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Simulation Data Management
Survey Report

SDM WG Survey Team

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This report was produced on behalf of the NAFEMS Simulation Data Management Working Group by a sub-team working under the leadership of Randy Cigel, comprising:

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Rod Dreisbach	Boeing Commercial Aircraft
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Finally, the NAFEMS SDMWG, and the survey team in particular, wish to thank the respondents for taking the time to complete the survey

Laura Michalske
Chairman
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Disclaimer

Whilst this publication has been carefully written and subject to peer group review, it is the reader's responsibility to take all necessary steps to ensure that the assumptions and results from any analysis which is made as a result of reading this document are correct. Neither NAFEMS nor the authors can accept any liability for incorrect analysis.

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1. Introduction

Simulation Data Management (SDM) is an emerging technology for improving the product development and sustainment process that encompasses the management of data, models, processes, documents and metadata intrinsic to performing modeling, simulation, and analysis. However, while there is a significant amount of interest in this new area, there is also a wide variation of opinion across the industry on what SDM comprises, how to justify the business impact of investing in SDM, and how to minimize the risk of actually implementing SDM.

Formed in February 2008, the Simulation Data Management Working Group (SDMWG) provides a vendor-neutral, end-user driven consortium that promotes the advancement of the technology and practices associated with the management of engineering simulation data and processes.

The group is comprised of a mix of industrial end-users, consultants, vendors, and academia; it is led and directed by representatives of the industrial user community. The heterogeneous nature of the SDMWG, a characteristic of the NAFEMS community as a whole, is a major strength of the group. The diverse backgrounds also meant that it could not necessarily be assumed that all would share a common view of what SDM comprises. It is human nature to allow one's vision to be influenced by prior experience and it would not be at all surprising that a Product Data Management (PDM) or Product Lifecycle Management (PLM) vendor would not share the priorities of a simulation software (CAE) vendor or the developer of a process-integration or process-automation toolset. Similarly, users from highly regulated industries such as Aerospace and Defense whose products need to be supported over many decades may see things differently from industries such as consumer goods where a product lifecycle might be measured in months.

To provide an understanding of the viewpoints of these various constituencies as well as to provide a baseline set of user requirements against which further SDM definition work could be targeted, the SDMWG decided to conduct a user survey, first of its own members and then opening it to the full NAFEMS membership. There was a total of 93 respondents to the overall survey although the number of respondents to each question varied slightly. Those statistics are reported within each section of the report.

The survey questions were aimed at determining the scope of an SDM system in terms of categories of data to be handled, the level of abstraction and the process functionality offered. Users were asked questions such as, "Should the SDM system be the controlling application for the category of data, should it merely be able to access the data through interfaces to other systems or, finally, is it simply out of scope?"

The survey content and findings are reported within logically grouped sections within this report, along with an in-depth review of each section. These sections are:

- Demographics
- Scope of Simulation Data Management
- Product definition data
- Lifecycle state
- Simulation process and workflow
- Data related to other technical areas
- Granularity and classification of data
- Life expectancy of the data to be managed
- Data integrity and export to neutral formats
- Technological approach
- Additional input

- Suggestions for the NAFEMS SDMWG
- Conclusions

The relevant question or questions from the original NAFEMS survey is contained within the text of each major section so that the reader can directly refer to the question content and the answer options available to the survey respondent.

2. Demographics

This chapter describes the numbers, locations, company affiliations, areas of technical interest and expertise of the respondents to the survey. It also describes the background of the respondents and their frequency of using data management systems. It is intended to provide the reader a context in which to understand the responses to the survey and results that are presented.

Chapter 2.2 forms a foundation for the rest of the report. It describes how responses to the survey were grouped into families in order to improve the quality and insight of the analysis and conclusions drawn.

2.1 Geographic location and nature of organization

The first block of questions in the survey aimed simply at gaining an understanding of the geographic location and organization affiliation of the respondents.

Survey Section 1.0 Question 4:

Geographic location (continent)?

Response options:

- ☐ *North America*
- ☐ *Europe*
- ☐ *Asia*
- ☐ *South America*
- ☐ *Africa*
- ☐ *Australia*

Number of responses: 90

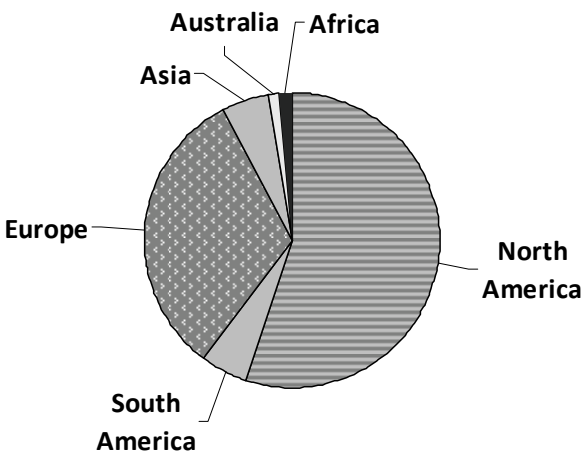


Figure 1: Locations of respondents

There were 93 participants in the survey. Respondents were asked to identify their geographical location as well as the distribution of their company offices and facilities. The number and distribution of respondents was, in part, a function of how effective NAFEMS was in making known the availability of the survey. It was announced in North American and European ISO and NAFEMS conferences, promoted by the members of the SDMWG – which has an international membership, and it appeared on the NAFEMS web site.

Approximately 55% of the respondents were located within North America. There was also substantial participation from the European nations at approximately 30%, with the other continents summing to the remaining 15% (Figure 1). Overall, responses predominately came from employees in large companies with an international presence. Consultancies were more likely to be geographically constrained to a single country, but even then many operated out of multiple locations.

Respondents were asked to describe the nature of the organization they work for by selecting an affiliation from a list. The options and responses are shown in Table 1 below.

Survey Section 1.0 Question 5:

Nature of your organization: [select one] ?

Response options:

- ☐ *OEM*
- ☐ *Tier 1 Supplier*
- ☐ *Tier 2 Supplier*
- ☐ *Other Supplier*
- ☐ *Consultancy*
- ☐ *Software vendor*
- ☐ *Research organization*
- ☐ *Academia*
- ☐ *Other (describe organization type)*
- ☐ *text box provided*

Number of responses: 90

Table 1: Survey respondents by affiliation

Nature of organization	Responses
OEM	30
Tier 1 Supplier	10
Tier 2 Supplier	3
Other Supplier	0
Consultancy	11
Software Vendor	27
Research Organization	4
Academia	2
Other (Unidentified)	6

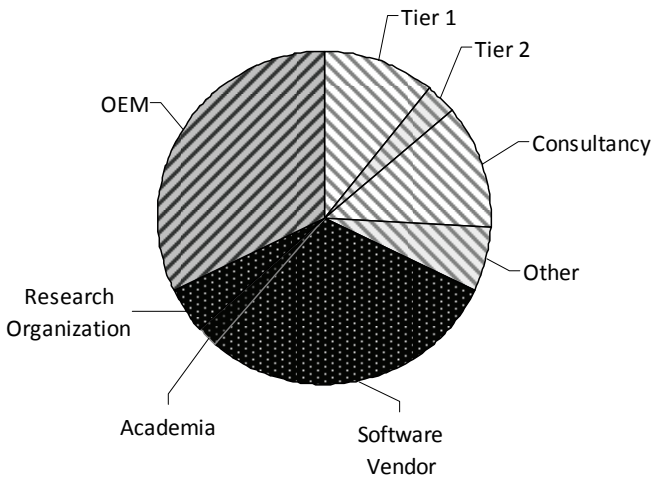


Figure 2: Respondent affiliations

The respondents to the survey were evenly distributed between major Original Equipment Manufacturers (OEMs) and software vendors (the remaining categories including consultants and suppliers made a mixed group of similar size). The responses came from around the globe, but the majority was from North America and Europe. Affiliations included manufacturers, consultants, vendors, research organizations, and academia.

