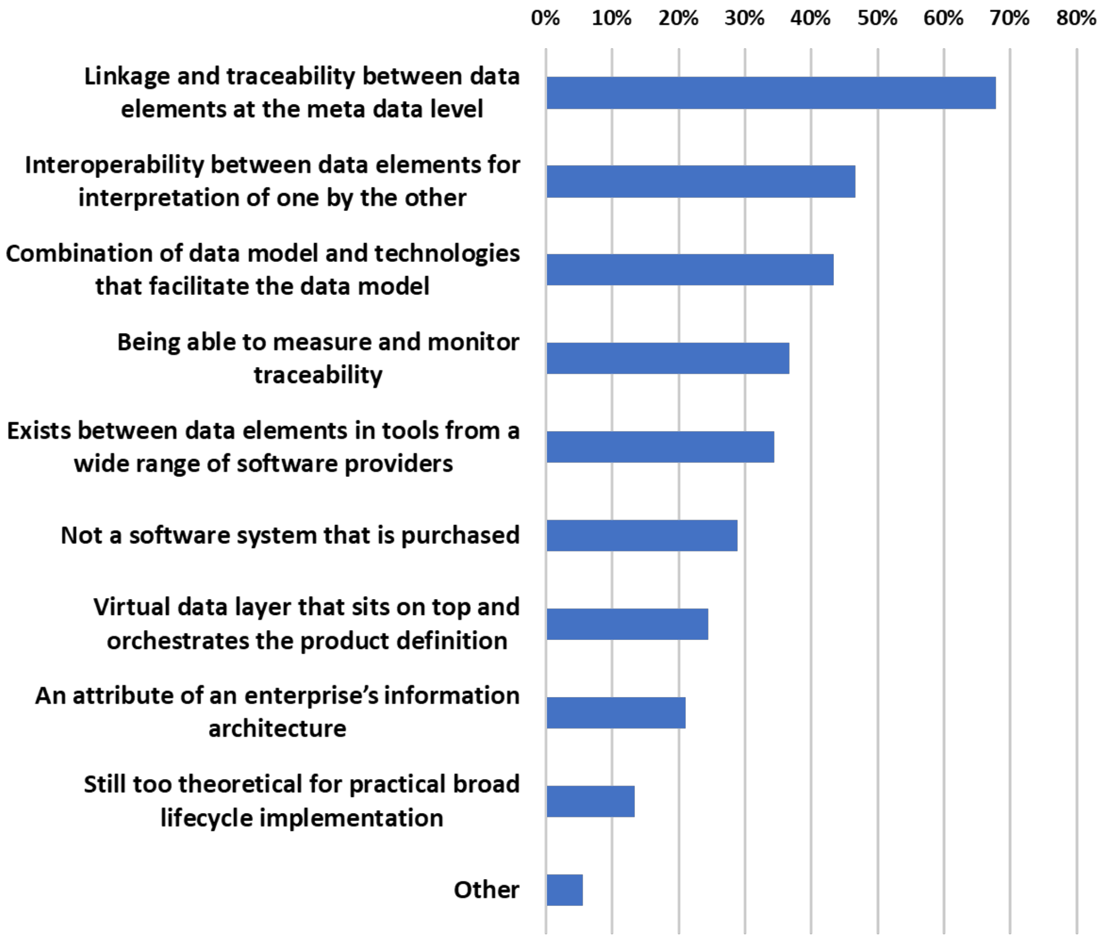

Figure 7 — Most Significant Characteristics that Describe What a Digital Thread Is (% of respondents)

Digital thread has risen dramatically in prominence over the last 3 to 5 years. Respondents were asked what has changed over that period to elevate interest in digital thread within their company. Results are shown in Figure 8.

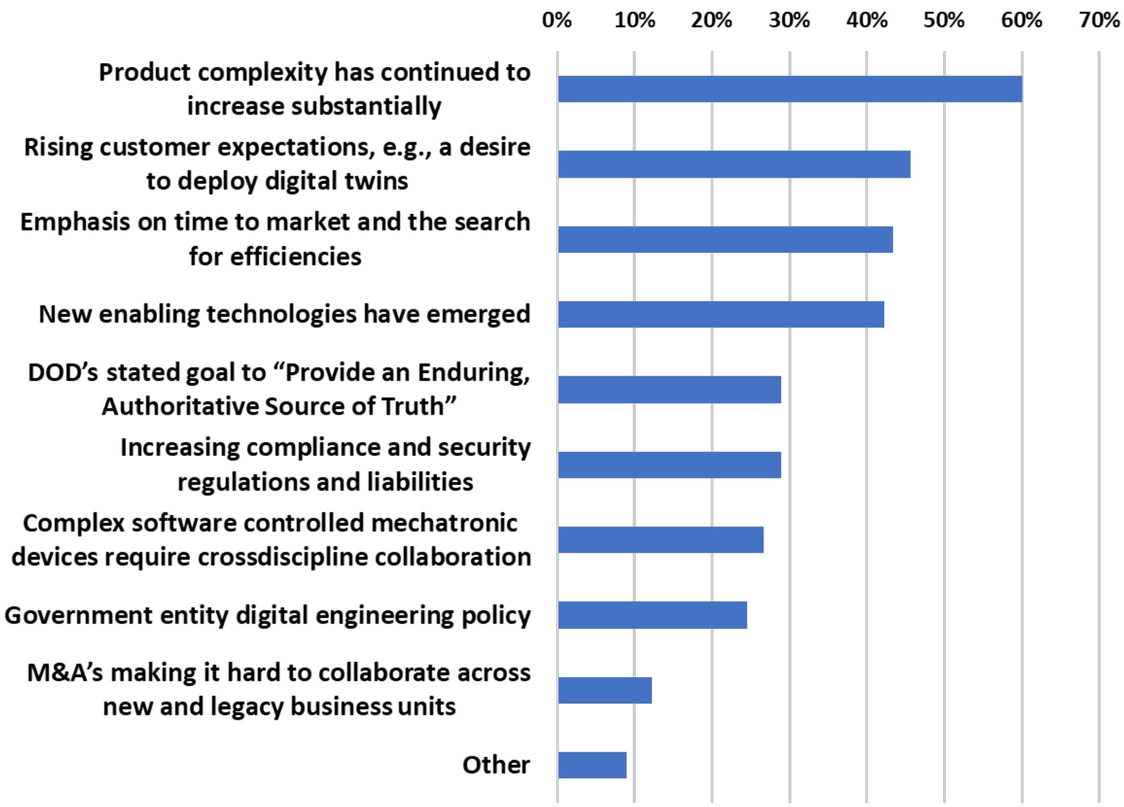

Figure 8 — Reasons for Digital Thread's Rise to Prominence (% of respondents)

The Current Reality of Digital Thread in Industry

Interviews

The 10 industry interviews revealed a wide range of digital thread realities. All of these companies are motivated and moving with a sense of purpose. All have implementations supporting multiple use cases. Most of these use cases are in support of product development, providing some degree of requirements traceability and integration between engineering and production.

One area of divergence was in the maturity of awareness and support within management. For some, senior management is fully engaged and supportive of major programs with the view that broad investment in digital thread will provide the fundamental transformation of their business which is needed in response to critical business drivers. For others, each incremental implementation is viewed as a new project which must be justified.

Another area of divergence is in the general approach to implementation. For some, the focus of digital thread implementation is providing interfaces to source applications to be able to extract and associate product data artifacts and attributes, something like a search engine. For others, the key is the association and traceability of dependencies between artifacts in support of a use case, such as the linkage and traceability of requirements through functional/physical design to simulation and test for design optimization and validation. And yet for others, the key and their current focus is on data governance, which they believe will provide the necessary foundation for support of a richer and more extensive set of product lifecycle use cases.

Survey

The inquiry into current state began by asking what critical business issues respondents are trying to address with their digital thread efforts. Results are shown in Figure 9.

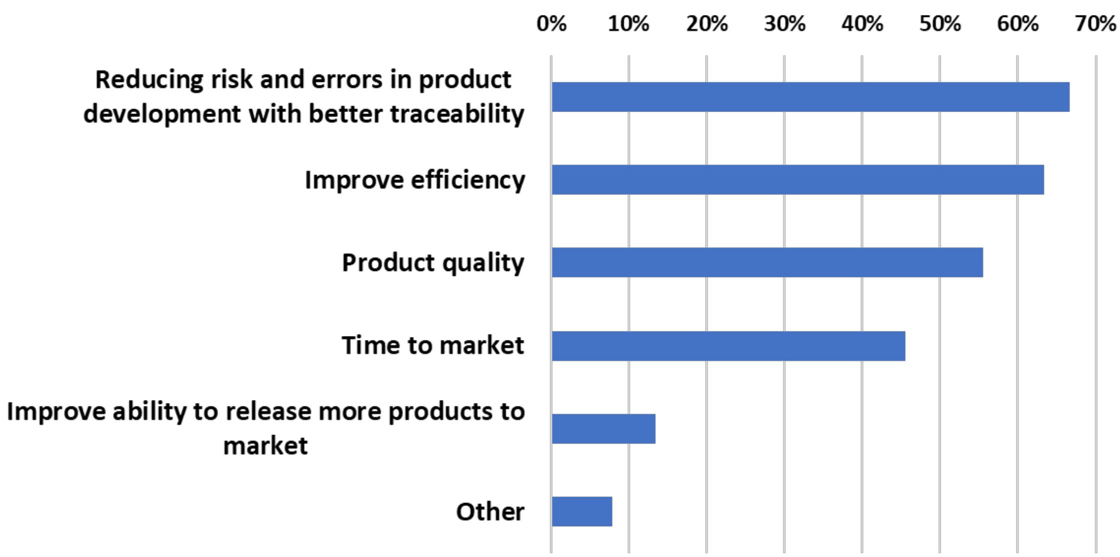

Figure 9 — Business Issues Being Addressed with Digital Thread Efforts (% of respondents)

Current Value Footprint

Respondents were asked a series of questions to define the extent of their current digital thread implementation(s) along several dimensions.

Respondents were asked within which product lifecycle stages are digital thread implementations currently in place. Results are shown in Figure 10.

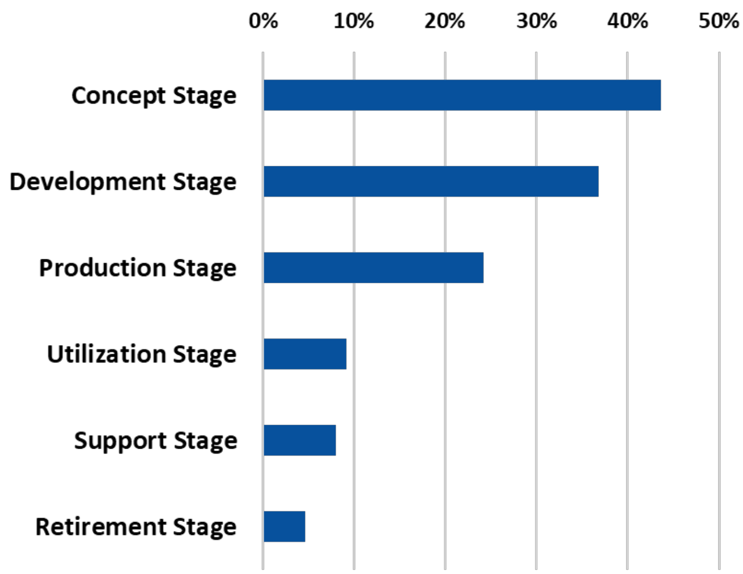

Figure 10 — Prevalence Digital Thread Implementations Currently in Place Within the Various Product Lifecycle Stages (% of respondents)

Respondents were asked which product lifecycle data categories are linked together as a digital thread in their company today. Results are shown in Figure 11.