2.2 Presentation and interpretation of survey results

In analyzing the replies to the survey, it was felt that several different reporting groups defined by combinations of affiliations would be useful in order to identify and report on the trends and messages from the survey responses. The affiliations were grouped and results tallied as described in this section. Note also that a consistent shade or pattern was assigned to each report group to make it easier to follow the plots of responses used throughout this report:

Report group 1:

This grouping was created to show differences in responses between OEM end-users, developers (including vendors), and all others in the supply chain. The group composition was defined as follows:

"OEM" = Original Equipment Manufacturer

"Supply Chain" = Tier 1 Supplier + Tier 2 Supplier + Other Supplier
+ Consultancy + Other

"Developer" = Software Vendor + Research Organization + Academia

Report group 2:

This grouping was created to show differences in responses between "Users" and "Developers (vendors)." The group composition was defined as follows:

"User" = OEM + Tier 1 Supplier + Tier 2 Supplier + Other Supplier
+ Consultancy + Other

"Developer" = Software Vendor + Research Organization + Academia

Report group 3:

This grouping simply combines all responses into one super group "All".

Table 2 shows the principal group combinations used to present results throughout this report, along with the theme (shade or pattern) used when plotting responses in each category.

Table 2: Affiliations of respondents combined into report groups

Affiliation combinations							
		Report group 1			**Report group 2**		**Report group 3**
Name of grouping and label used in plots		*OEM*	*Supply Chain*	*Devel-oper*	*User*	*Devel-oper*	*All*
Shade or pattern used in plots							
Type of organization	**Responses**	Composition					
OEM	30	✓			✓		✓
Tier 1 Supplier	10		✓		✓		✓
Tier 2 Supplier	3		✓		✓		✓
Other Supplier	0		✓		✓		✓
Consultancy	11		✓		✓		✓
Software Vendor	27			✓		✓	✓
Research Organization	4			✓		✓	✓
Academia	2			✓		✓	✓
Other (Unidentified)	6		✓		✓		✓

Such breakdown broadly achieves its objective of highlighting the differences between groups with different interests but is not rigorous. For example, detailed examination shows that two of the consultancies claimed to develop software for their clients, suggesting they should be placed within the Developer category, despite the fact that the remaining nine consultants have profiles far more closely aligned with the user community. Equally, some of the software vendors declared an interest as end-users of the software, presumably working with clients on a consultancy basis.

2.3 Area of interest in simulation

This question sought to determine the respondent's background or areas of interest in simulation. Combined with responses to other questions in the survey, it was also intended to shed light on the nature of using simulation data management within various engineering disciplines.

Survey section 1.1 question 1:

What is your area of interest or expertise in simulation? [Select all that apply]

Response options:

- ☐ *Acoustics*
- ☐ *Aerodynamics & CFD*
- ☐ *Crash*
- ☐ *Electrical / Electronic / Electromagnetics*
- ☐ *Fatigue*
- ☐ *Kinematics*
- ☐ *Manufacturing*
- ☐ *Materials*
- ☐ *Mechatronics*
- ☐ *Multi-body dynamics*
- ☐ *NVH (Noise Vibration Harshness)*
- ☐ *Process*
- ☐ *Simulation software development*
- ☐ *Structural analysis*
- ☐ *Systems*
- ☐ *Thermal*
- ☐ *Other (please specify)*

text box provided

Number of responses: 68

The responses are shown in Figure 3 using report group 2.

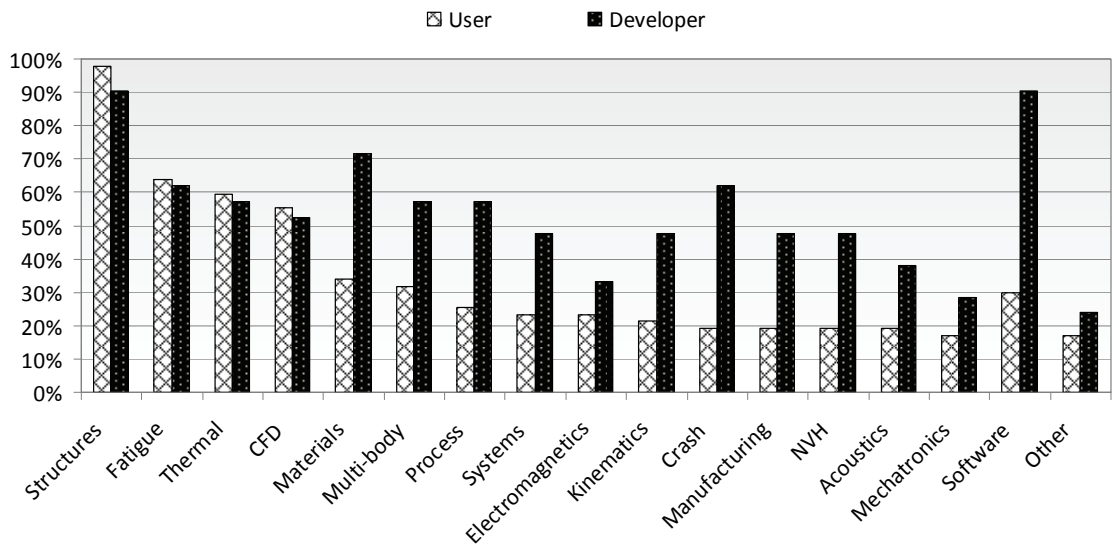


Figure 3: Area of interest or expertise in simulation

The Users that responded to the survey came mainly from interests in aerodynamics, fatigue, and structures. The Developers expressed wider interests and naturally included software development.

Lesser interest was expressed in electrical, manufacturing, mechatronics and systems.

2.4 Experience with SDM systems

This question sought to learn about the experience of the respondents in using systems for simulation data management.

Survey section 1.1 question 2:

What is your experience or usage of simulation data management (SDM) systems? [Select one]

Response options:

- ☐ *None*
- ☐ *Less than 5 years*
- ☐ *Between 5 and 10 years*
- ☐ *More than 10 years*

Number of responses: 85

The responses are plotted in Figure 4 using report group 2, but only User responses are shown.