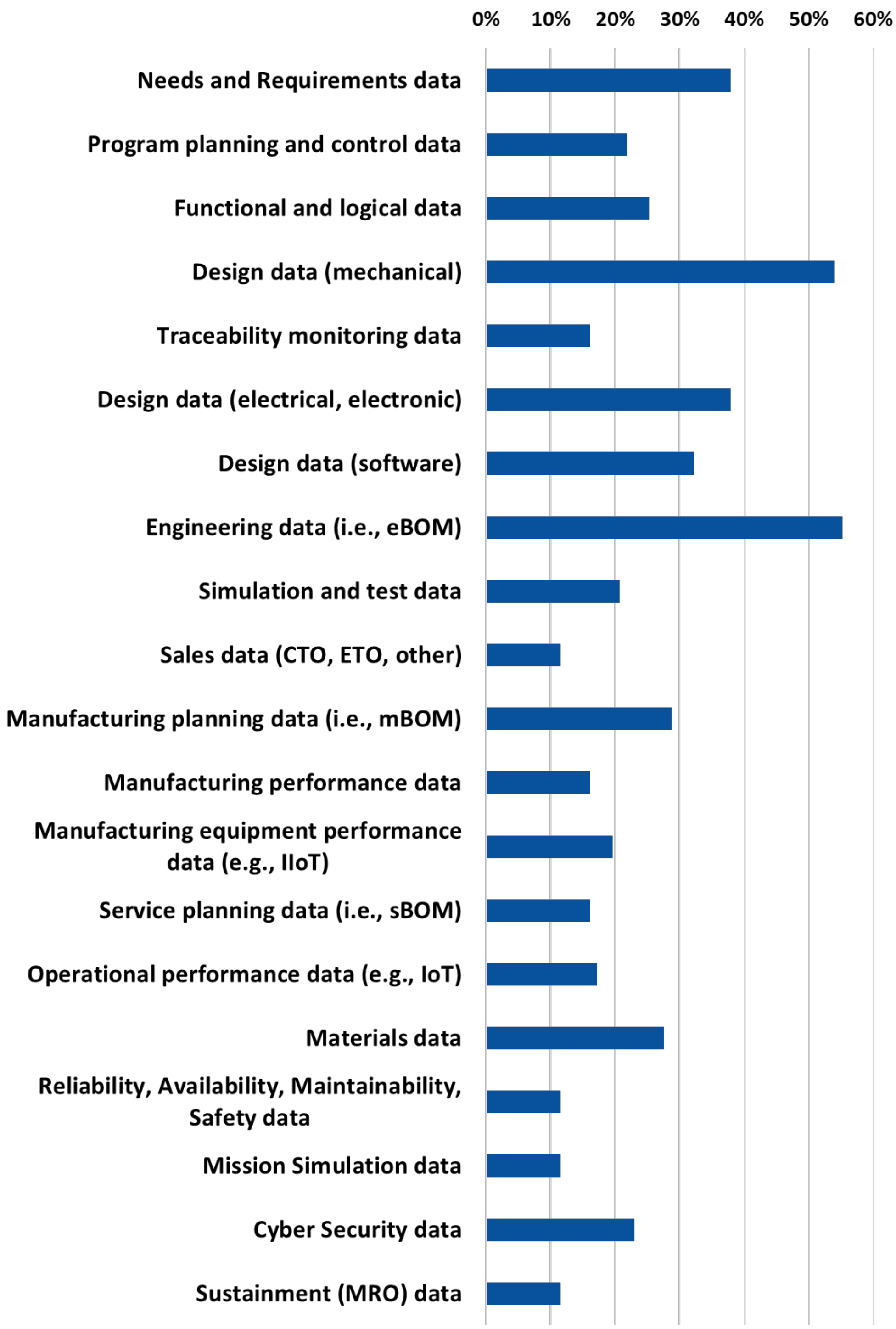

Figure 11 — Prevalence of Product Lifecycle Data Categories Currently Linked Together as a Digital Thread (% of respondents)

Respondents were asked which use cases for digital thread are implemented in their company today. Results are shown in the following figure.[2]

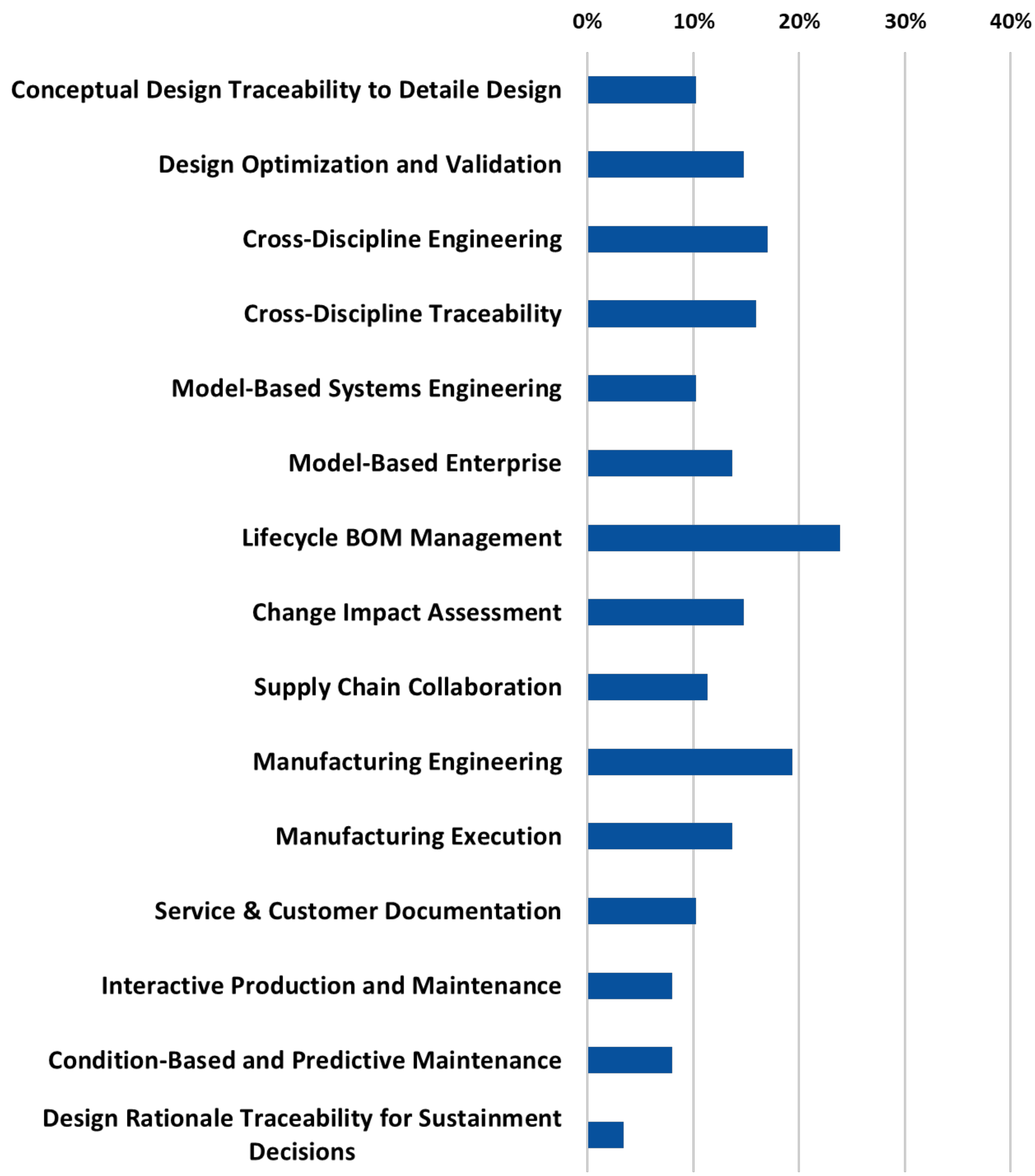

Figure 12 — Prevalence of Digital Thread Use Cases Currently Implemented (% of respondents)

[2] Use case descriptions are provided in Appendix B.

Respondents were asked for their opinion as to the importance of various use cases for achieving the digital thread vision within their company. Results are shown in Figure 13.

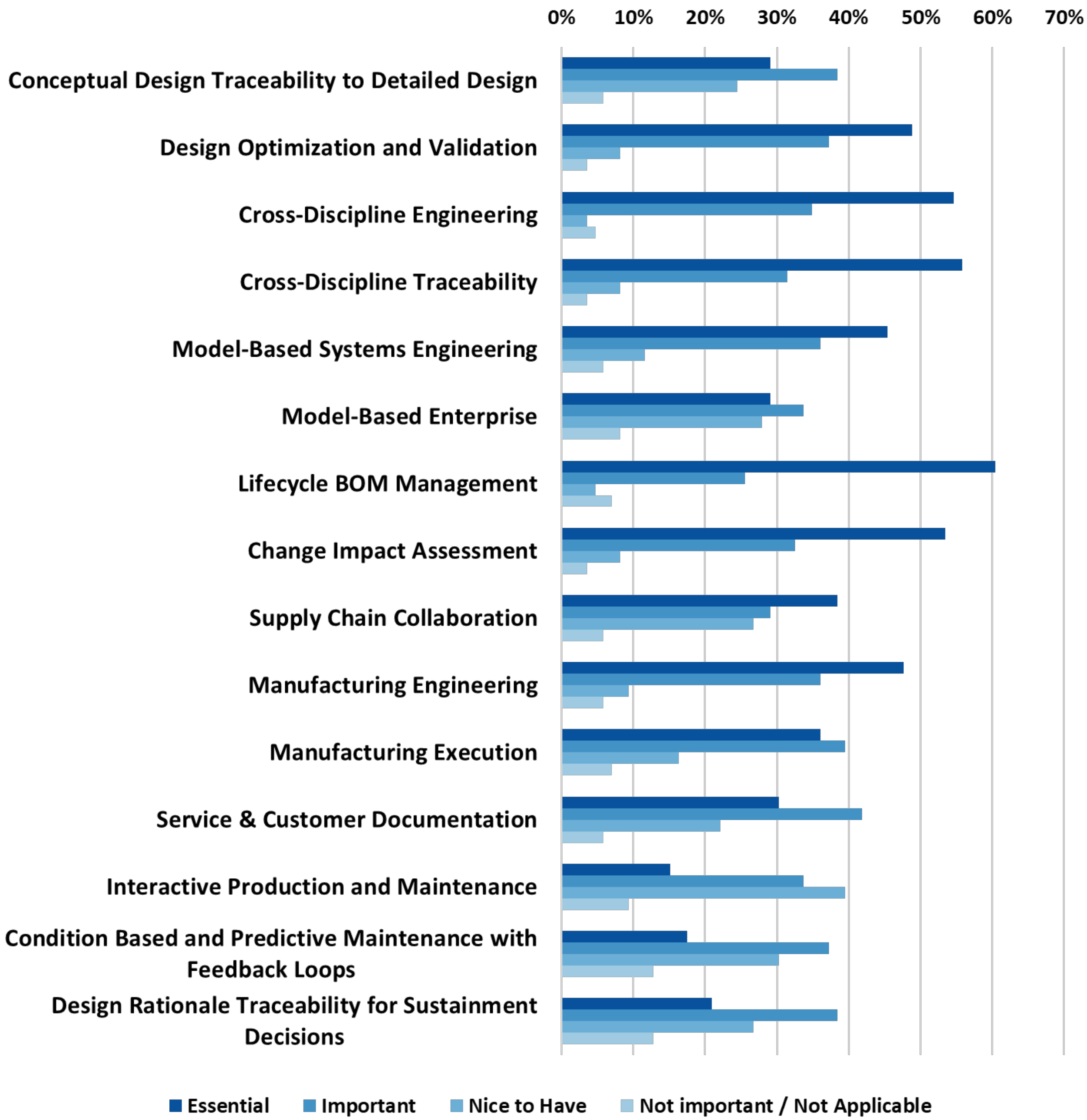

Figure 13 — Respondents' Assessment of the Importance of Various Use Cases for Achieving the Digital Thread Vision within Their Companies (% of respondents)

Respondents were asked to describe the extent of the user community that is currently contributing to and leveraging their digital thread use case implementations. Results are shown in Figure 14.