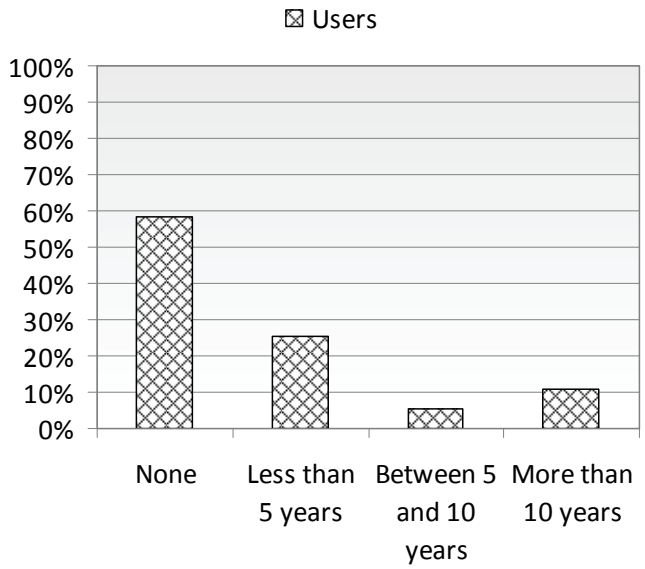


Figure 4: Experience in using SDM systems

Less than half of the User respondents had any experience with SDM systems. This may be due in part to SDM being a relatively new technology.

2.5 Experience or usage of PDM or PLM systems

This question sought to learn about the experience of the respondents with Product Data Management (PDM) or Product Lifecycle Management (PLM) systems. PDM systems have been used for Computer-Aided Design (CAD) data for many years, and may be used in some organizations for managing simulation data.

Survey section 1.1 question 3:

What is your experience or usage of product data management (PDM) or product lifecycle management (PLM) systems? [Select one]

Response options:

- ☐ *None*
- ☐ *Less than 5 years*
- ☐ *Between 5 and 10 years*
- ☐ *More than 10 years*

Number of responses: 86

The responses are plotted in Figure 5 using report group 2, but only User responses are shown.

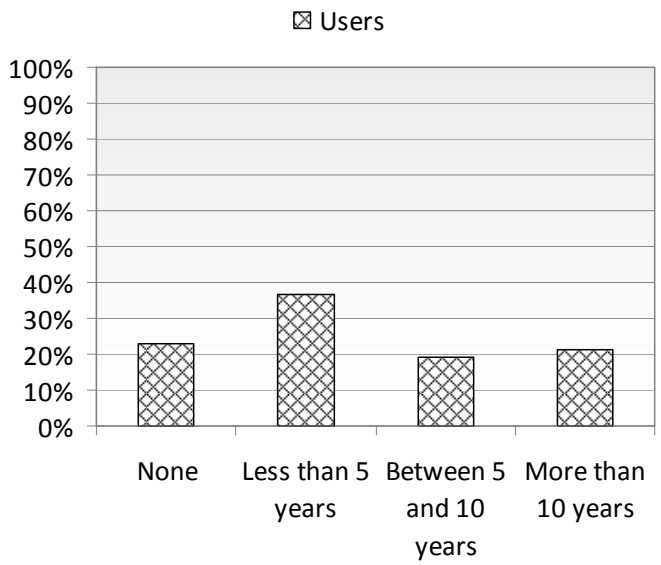


Figure 5: Experience or usage of PDM and PLM systems

The majority (75% of analysts) reported some experience with PDM or PLM systems. The greater experience with these systems may be indicative of the maturity of the commercially available software systems.

2.6 Frequency of using data management systems

In addition to the experience or familiarity respondents had with data management systems, the survey sought to learn about the frequency with which they use such systems.

Survey section 1.1 question 4:

How often do you use PDM (product data management), PLM (product lifecycle management), or SDM (simulation data management systems? [Select one]

Response options:

- ☐ *Never*
- ☐ *A few times a year*
- ☐ *Monthly*
- ☐ *Weekly*
- ☐ *Daily*

Number of responses: 86

The responses are plotted in Figure 6 using report group 2, but only User responses are shown.

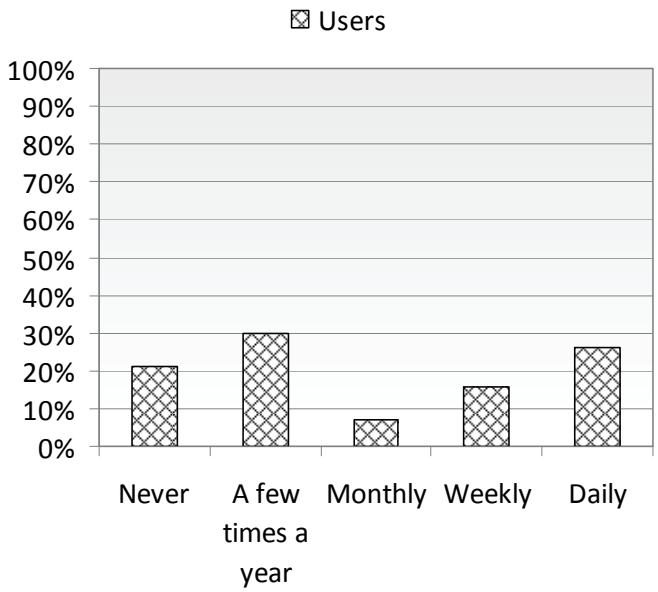


Figure 6: Frequency of use of data management systems

About 40% or the respondents use some type of data management system (PDM, PLM, SDM) on a regular basis (at least weekly), whereas the slim majority (52%) never or rarely used such systems.

2.7 Basis of interest in Simulation Data Management

This question asked respondents to indicate the reason, or in what capacity, they have an interest in the subject of managing simulation data.

Survey section 1.1 question 5:

What is your basis of interest in the subject of simulation data management? [Select all that apply]

Response options:

- ☐ *End-user who would benefit by having access to SDM capabilities in my work.*
- ☐ *Methods developer providing solutions to my company.*
- ☐ *Research and development working to advance the technology of SDM.*
- ☐ *Software vendor developing and providing SDM capabilities to my customers.*
- ☐ *Other (please specify)*
  text box provided

Number of responses: 84

The responses are plotted in Figure 7 using report group 2, but only User responses are shown.

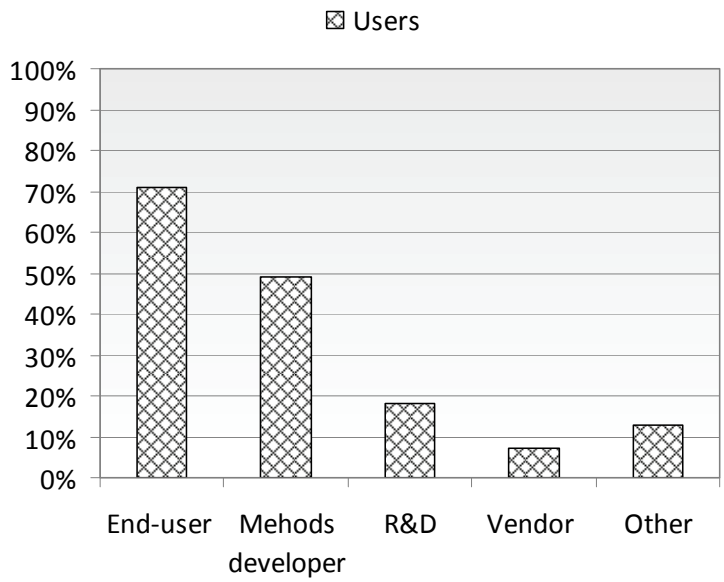


Figure 7: Basis of interest in subject of SDM

A large number (70%) of the User respondents reported that they believe SDM would benefit their day-to-day work. A substantial number of respondents also indicated that they are involved in developing methods or performing R&D related to simulation data management for their company. Multiple responses were permitted for this question.

To summarize Chapter 2, Demographics, respondents represented a wide range of backgrounds and affiliations, and they were about equally divided between OEM, Supply Chain, and Developers. Respondents were located world-wide, though heaviest in North America and Europe. Among the User group, 57% had no experience with SDM software, however 76% of them had experience with PDM or PLM software, and they use that type software at least monthly.

3. Scope of Simulation Data Management

The next major block of questions was formulated to determine the scope of an SDM system. It may appear surprising that such effort is required to scope the topic of SDM but from earlier discussions, it was evident that a number of interpretations are possible and distinct views are held by different groups. Even the name, Simulation Data Management, contains some ambiguities in that, it may simply be interpreted as data-management as applied to data objects which happen to arise from an engineering simulation activity. A broader interpretation would lead one to consider all the techniques and processes that may be applied to the management of simulation data. The first falls within the remit of an IT department, whereas the second is an engineering control activity.

A further reason for uncertainly is that some of the leading SDM systems are being developed from underlying PLM functionality, which tends to include a highly controlled environment for workflow management. This may bring with it a very different set of assumptions than those held by Developers of integration platforms used to support multi-physics analysis or process automation. Another distinct approach is implicit in the work of standardization bodies such as ISO where standards exist for the exchange and long-term archiving of simulation data in formats independent of applications.

The overall topic of the second block of questions was therefore "What data types and disciplines should be included within the scope of Simulation Data Management?" For the purpose of the survey, respondents were told to assume that **all simulation data** (physical data, analysis models, metadata, abstract data) **is within the scope of SDM**, irrespective of the discipline from which it arises and the questions sought to determine what else should be in scope.

The individual questions asked within this block were:

1. Should product definition data, such as CAD models, be in scope? *(Report Chapter 4)*
2. Which lifecycle states of data should be in scope? *(Report Chapter 5)*
3. Should simulation process data be in scope? *(Report Chapter 6)*
4. Should catalog or reference data such as material properties, standard parts, anatomical models, etc. be in scope? *(Report Chapter 7)*
5. Should test data be in scope? *(Report Chapter 7)*
6. Should business data be in scope? *(Report Chapter 7)*

The results of the detailed analysis from the chapters listed above are summarized and aggregated in Figure 8. Report group 3 was used.

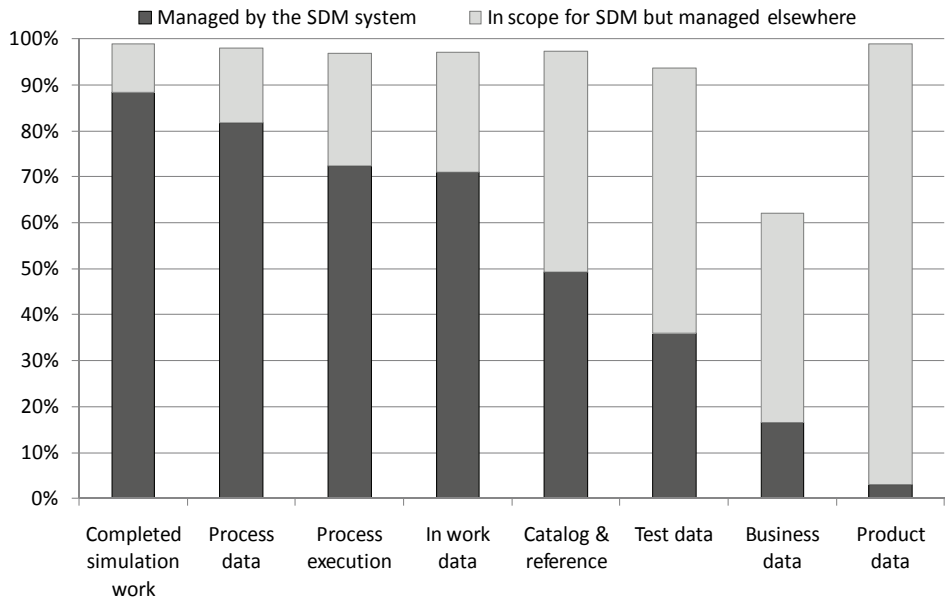


Figure 8: Scope of SDM

From Figure 8 it may be observed that strong support exists, going well beyond the simple storage of data, to include the management of processes. Since the responses from all categories of respondents were aggregated for this figure, the data have been interpreted to provide two distinct measures of scope. The first is that the class of data should be held within the SDM system and managed exclusively through its use. The second, alternative requirement is that the data should be accessible from within the SDM system, but the data itself should be stored and managed by a different system.

For the most relevant categories of data, these measures add to give 100%. For others, the stacked column does not reach 100%, showing that a proportion of respondents consider the data to be outside the scope of SDM and there are no requirements for its use.

The categories of data are ordered within Figure 8 according to the percentage of respondents that believe the data should be managed within the SDM system.

An overwhelming majority of respondents felt that all the types of data (except business data) referenced in Figure 8 are within the scope of an SDM system – business data had the least support with only about 60% of respondents saying that it was within scope. A majority of respondents felt that reports, process data, process execution, and in-work data should be managed within an SDM system. On the other hand, a large majority of respondents felt that product data, business data, and test data should be managed elsewhere. This may indicate recognition of the fact that many companies (especially large enterprises) already have existing infrastructure and systems to manage these types of data.

These issues are discussed in greater detail in the sections that follow. The discussion broadly follows the priority order taken from the chart above but with the exception that the relationship with product definition data is examined first.

4. Product Definition Data

This section addresses the issue of how much product definition data beyond that related specifically to simulation models should be included in an SDM system.

Survey section 2.0 question 4:

Should product definition data, such as CAD models, be in scope? [Select all that apply]

Response options:

- ☐ *No.*
- ☐ *Yes, by establishing and managing links between product definition data objects managed in a PDM system and simulation data objects managed in an SDM system.*
- ☐ *Yes, by having capabilities to search, or browse, for data managed in PDM systems from the SDM system.*
- ☐ *Yes, by… (please specify)*
  text box provided

Number of responses: 78

This subject tends to be somewhat controversial, especially within larger organizations that have already invested in CAD data management systems and/or enterprise PLM/PDM systems. IT organizations are often resistant to adding additional and separate data storage and management systems exclusively for use by the simulation/analysis community but those "enterprise level" systems are often viewed as too "heavyweight" and restrictive by the users of simulation/analysis tools.

The responses to the question are shown in Figure 9 using report group 1.

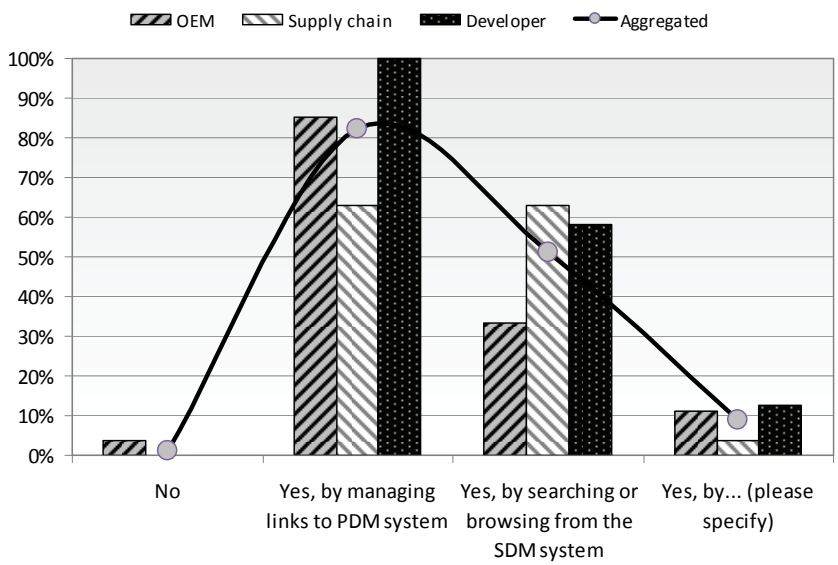


Figure 9: Management of product definition data

Despite the importance of a direct connection to product definition data, the survey respondents largely assumed that such data will be maintained within an enterprise PLM/PDM system. Almost all respondents assume some form of linkage to the PLM/PDM system, presumably as the source of geometric design content for the simulation models and to provide context for the overall project. It is evident that not all respondents view the link as being of a similar level of priority given one Developer comments below.