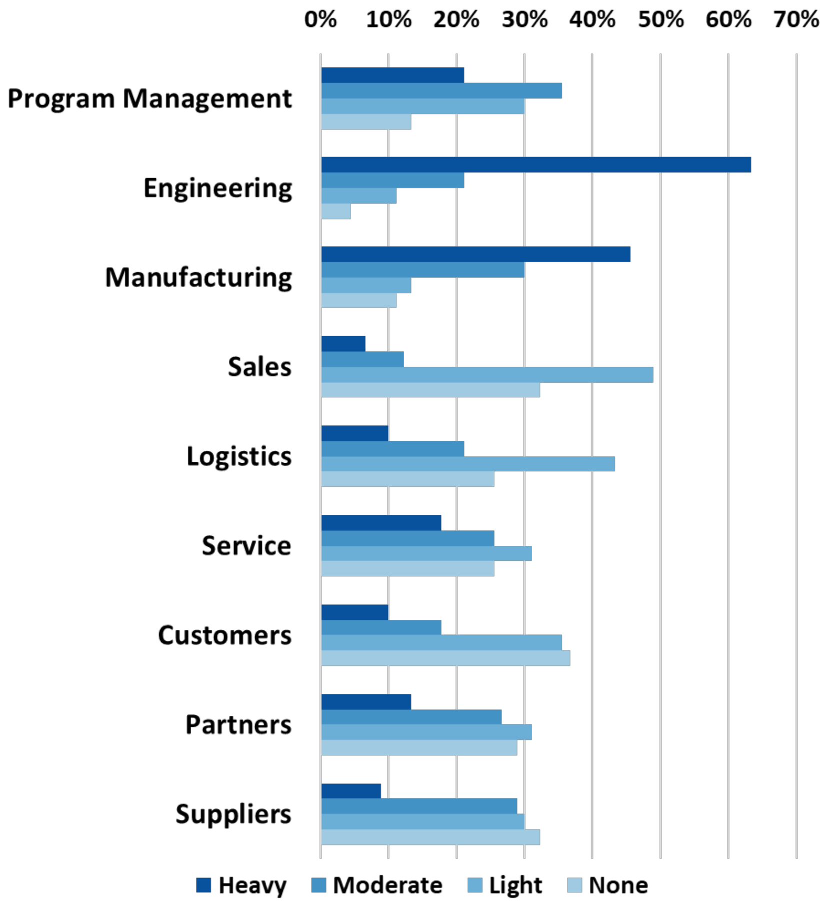

Figure 14 — Extent of the User Community Currently Contributing to and Leveraging the Respondents' Digital Thread Use Case Implementations (% of respondents)

Technology

Respondents were asked three questions about the technologies used to enable the digital thread use cases that are currently implemented within their company.

First, they were asked what technologies are used to create and consume product lifecycle data in these use cases. Results are shown in Figure 15.

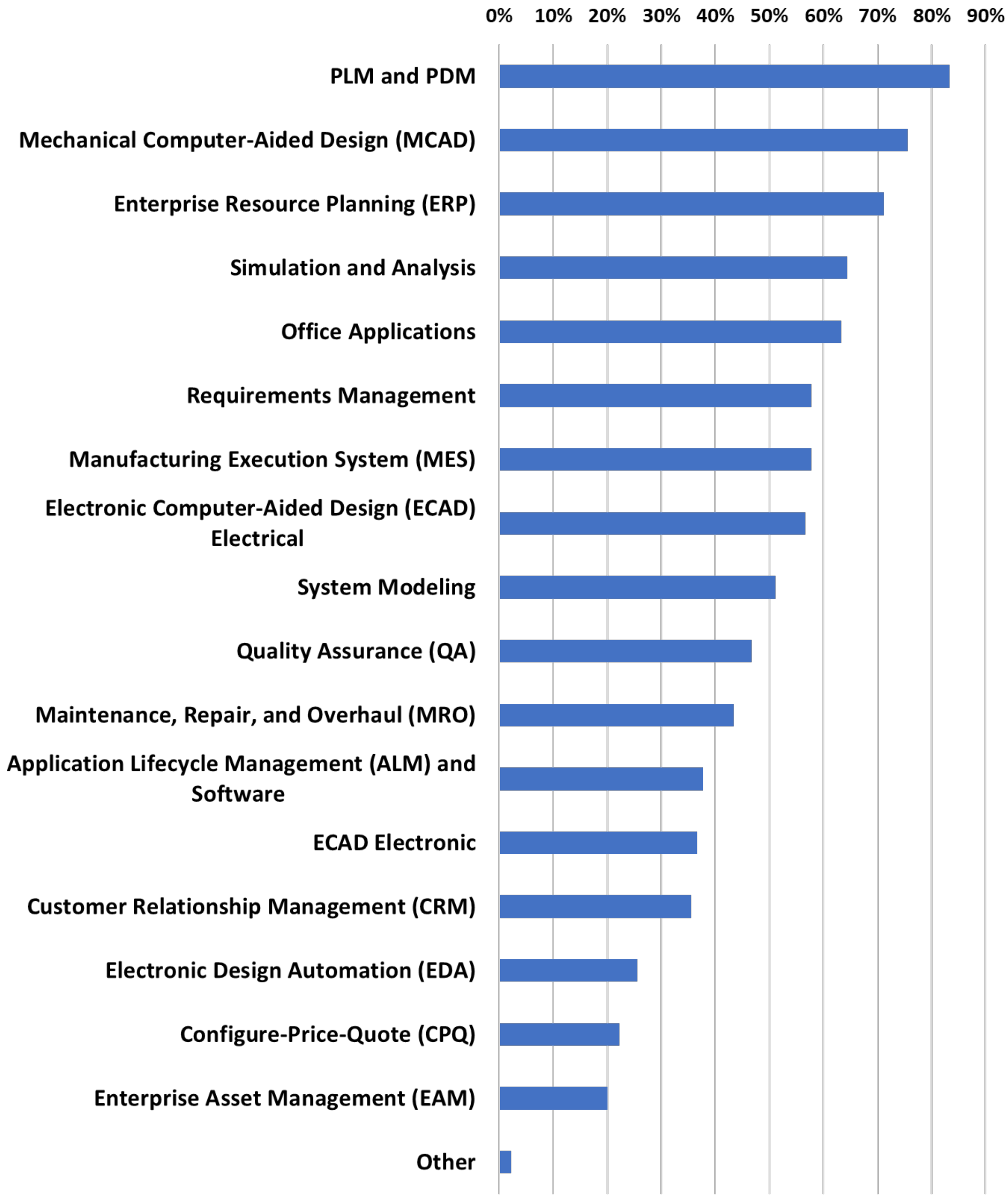

Figure 15 — Technologies Used to Create and Consume Product Lifecycle Data in Respondents' Currently Implemented Use Cases (% of respondents)

Then, they were asked what technologies are used to link product lifecycle data in these use cases. Results are shown in Figure 16.

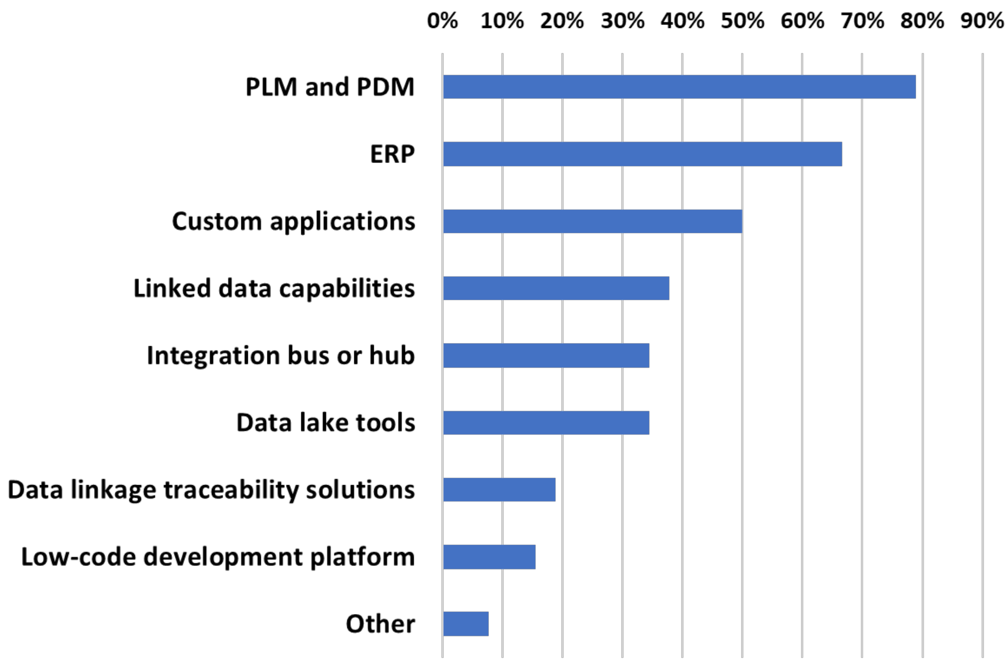

Figure 16 — Technologies Used to Link Product Lifecycle Data in Respondents' Currently Implemented Use Cases (% of respondents)

Respondents were asked how they are implementing digital thread solution(s) to support the full product lifecycle. Results are shown in Figure 17.

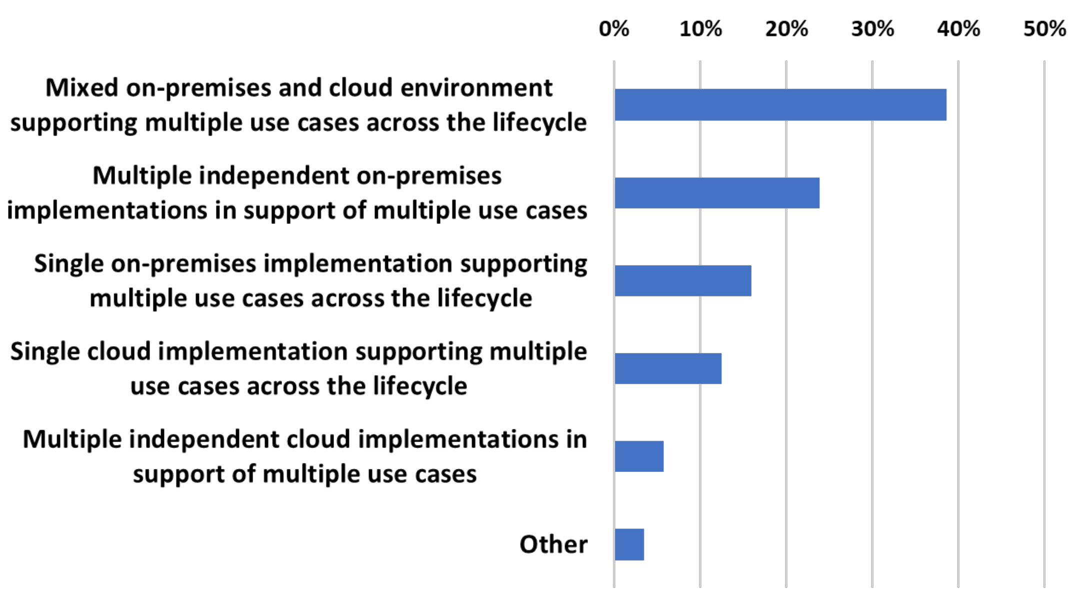

Figure 17 — Implementation Configurations of Respondents' Current Digital Thread Solutions (% of respondents)

Self-Assessment

Through a series of questions respondents were asked to assess their positioning for successful pursuit of a digital thread strategy.