> "The coupling of SDM to PLM systems, while interesting, is not the first thing companies we have worked with look to accomplish. They tend to focus in on the execution of the simulation lifecycle from the modeling stage onward"

5. Lifecycle State

Simulation by its very nature involves performing "what-if" studies, the output of which may or may not impact the final design. Perceptions vary on which type of lifecycle data – in-work, completed work or both – should be captured and managed by the SDM system. The questions in this section sought to gain insight into this issue. At a finer level of granularity, should the management of data states such as "review", "released", or "obsolete" be supported? Finally, should the SDM system support multi-level versioning and maintain relations to design options?

5.1 In-work versus completed analysis

This question sought to determine whether the completed analysis work or the more transitory in-work data needs to be managed by the SDM system.

Survey section 2.0 question 3:

Which lifecycle states of data should be in scope?
[Select all that apply]

Response options:

- ☐ *Completed analysis work: The collection of input data, models, output data, and reports that comprise a completed analysis package.*
- ☐ *In-work data: the day-to-day input files, models, output files, and their revisions that are developed in the course of working toward a final simulation and final analysis results.*

Number of responses: 77

These were defined as follows:

Completed analysis work:

> The collection of input data, models, output data, and reports that comprise a completed analysis package.

In-work data:

> The day-to-day input files, models, output files, and their revisions that are developed in the course of working toward a final simulation and final analysis results

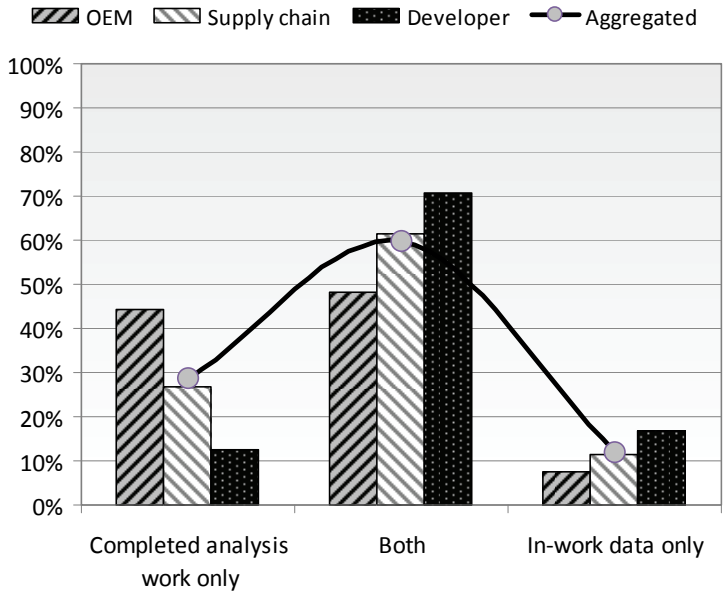


Figure 10: Management of lifecycle states of data

Figure 10 first shows the proportion of respondents that selected one of the options but not the other. The final category shows those that selected both. Report group 1 was used.

The majority of respondents (60%) see SDM systems as a repository for both completed simulation work and in-work analysis data. For OEMs, however, a sizable minority of 44% exists which would reserve the use of an SDM system for signed-off simulation work only. Could this represent a concern about storage requirements for the higher volumes of in-work data as opposed to just storing completed work? Or perhaps their vision is that in-work data is seen as too transitory?

The thinking of the small number of respondents that required an SDM capability for in-work data only can only be speculated upon. It is possible that they see SDM as a workgroup tool, while completed work becomes the responsibility of either the company at an enterprise level or their client.

The data from this question is captured in the overview chart in Chapter 1 (Figure 8) by the first and fourth bars.

5.2 Management of data states

Later in the survey a single question was posed to further gauge opinions on management of data states, versions, and design options.

Survey section 6.0 question 3

To what extent should management of data states (examples: "in-work," "reviews," "released," and "obsolete") be supported… Capabilities for managing revisions and versions of data objects should be included…? [Select all that apply]

Response options:

- ☐ *For all simulation data objects*
- ☐ *For all simulation process objects*
- ☐ *Multilevel versioning (i.e., hierarchy of major and minor modifications / corrections?)*
- ☐ *Relate simulation objects to the effectivity or option selected in the design product?*
- ☐ *None of the above*
- ☐ *Other (please specify)*
  a text box was provided

Number of responses: 68

Examples of data states included "in-work", "review", "released", and "obsolete". The question also referenced capabilities for managing revisions and versions of data objects.

The responses are shown in Figures 11 and 12. Report group 1 was used.

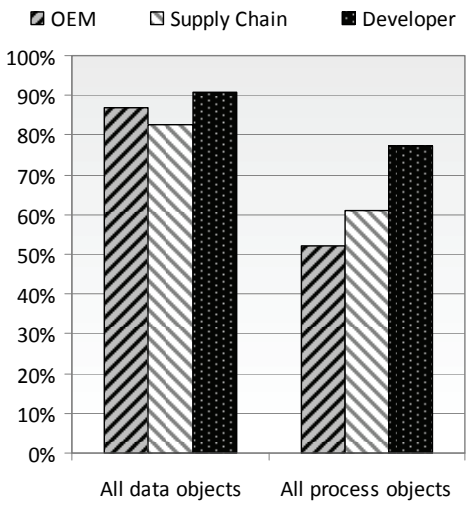


Figure 11: Assignment of lifecycle states – applicability

A majority (more than 88%) of both Users and Developers say that all simulation data objects need to be included and assigned lifecycle states, suggesting stronger support for the management of in-work data than does the previous question determining scope.

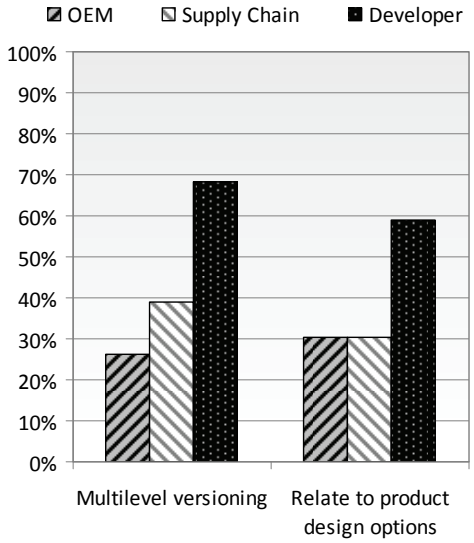


Figure 12: Assignment of lifecycle states – strategies

OEM requirements seem less comprehensive than Developer intentions in terms of management of simulation process objects, support for multi-level versioning, and the ability to relate simulation objects to design options.

6. Simulation Process and Workflow

Three questions in the survey were related to simulation process and workflow:

1) Should process data be managed?
2) What level of simulation or analysis process capability should be provided?, and
3) Should a hierarchical process capability is required?

See also section 7.3, for business data and process.

6.1 Process data

This question sought to determine whether simulation process data should be in scope, either by explicitly defining the process or by reference to templates.

Survey section 2 question 2:

Should simulation PROCESS data be in scope? [Select all that apply]

(Note: related questions will also be found in section 9.0 "Process Capabilities")

Response options:

- ☐ *Process data (process definition or templates)*
- ☐ *Relationships between data and processes*
- ☐ *Other (please specify)*

Number of responses: 77

The responses to the question are shown in Figure 13 using report group 1.

Over 80% of the respondents believe that process data was definitely in scope for an SDM system. One OEM made the comment

> "I think a standardization of simulation processes to ensure repeatability and possibility to compare results from different runs should be pushed as much as possible, following the stream of physical test standardization (already established). To this end process data traceability is key"

A further option was provided to determine whether maintaining the relationships between data and processes was in scope. A majority of both OEMs and Supply Chain companies was in favor, but their responses were significantly lower than that of the Developers.

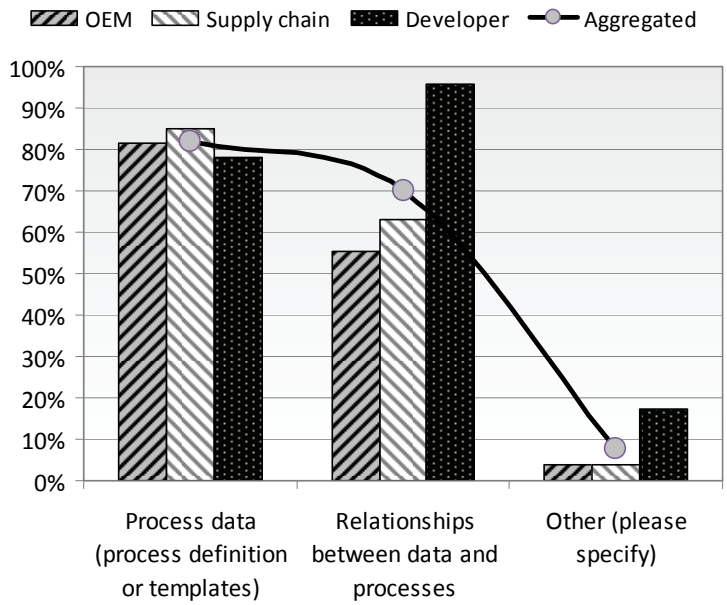


Figure 13: Management of process and workflow

The answers to the latter question suggest that industry is somewhat less interested in metadata and the capture of interrelationships between data objects than are the Developers. This may simply be a reflection of a deeper understanding of database technology capabilities on the part of the development community.

6.2 Analysis process capabilities

This question asked about capabilities to define and capture analysis processes.

Survey section 7.0 question 1:

What analysis process capabilities should a simulation data management system provide? [Select all that apply]?

Response options:

- ☐ *An analysis process flow should be implicitly established, and can be followed, from relationships assigned between managed objects.*
- ☐ *An analysis process flow can be explicitly defined and stored to document the process, provide an audit trail, and permit reuse.*
- ☐ *It should be possible to define (author) and run an executable analysis process with defined data flows and the ability to launch analysis applications.*
- ☐ *It should be possible to interface with separate software for process execution (or process orchestration) and to provide management of the data objects created or consumed by the process execution.*
- ☐ *None required*
- ☐ *Other (please specify)*

Number of responses: 65

The results for the capture and the execution of such processes are presented below in Figures 14 and 15, respectively. Report group 3 was used.

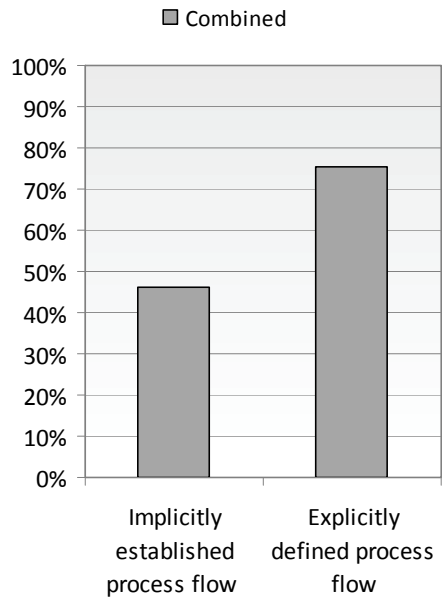


Figure 14 Representation of process data

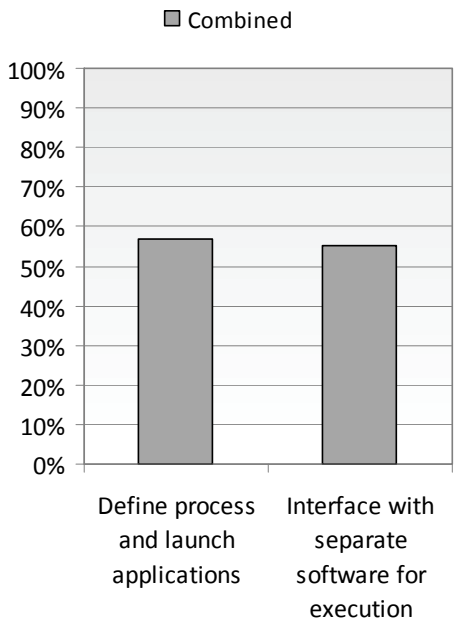


Figure 15 Execution of processes

Fewer than 10% responded "None required", so over 90% of the respondents believe that capabilities to define and capture analysis process flows should be enabled by an SDM system. Of those 90%, approximately 70% believe that this ability to define and capture analysis processes should be done within the SDM system, and approximately 55% think this should include the added capability for

executing those analysis processes from within the SDM system. Over 50% of the respondents believe that it should be possible to interface with software outside of the SDM system for analysis process execution and to provide management of the data objects created or consumed by the process execution.

6.3 Hierarchical process modeling

Respondents were asked whether it should be possible to manage hierarchical views of processes, so there are filtered views of different levels of process detail.

Survey section 7.0 question 2: ***Should there be a hierarchical process capability allowing filtered views of different levels of process detail?***
Response options: ☐ *Yes* ☐ *No*
Number of responses: 65

They were also asked if there should be a hierarchical process capability allowing filtered views of different levels of process detail.

Survey section 7.0 question 3: ***Should there be an ability to control access or visibility to data based on hierarchical levels of process detail?***
Response options: ☐ *Yes* ☐ *No*
Number of responses: 64

The responses to these two questions were indistinguishable. Over 80% responded "Yes" to both questions.

The high number of responses in this section is indicative that the respondents are seeking much more than an electronic filing cabinet for their data. They are seeking to enable process capture and automation. The requirements covered in this section can probably be much better understood by defining and analyzing particular use cases.

The second question contains the idea that end-users are authorized to view process descriptions at some level in a hierarchy, and that they are then authorized to view data associated with that process level, is interesting. There is, of course, a strong interaction and probable conflict with system security and data administration requirements (see Section 1).