Respondents' assessment of the maturity of the digital thread strategy realization within their company is shown in Figure 18.

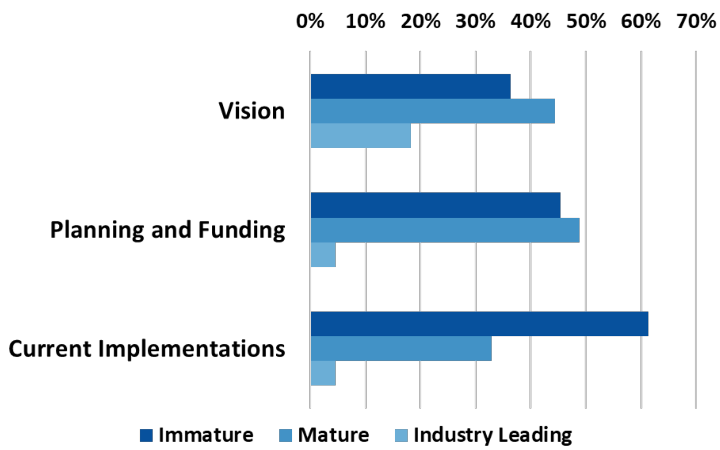

Figure 18 — Self-Assessment of Digital Thread Maturity within Respondents' Companies (% of respondents)

Respondents were asked if they have metrics in place to track the effectiveness of their digital thread strategy, and those who responded "yes" were asked to provide a brief description. A representative sample of responses is provided below.

- Number of systems integrated in the digital thread
- Number of data elements in a central data model enabled for the digital thread
- Number of data elements enabled for the digital thread
- In some areas later in the development phase with focus on documentation
- Highly variable based on mission. Generally, time to market, first time quality, manufacturing cost / realized learning curve, and sustainment costs are the most prominent metrics.
- We aim for more than pockets of excellence, but digital thread consistency being measured against strategic programs
  - Tracking user adoption of rapid standup metrics of IDEs (Integrated Digital Environments) that manifest our Digital Thread strategy through integration of ASoTs (Authoritative Sources of Truth)
  - Degrees of separation between lifecycle elements
  - As Planned / As Released Baseline integrity and traceability to primary and secondary items
- Impact Analyze
- Considering traceability - is it enough to support a decision?
- Product quality (physical prototypes compared to virtual simulations results)
- Partly KPI´s based on single use cases only

- We have KPIs per system to include more aircraft in the scope of the digital thread.

Some respondents provided insight as to how they develop metrics.

- Firstly, we analyze our business maps, we create value streams about workflows. After that, we detect some steps without digital platforms such as PDM, ERP, MES systems. We think how to implement the steps into digital systems.
- Our metrics for digital thread are wrapped up within the implementation progress of next generation PLM capabilities. The PLM is growing to accommodate the requirements of digital thread linkages.
- We would track Digital Thread metrics as part of our overall model and data governance approach.

Respondents were asked to list and characterize the principal inhibitors to formulating and executing a digital thread strategy within their company. Results are shown in Figure 19. Inhibitors are listed in order of decreasing significance.

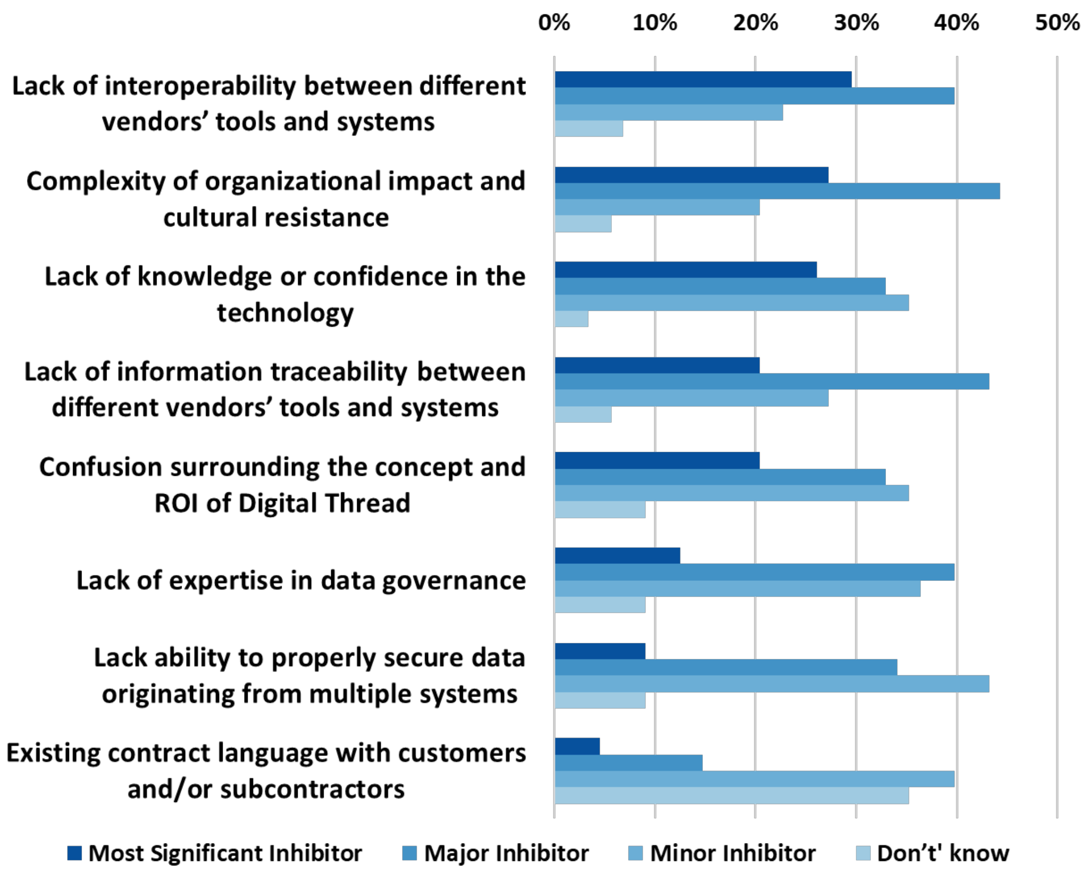

Figure 19 — Principal Inhibitors to Formulating and Executing a Digital Strategy within Respondents' Companies (% of respondents)

Respondents were then asked to propose potential means for mitigation of the Most Significant Inhibitor. Results are shown in Figure 20.

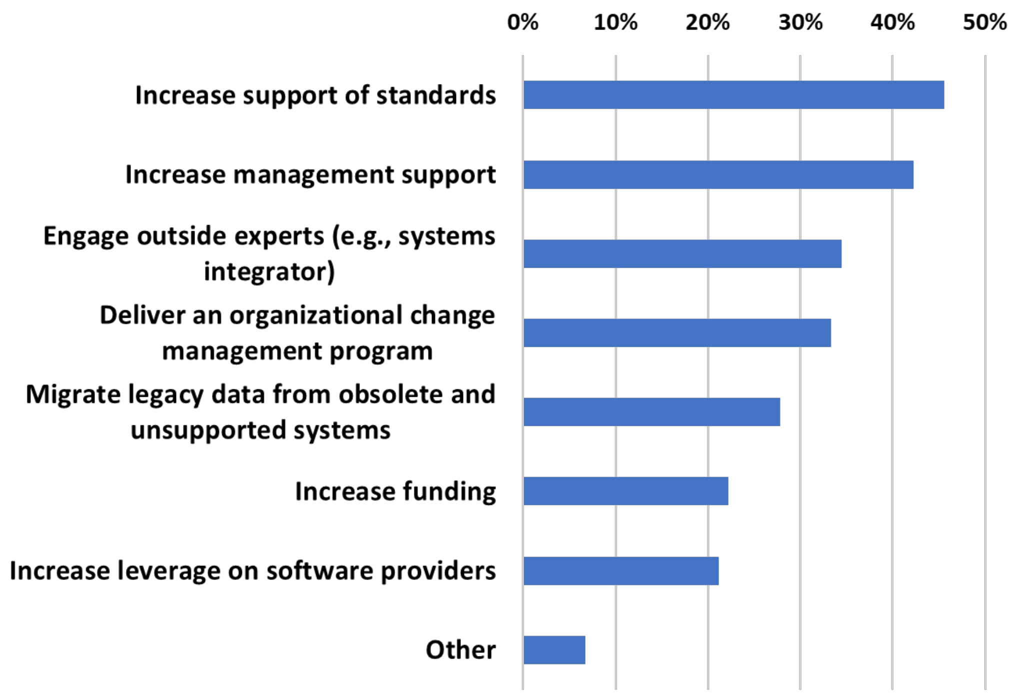

Figure 20 — Respondents' Proposed Means for Mitigation of Inhibitors to Formulating and Executing a Digital Strategy within Their Companies (% of respondents)

Planning Investment for Digital Thread Expansion in Industry

Interviews

Looking to the future, all of the industry interviewees said they are taking a broader view within their companies. For most, early digital thread implementations were concentrated in product development. Going forward, there will be more investment in production and in service. In most of the respondents' companies, there will be increased emphasis on extending the digital thread community to more fully include customers, partners, and suppliers.

Some of the most frequently cited examples for future investment include:

- Requirements traceability with supplier allocation, validation, and verification
- Requirements traceability across system to sub-system levels
- Systems engineering exchange with suppliers
- Integration between Engineering and Production for manufacturing planning
- Integration between Engineering and Service for technical documentation

- Integrated master schedule
- Electrical and software integration with mechanical design artifacts in PLM
- Full digital thread search (i.e., Google-like)

This expansion of the digital thread value footprint presents new challenges for those with responsibility for planning and implementation. Several have recognized the need for fundamental transformation, such as transformation from “digital document/digital deliverable” to a truly data-driven way of working. Some look to co-development to achieve a deeper integration between Engineering and Service and/or Engineering and Production.

For some interviewees, implementation of model-based systems engineering (MBSE) is a fundamental driver of future investment. For others, investment is to improve product program execution efficiency by ensuring production teams have the latest engineering-released information and layering business analytics on a readily accessible information resource.

These increased ambitions will strain current structures for digital thread planning and implementation. Several of the interviewees have been successful in establishing programs that enjoy strong support from a well-informed and motivated senior management. Others are struggling with building awareness within their leadership and achieving early successes as proof points to motivate executive engagement and funding for execution.

Survey

Respondents were asked what pain points they are targeting in future digital thread implementations within their company. Results are shown in Figure 21.