7. Data Relating to Other Technical Areas

This section of the survey contains a series of questions which addresses the other types of technical data that respondents felt should be available to simulation end-users and where this related technical data should be managed – either in the SDM system or in other enterprise IT infrastructures such as PDM or PLM systems. For each question, the respondents had the option to denote that this type of data should not be managed at all within an SDM system or, if managed, whether that data should be accessible directly within the SDM or via links to that reference data stored within other IT systems.

7.1 Reference data

Reference data in the context of this question refers to any type of product-related data that is used in performing a simulation. This data is often contained in standard libraries of information that are utilized across many disciplines within an organization – the most common example being material properties

Survey section 2.0 question 1:

Should catalogue or reference data such as material properties, standard parts, anatomical models, etc. be in scope? [Select all that apply]

Response options:

- ☐ *No*
- ☐ *Yes, by managing them within an SDM system*
- ☐ *Yes, by establishing and managing links between catalog or reference data objects managed in a PDM system and simulation data objects managed in an SDM system*
- ☐ *Yes, by having capabilities to search or browse for data managed in catalog / reference data systems from the SDM system*
- ☐ *Yes, by… {please specify)*
  a text box was provided

Number of responses: 78

The comments of one respondent reflect the logical desire to have access to all data relevant to the simulation activity but also express some uncertainty about where that reference data should be managed:

> "Within the context of a (future) simulation driven development, all technical data relevant for every life cycle phase of the systems under development should be accessible and traceable. I do not know whether a SDM environment is the right tool to manage this information (we are now starting to scout this kind of technology) or not. Maybe a more general PLM approach embedding PDM and SDM (and maybe a test results data management system as well, if not included within the SDM) is more appropriate."

The responses to the question are shown in Figure 16 for Report group 1.

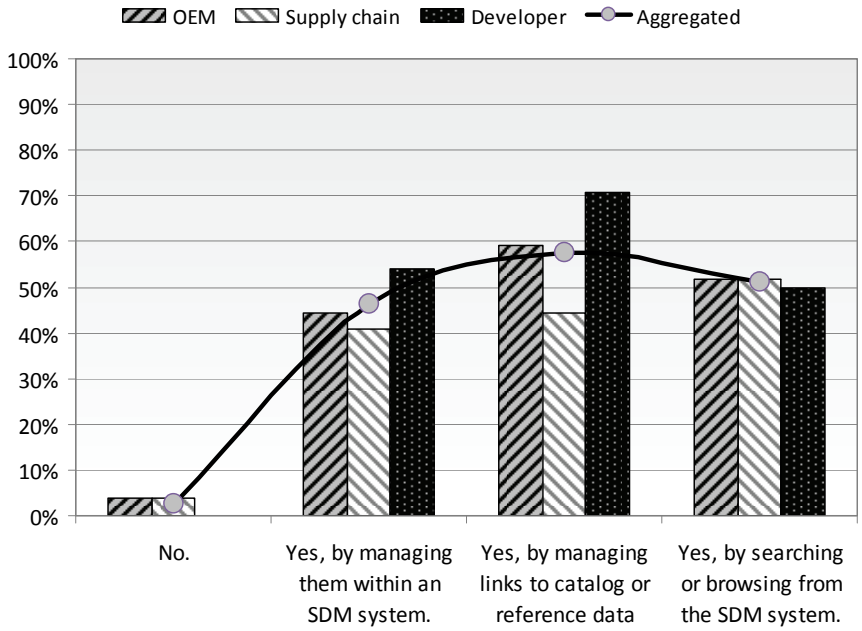


Figure 16: Management of reference data

While the vast majority of respondents see a need to have access to simulation-related reference data, slightly less than 50% overall believe that this information should be managed directly by the SDM system itself.

7.2 Test data

Physical test information is widely used within many organizations as the repository of product validation results as well as for developing product duty cycles, operating loads and boundary conditions, and pass/fail metrics based on both in-lab and real world, in-service conditions – all of which are valuable as inputs into the virtual performance simulation process. In addition, actual product test results are often used to calibrate/correlate and validate the accuracy of virtual prototypes. This question explores that close relationship with the performance engineering data generated within the physical realm vs. the virtual realm.

Survey section 2.0 question 5:

Should test data be in scope? [Select all that apply]

Response options:

- ☐ *No*
- ☐ *Yes, by managing them within an SDM system*
- ☐ *Yes, by establishing and managing links between test data objects managed in a PDM or test data system and simulation data objects managed in an SDM*
- ☐ *Yes, by having capabilities to search, or browse, for data managed in test data management system from the SDM system*
- ☐ *Yes, by... (please specify)*
  a text box was provided

Number of responses:78

The responses to the question are shown in Figure 17 using report group 1.

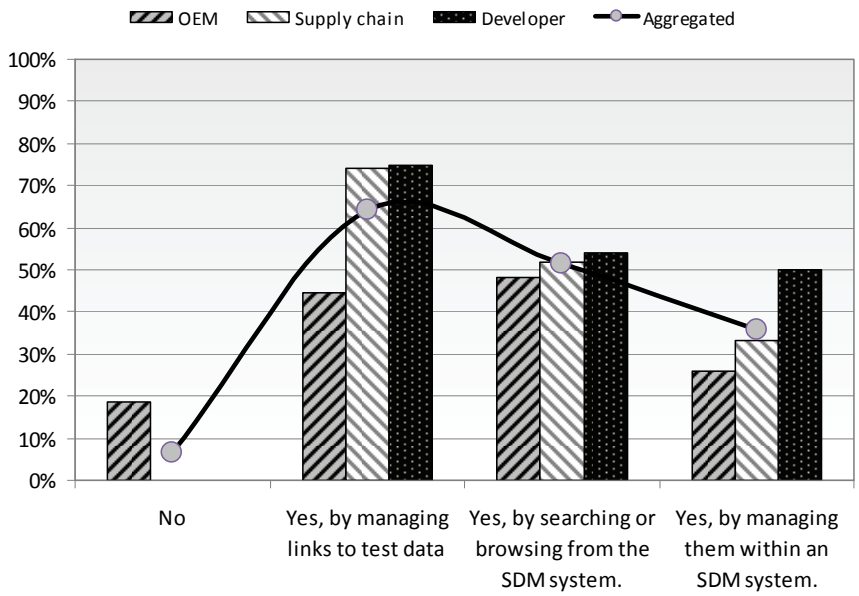


Figure 17: Management of test data

While the vast majority of respondents see a need to have access to simulation-related test data, only 36% overall believe that this information should be managed directly by the SDM system itself. Supply Chain respondents rated the requirement to have access to this test data significantly higher than the OEMs by establishing and managing links to where that data is accessible. Interestingly enough, Supply Chain respondents also rated access to test data significantly higher than the product definition reference data in the previous question. Users are less interested than the Developers in test data access, with 20% of OEMs requiring no access whatsoever to test data from within an SDM system.

7.3 Business data

7.3.1 General relevance

This question explores the need to maintain and relate information about the business and financial aspects of a program with the simulation activities performed during a specific program, directly within the SDM environment *vs*. an enterprise business system.