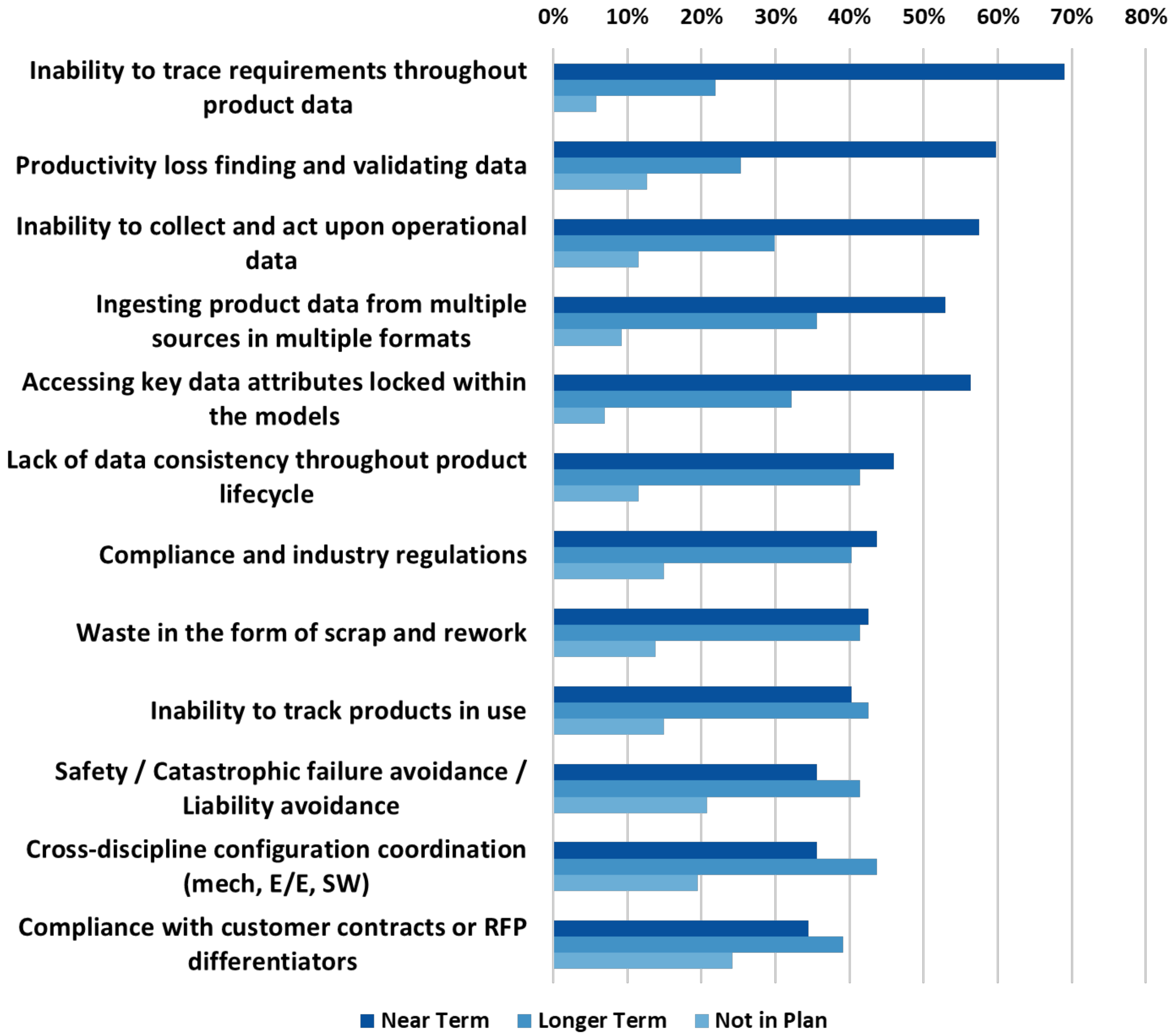

Figure 21 — Pain Points Respondents will be Targeting in Future Digital Thread Implementations (% of respondents)

Respondents were asked what new value opportunities they are targeting in future digital thread implementations within their company. Results are shown in Figure 22.

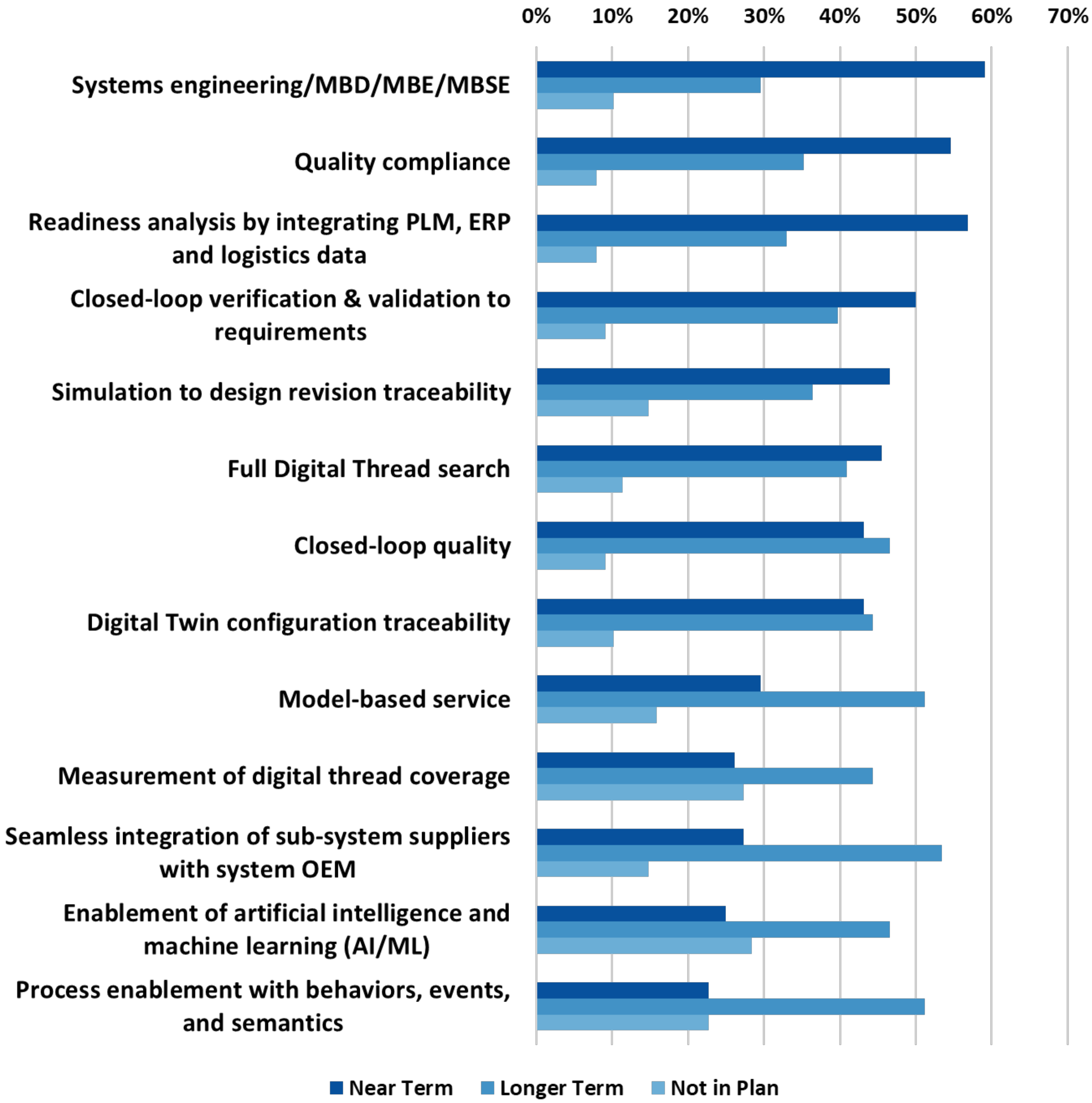

Figure 22 — New Value Opportunities Respondents will be Targeting in Future Digital Thread Implementations (% of respondents)

Expanding Value Footprint

Respondents were asked a series of questions to define their plans for expanding their current digital thread implementation(s) along several dimensions.

Respondents were asked how they plan to expand their digital thread implementations currently in place within and across lifecycle phases over time. Results are shown in Figure 23.

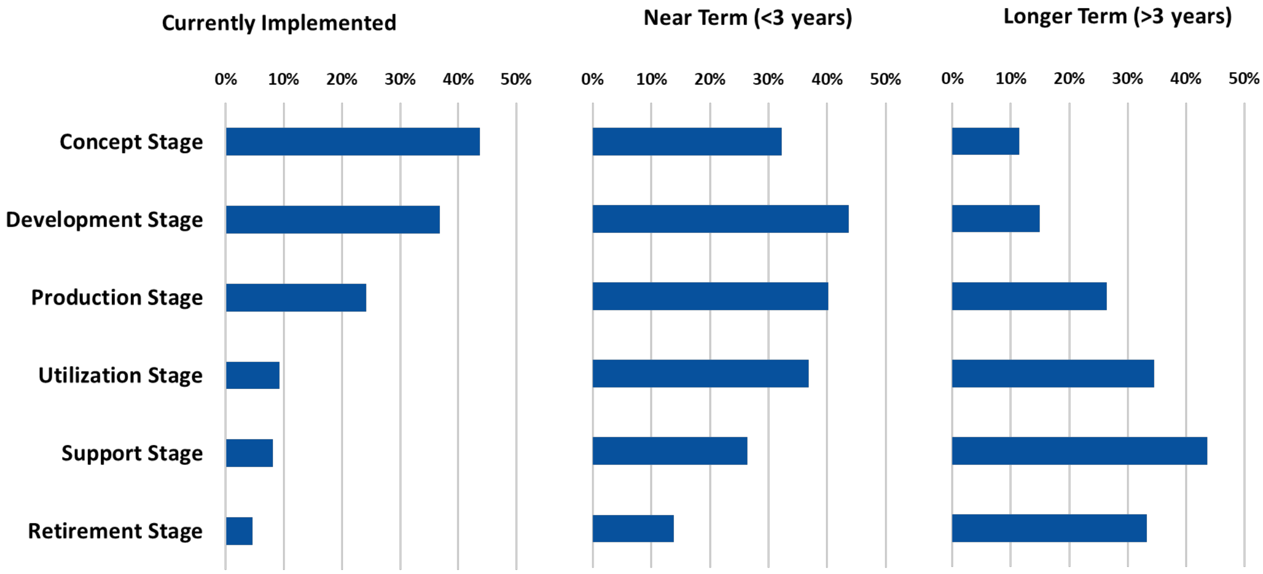

Figure 23 — Respondents' Plans to Expand Current Digital Thread Implementations Within and Across Lifecycle Phases Over Time (% of respondents)

Respondents were asked how they plan to expand linkages currently in place within and across product lifecycle data categories over time. Results are shown in Figure 24.

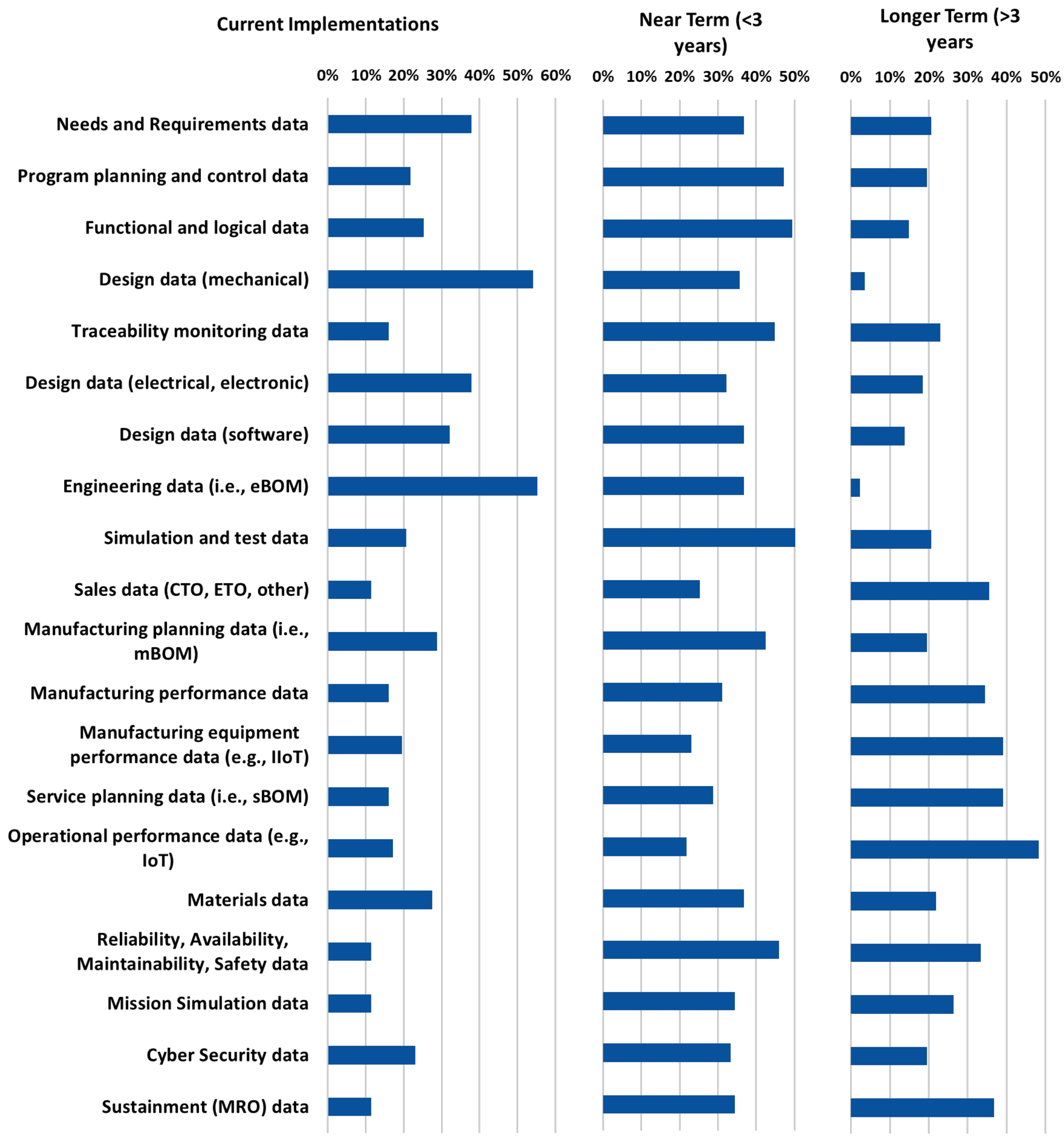

Figure 24 — Respondents' Plans to Expand Current Linkages Within and Across Product Lifecycle Data Categories Over Time (% of respondents)

Respondents were asked how they plan to expand implementation of use cases for digital thread in their company over time. Results are shown in Figure 25.

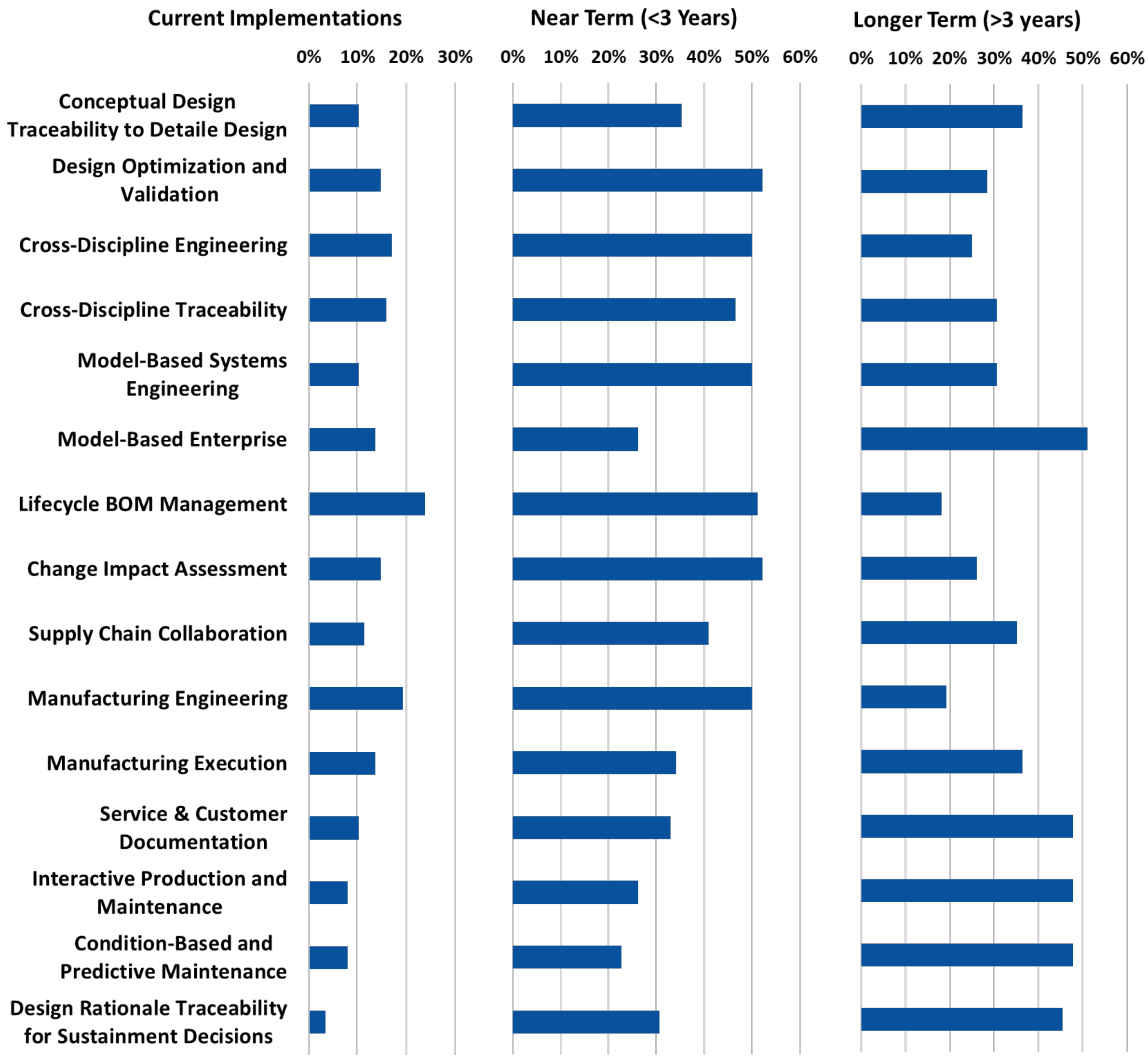

Figure 25 — Respondents' Plans to Expand Implementation of Use Cases for Digital Thread Over Time (% 0f respondents)

Respondents were asked how they envision the extent of community involvement increasing as they pursue their company's digital thread plans. Results are shown in Figure 26.

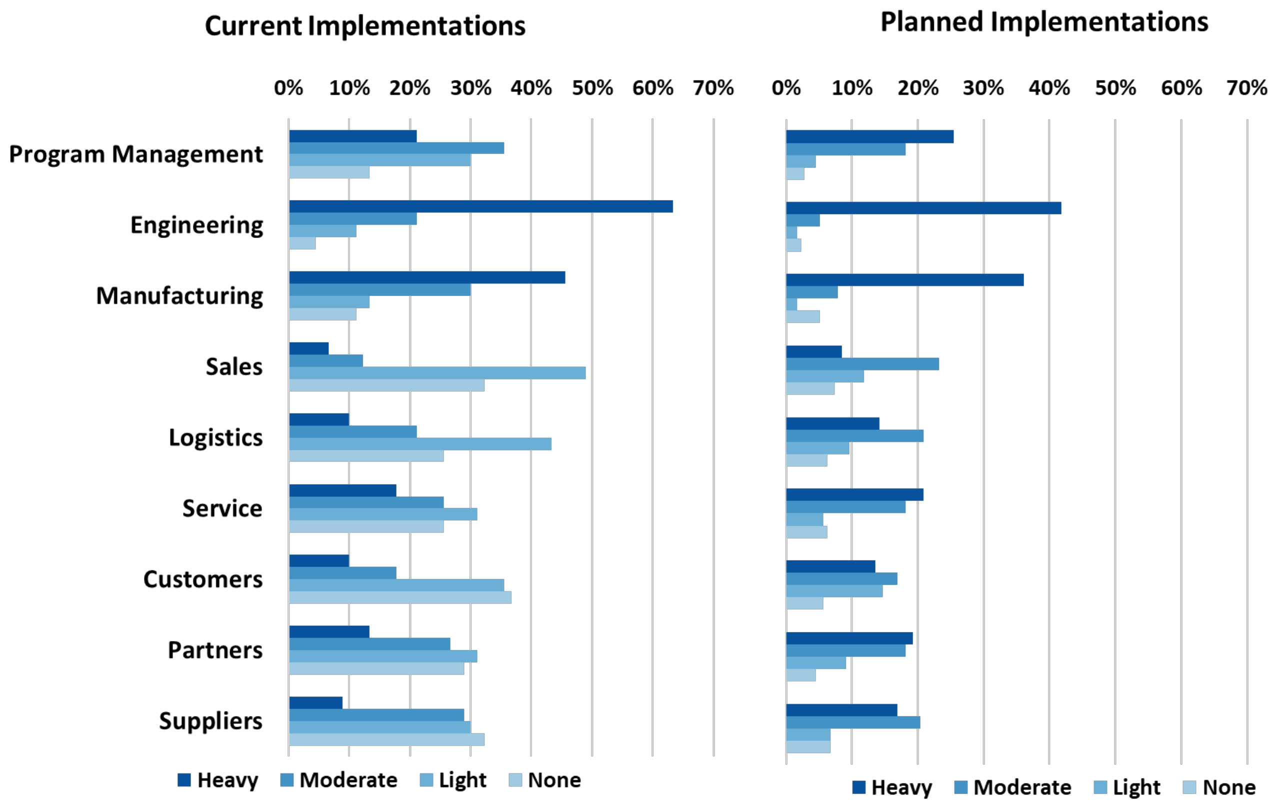

Figure 26 — Respondents' Vision for Expansion of Community Involvement as They Pursue Their Companies' Digital Thread Plans (% of respondents)

Solution Capability and Provider Alignment

Interviews

Results from the 10 industry interviews on the topic of solution capability and provider alignment were mixed.

Some interviewees were quite critical, especially regarding data model accessibility and flexibility to comply with their corporate data governance strategy. Another criticism was that PLM solution providers do not appear to be leveraging open, modular, event-driven architectures, calling into question their longer-term viability as core components of a digital thread. These interviewees stated that it is unclear which solution capabilities can be implemented in phases or how features interact with or depend on deployment of other features. Consequently, a viable deployment strategy of PLM features, in coordination with other contributing data sources, is difficult to derive. These comments draw a contrast with earlier packaging and deployment models when solutions were sold in modules, each with a defined set of features and functions, as well as clear and documented interdependencies between modules. It may be true that functions and features and the data they create and consume are more effectively integrated within the modern PLM solution platforms, but these interviewees see a significant downside when planning a deployment roadmap, especially within a broader enterprise landscape.

Other interviewees were neutral or slightly positive on this topic. They feel that some providers are moving in the right direction; some are not. Several felt that, in general, solution capabilities have improved significantly over the last 5-10 years and that, despite some remaining gaps, are now fully capable. Some expressed satisfaction that "good partnering" is happening.

A nearly universal concern is lack of openness and dependence on 3rd party connectors for connectivity and data interchange with the PLM solutions. Interoperability and openness have improved but are fragile and there are emerging signs of potential backsliding. There is a sense that PLM vendors are feigning openness, while trying to lock businesses into their platform at the same time.

Another broadly felt frustration is that the solution providers want to provide generic capabilities rather than support industry-specific, e.g., A&D, needs. As a result, even with the best of intentions, the business requires customizations, and the providers do not architect their solutions to support efficient management of customizations over release cycles.

An emerging concern is protection of intellectual property and ownership of the data. With the advent and increasing adoption of cloud-based solutions there is a new level of ambiguity surrounding this topic.

Survey

As was done in other subject areas, survey questions were crafted with pick lists derived from the interviews.

Respondents were provided with a list of choices and asked to indicate any notable examples of gaps in capabilities offered by their chosen solution providers. Results are shown in Figure 27.

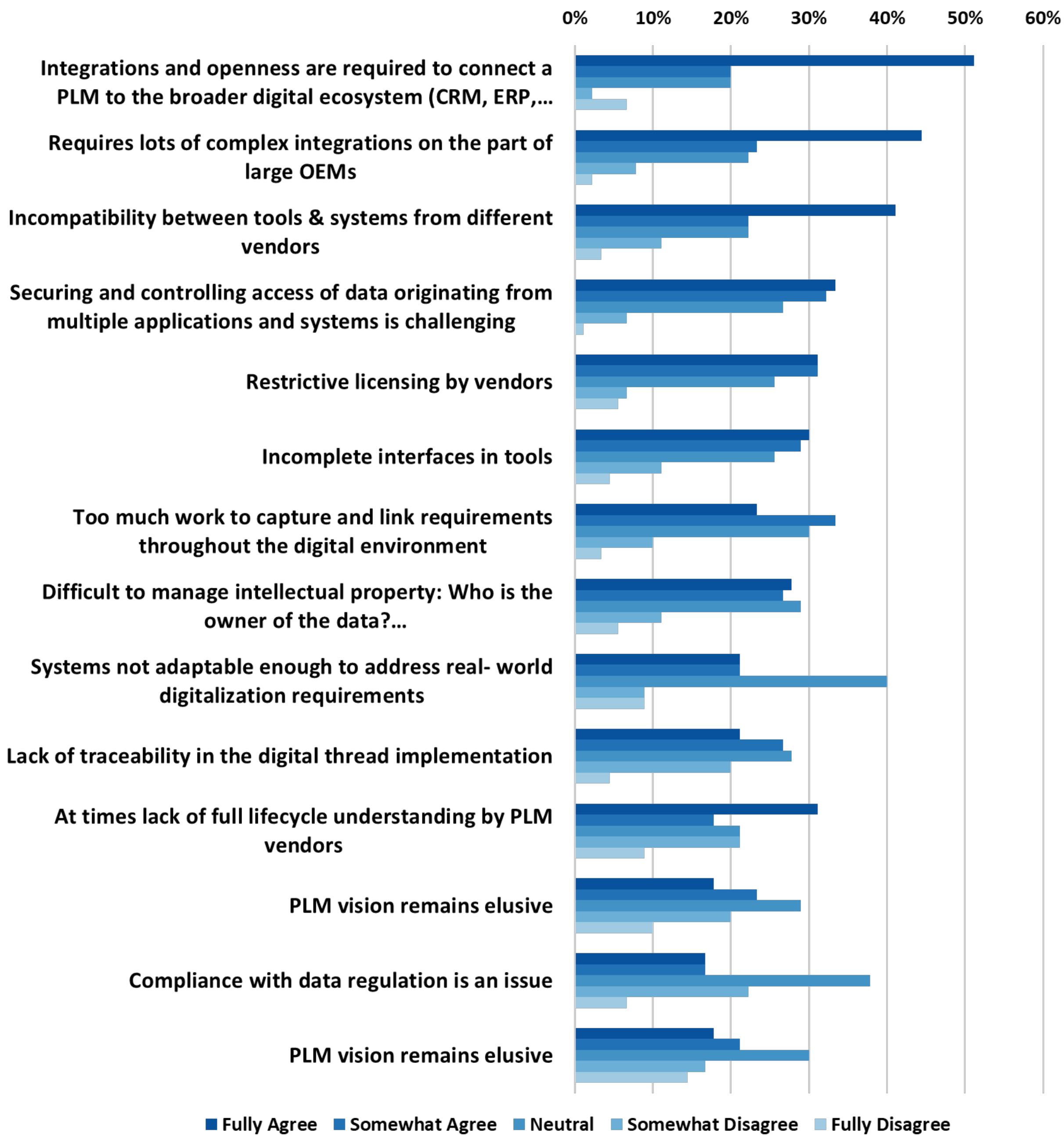

Figure 27 — Notable Examples of Gaps in Capabilities Offered by Respondents' Chosen PLM Solution Providers (% of respondents)

Respondents were asked how well their perspectives and strategies for digital thread investment are aligned with those of their chosen PLM solution providers. Results are shown in Figure 28.

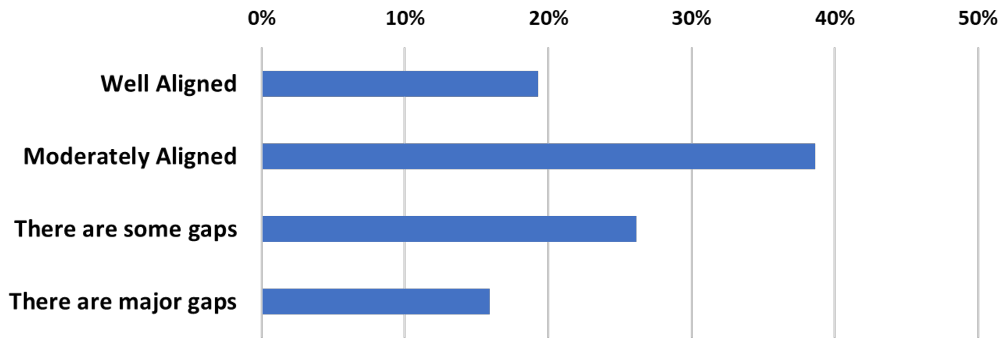

Figure 28 — Degree of Alignment of Perspectives and Strategies for Digital Thread Investment Between Respondents and Their Chosen PLM Solution Providers (% of respondents)

Respondents were provided a list of choices and asked to indicate any notable examples of alignment or misalignment between their company and their chosen solution providers. Results are shown in Figure 29.

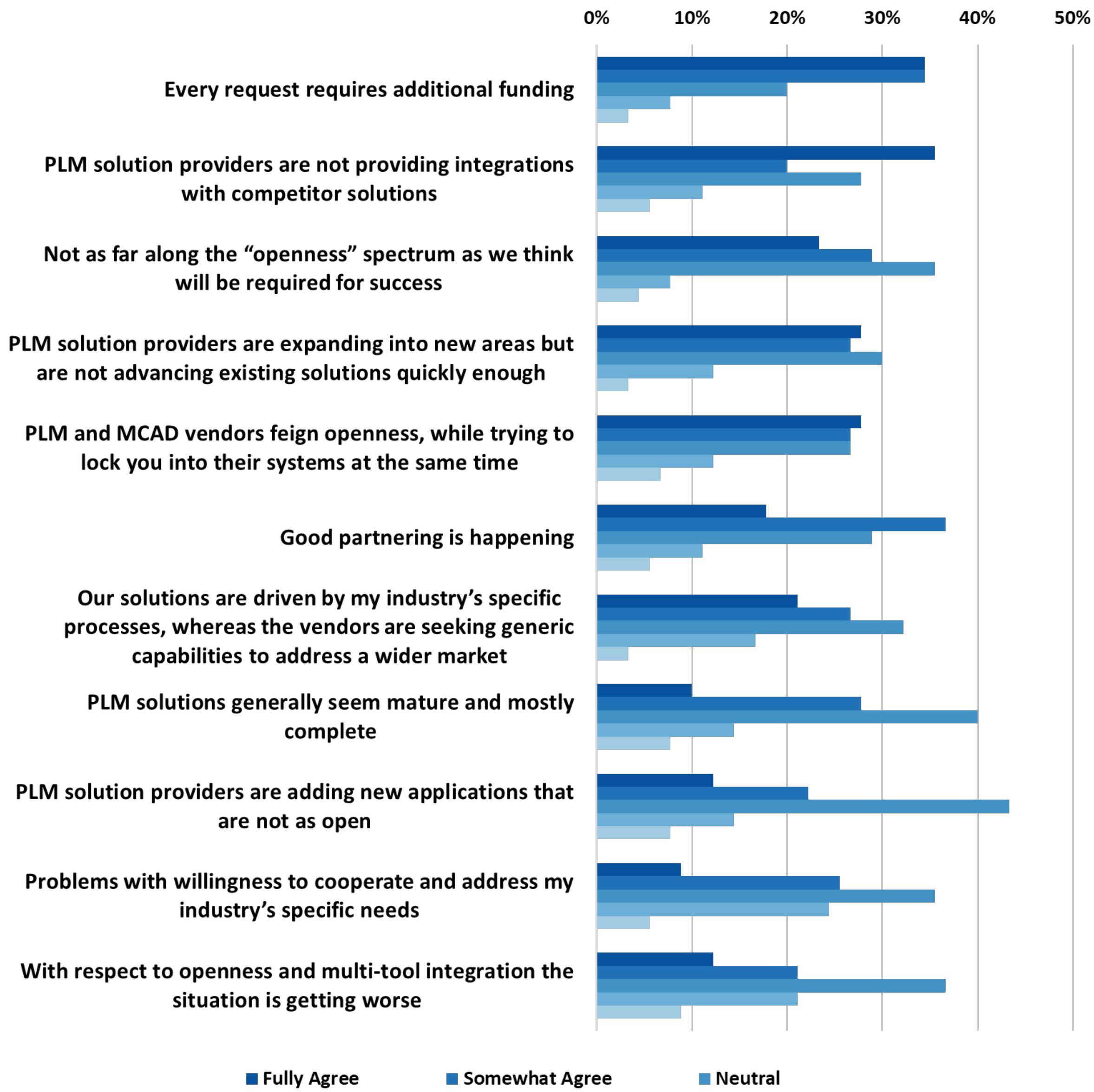

Figure 29 — Notable Examples of Alignment or Misalignment Between Respondents and Their Chosen PLM Solution Providers (% of respondents)

Summary Observations

The following key takeaways can be derived from the analysis of the interview and survey results:

- CIMdata's analysis clearly indicates that digital thread investment within the ecosystem of industrial users, their customers, suppliers, and solution providers has reached an inflection point. Initial implementations of targeted digital thread solutions have provided proof points of value and essential learnings. New rounds of investment are ramping up, guided by these early achievements and with expectations driven by the value potential revealed.
- Review of the companies represented, and the positions held by the interviewees and survey respondents confirms that the information received is representative of the most influential companies and leading thinkers within the aerospace and defense industry.

The What and Why of the Digital Thread

- Nearly half of companies surveyed do not have a commonly accepted definition of digital thread. Less than 10% use a published definition. This suggests that the conceptual understanding of digital thread within industry is very immature.
- Though there may not be a consistent and widely accepted definition of digital thread, there is a broadly shared perception of what a digital thread ***does*** and what a digital thread ***is***.
- The most prominent characteristics of what a digital thread ***does*** are "establishes traceability of product information" (75%) "across multiple domains in the lifecycle (mechanical, E/E, software and firmware)" (50%).
- The most prominent characteristics of what a digital thread ***is*** are "linkage and traceability between data elements at the meta-data level" (70%), "interoperability between data elements for interpretation of one by the other" (45%) and "combination of data model and technologies that facilitate the data model" (45%).
- The main reasons for the digital thread's rise to prominence are "product complexity has continued to increase substantially" (58%), "rising customer expectations, e.g., a desire to deploy digital twins" (46%), "new enabling technologies have emerged" (43%), and "emphasis on time to market and the search for efficiencies" (42%).

The Current Reality of Digital Thread in Industry

- Improving efficiency (65%), product quality (56%) and time to market (43%) are critical business goals driving digital thread efforts, but number 1 is "reducing risk and errors in product development with better traceability" (68%).
- As would be expected, digital thread implementations are most prevalent in the concept (46%) and development (38%) lifecycle stages. They are also significant in production (24%) but are rare (10% or less) in later lifecycle stages.
- Currently, the most prevalent digital thread linkages are between design-related data categories, i.e., needs and requirements data (38%), mechanical design data (54%), E/E

design data (39%), software design data (32%), and engineering bill of materials data (56%).

- The prevalence of current digital thread use case implementations is surprisingly low.
- The importance assigned to digital thread use cases is surprisingly broad and high.
- The most striking indicator that digital thread investment is in very early days is the contrast between importance assigned to digital thread use cases and the prevalence of current implementations. For example, lifecycle BOM management is considered essential by 62% and important by 26% of respondents but is currently implemented within only 25% of respondents' companies.
- Not surprisingly, the user communities contributing to and leveraging current digital thread implementations are primarily Engineering and Manufacturing and to a lesser but still significant degree Program Management and Service.
- A wide variety of application systems are used to create and consume product lifecycle data. Number 1 is PLM and PDM (84%), followed by MCAD (75%) and ERP (72%).
- The technologies used to link product lifecycle data segregate into three tiers. The top tier, which has the longest history, includes PLM and PDM (80%), followed by ERP (68%), and custom applications (52%). The middle tier consists of application and data integration tools. These are followed by the third tier of newer specialty technologies for combining data from multiple sources and establishing linkages and traceability. We can expect the ranking of these specialty technologies to rise significantly over the next few years.
- Respondents' self-assessment of the maturity of the digital thread within their companies is very good news for solution providers. A majority of respondents assigned a rating of mature or industry leading to their company's vision (64%) and level of planning and funding (56%). This suggests that they are ready to invest in implementations which the majority rate as immature (62%).
- Most respondents struggle with metrics to track the effectiveness of their digital thread strategy. Those who have metrics focus on the number of systems or the number of data elements integrated within the digital thread. A few are focused on number of links and traceability between data elements.
- The number 1 inhibitor to formulating and executing a digital thread strategy is "lack of interoperability between different vendors' tools and systems." The number 1 proposed means for mitigation is to "increase support of standards", which was followed closely by "increase management support."

Planning Investment for Digital Thread Expansion in Industry

- Looking to the future, interviewees are taking a broader view of the digital thread's value potential, with more investment in production and service use cases. They view the next stage as more complex and transformative to their companies. Fortunately, several have been successful in establishing programs that enjoy strong support from a well-informed and motivated senior management. However, many others have not.

- All Top 6 pain points being targeted in future implementations relate to accessibility and traceability across data elements, especially traceability of requirements throughout the product data lifecycle.
- Systems engineering is featured prominently in many responses, including ranking as the top new value opportunity being targeted in future digital thread implementations.
- Investment, which has been concentrated in the Concept and Development lifecycle stages, will shift in the near term to Development and Production, while ramping up in the later lifecycle stages. In the longer term, investment will shift substantially to the later lifecycle stages.
- From the data perspective, investment, which has been concentrated on establishing linkages between design-related data categories, will in the near term be more broadly dispersed across the product lifecycle. In the longer term, investment will shift toward linking data within and between categories associated with the later lifecycle stages.
- Investment in use case implementations will follow a similar pattern as investment in lifecycle stages and in data linkages, increasing in intensity and broadening in the near term, and then decreasing in intensity and shifting to the later lifecycle stages in the longer term.
- It is notable that in the near term there is a heavy investment emphasis in three areas:
  - Systems engineering, design optimization, validation, and traceability
  - Lifecycle BOM management and change impact assessment
  - Manufacturing engineering

Solution Capability and Provider Alignment

- Results from industry interviews on the topic of solution capability and provider alignment were mixed. Some interviewees were quite critical, especially regarding data model accessibility and flexibility to comply with a corporate data governance strategy. Another criticism was that PLM providers do not appear to be leveraging open, modular, event-driven architectures, calling into question their longer-term viability as core components of a digital thread.
- Other interviewees were somewhat neutral or slightly positive on this topic. They feel that some providers are moving in the right direction; some are not. Several felt that solution capabilities have improved significantly overall in the last 5-10 years and that, despite some remaining gaps, are now fully capable. Some expressed satisfaction that “good partnering” is happening.
- A nearly universal concern is lack of openness and dependence on 3rd party connectors for connectivity and data interchange with the PLM solutions. Interoperability and openness have improved but are fragile and there are emerging signs of potential backsliding.
- Even with the best of intentions, A&D companies require customizations, and the providers do not architect their solutions to support efficient management of customizations over release cycles.
- With the advent and increasing adoption of cloud-based solutions there is a new level of ambiguity surrounding protection of intellectual property and ownership of the data.

- The survey responses reinforced the interviewees concerns, with their top capabilities gap being “integrations and openness are required to connect a PLM to the broader digital ecosystem (CRM, ERP, PPM, etc.).
- Respondents were split on the question of whether their solution providers are aligned with their perspectives and strategies for digital thread investment, with the majority (60%) feeling they are moderately or well aligned. A significant minority (40%) felt there were some or major gaps.
- Of the Top 5 examples of misalignment between respondents and their chosen solution provider, three relate to lack of openness.

About A&D PLM Action Group

The Aerospace & Defense PLM Action Group (www.ad-pag.com) is an association of aerospace and defense companies within CIMdata's globally recognized PLM Community Program, which functions as a ***PLM advocacy group*** to:

- Set the direction for the aerospace & defense industry on PLM-related topics that matter to members (*including promoting, not duplicating, the work of standards bodies*)
- Promote common industry PLM processes and practices
- Define requirements for common interest PLM-related capabilities
- Communicate with a unified voice to PLM solution providers
- Sponsor collaborative PLM research on prioritized industry and technology topics

CIMdata administers Group operations, coordinates research, and manages the progression of policy formulation.

About CIMdata

CIMdata, an independent worldwide firm, provides strategic management consulting to maximize an enterprise's ability to design and deliver innovative products and services through the application of Product Lifecycle Management (PLM). CIMdata provides world-class knowledge, expertise, and best-practice methods on PLM. CIMdata also offers research, subscription services, publications, and education through international conferences. To learn more about CIMdata's services, visit our website at http://www.CIMdata.com or contact CIMdata at: 3909 Research Park Drive, Ann Arbor, MI 48108, USA. Tel: +1 734.668.9922. Fax: +1 734.668.1957; or at Oogststraat 20, 6004 CV Weert, The Netherlands. Tel: +31 (0) 495.533.666.

Appendix A: Partial List of Respondents' Job Titles

For those survey respondents who provided their name and corporate email address, we searched CIMdata's customer relationship management (CRM) database and LinkedIn to learn their job title. Those job titles are listed below.

A&D Industry Consulting Director
A&D PLM Strategist & Architect
Aerospace Engineer, Human Factors Researcher, Safety and Certification Specialist
Applications Analyst Senior Staff
Associate Director, Engineering Systems
Business Analyst
Business Development Manager and AI Expert
CAD & PLM Team Leader
CEO
Chief Architect
Chief Engineer, Virtual Systems
Chief Engineer, Consulting & Systems Engineering
Consultant
COO
Digital Enterprise Transformation Architect
Digital Manufacturing Capability Lead
Director- Industry advisor - Manufacturing & Supply Chain - EMEA
Director IT Business Partner
Director, Business Development (Co-founder)
Director, Corporate PLM
Domain Consultant - New Product Innovation (NPI), Innovation & Transformation Group
Engineer
Engineering Design Systems (EDS) Regional Manager
Engineering Manager
Engineering Manager BOM & Configuration Management Product Development & Global Technology
Engineering PLM Deployment Manager
Head of Competence Center PLM+
Head of Digital PLM
Industrial Modelling and Simulations Senior Technologist
Instructor
Integration Product Line Manager
IT Architect Engineering IT
IT Enterprise Architect Engineering
IT Manager
Lead Engineer
Lead Engineer - MCAE Applications

Manager - Model-Based Engineering
Manager of Engineering Product Services
MBE Domain Advocate, Advanced Systems Digital Transformation Initiative
ME - Technical Fellow
Mechanical Engineer & Project Manager
PLM and Configuration Engineer
PLM Integration Engineer
PLM Program Manager, IT
PLM Systems Engineer, PLM COE, Engineering Processes and Tools
PLM Systems Manager
President
President & CEO
Principal Engineering Specialist (PES), Data & Configuration Management
Principal R&D engineer
Process & Systems Analysis Lead
Process Lead
Product Lifecycle Management Manager
Product Manager
Product Owner | Strategy Lead, R&D Digital
Program Manager, enterprise Product Lifecycle Management Integrated Decision Environment
Project Manager
Research Engineer
Senior Director, Technical Product Management
Senior ECO Specialist
Senior Enterprise Architect
Senior Manager, Architecture Integration & Interoperability Standards
Senior Manager, Software Engineering
Senior Manager, Systems Engineering
Senior Product Owner Engineering and Simulation
Senior Project Manager and SME and Architect
Senior Propulsion Manager
Senior Systems Engineer
Sr. Business Engineer, Associate Technical Fellow
Sr. CAx Systems Engineer
Sr. Manager, COE PLM Solutions
Systems Product Development Engineer
Technical Fellow, PLM
Technical Lead
Technical Product Owner
Technical Strategy Lead
Vice President, Intelligent Systems Engineering

Appendix B: Use Case Descriptions

Each of the use cases offered as pick list items in the online survey is described in the table below.

Use Case	
Title	**Description**
Conceptual Design Traceability to Detailed Design	Ensure reuse of pre-contract award work for post-contract award development
Design Optimization and Validation	Closed-loop requirements linking and tracing through design, implementation, and testing
Cross-Discipline Engineering	Design coordination and integration of mechanical, electrical, electronics and embedded software product content
Cross-Discipline Traceability	Dynamic tracking of traceability across managed lifecycle content
Model-Based Systems Engineering	Modeling, simulation, and virtual analysis at all stages of the RFLP
Model-Based Enterprise	Enable the enterprise to interact with rich engineering deliverables, validate products before going into production, and improve design review efficiency
Lifecycle BOM Management	Complete highly visual product definition driven from CAD and other descriptive artifacts for comprehensive configuration management across the lifecycle
Change Impact Assessment	Traceability between interrelated digital and physical assets to assess cost and lead time impact of change and to mitigate compounding risks of change on change
Supply Chain Collaboration	Co-design connectivity across the supply chain for both product and production
Manufacturing Engineering	Derive plant specific mBOMs from eBOMs; derive process plans and work instructions based on upstream eBOM
Manufacturing Execution	Deliver work instructions based directly on digital thread from mBOM down to the shop floor
Service & Customer Documentation	Develop technical documentation based directly on digital thread content

Use Case	
Title	**Description**
Interactive Production and Maintenance	Interact with products based on augmented reality using models and technical documentation
Condition-Based and Predictive Maintenance with Feedback Loops	Traceable linkages that aggregate sensor data, artificial intelligence models, and physics-based reliability models to aid in proactive maintenance and sustainment work
Design Rationale Traceability for Sustainment Decisions	Traceability of design rationale from early conceptual architecture through in-field sustainment