Survey section 2.0 question 6:

Should business data be in scope? [Select all that apply]

(Examples of business data include, project schedules, work assignment and timekeeping information, and budget / labor data)

Response options:

- ☐ *No*
- ☐ *Yes, by managing them within an SDM system*
- ☐ *Yes, by establishing and managing links between business data objects managed in a PDM or business data system and simulation data objects managed in an SDM system*
- ☐ *Yes, by having capabilities to search, or browse, for data managed in business data management system from the SDM system*
- ☐ *Yes, by... (Please specify)*
  a text box was provided

Number of responses: 79

The responses to the question are shown in Figure 18 using report group 1.

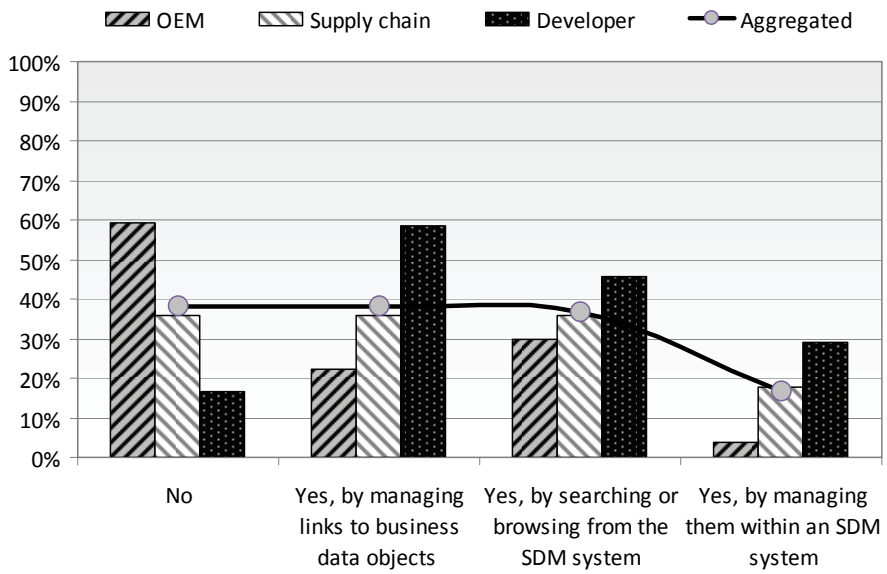


Figure 18: Management of business data

Overall, 38% of the respondents believe that business data should be out-of-scope for SDM, with a particularly strong NO vote (59%) from the OEMs. This is not particularly surprising, given the global scope of these organizations, their large investment in IT resources, and their reliance on enterprise-wide systems such as PLM/PDM, ERP, CRM, SCM, etc.

In general, Developers attached a significantly higher importance than Users to the ability of either managing this type of data within the SDM or providing links to this data via access to enterprise business data management systems such as PLM or ERP.

7.3.2 Business type process capabilities

This question is related to the one in Section 7.3.1 but was intended to focus on the work processes, data and tasks that are specific to the simulation/analysis activities as opposed to the more enterprise-level business activities and financial data.

Survey section 7.0 question 4:

What business type process capabilities should a simulation data management system provide? [Select all that apply]

Response options:

- ☐ *Process work requests and assign analysis tasks*
- ☐ *Check and report analysis work progress (analysis dashboards)*
- ☐ *Track project completions*
- ☐ *Track analysis resources (time, cost)*
- ☐ *Manage the review, sign-off, and release of simulation data with appropriate lifecycle state changes (i.e. "in-work," "review,'' "release")*
- ☐ *Manage review and sign-off of analysis reports*
- ☐ *Interface with enterprise business systems*
- ☐ *None required*
- ☐ *Other (please specify)*
  a text box was provided

Number of responses: 65

The responses are shown in Figure 19 for Report group 2.

Over 90% of all respondents indicated that multiple categories of business type process capabilities should be provided by an SDM system. "Yes" answers by the Developers were consistently higher than by the two categories of Users across all the categories with the most significant differences being in the areas of:

1. Manage the review, sign-off and release of simulation data with appropriate lifecycle state changes (i.e., "in-work", "review", release")

2. Interface with enterprise business systems

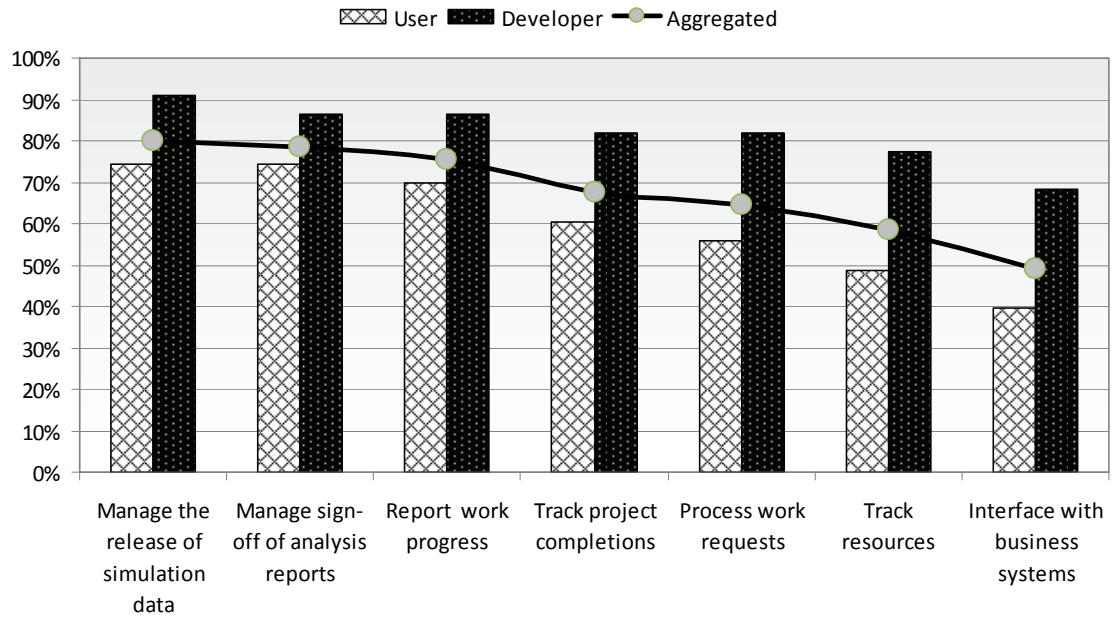


Figure 19: Business functionality required for the management of simulation

OEMs were more strongly against maintaining enterprise business content than were the Supply Chain companies. Speculating, this may reflect the greater separation of responsibility across the different functions within the larger companies; a situation where analysts have no authority to influence business and project management activities within the larger OEM organizations.

The results of this question appear to be somewhat at odds with the answers to the survey question reported in Section 7.3.1 on the relevance of business data to SDM scope. Possibly more care should have been taken to distinguish between simulation process management and overall business process management. This question really intended to address the simulation business process vs. the overall business process at the enterprise level.

8. Granularity and Classification of Data

The questions in this section deal with the level of detail of the objects that need to be managed, and the requirements for organizing, classifying, and viewing the data objects and their relationships.

Granularity refers to the level of abstraction or aggregation of the data.

8.1 Level of data abstraction / granularity

Respondents were asked about the various levels of granularity of the data that needs to be managed.

Survey section 3.0 question 1:

Select the statements that describe your view of the level of data abstraction that should be handled by an SDM system: [Select all that apply]

Response options:

- ☐ *There is a need to manage data at a high object level of abstraction (e.g., files, documents, object relationships)*
- ☐ *There is a need to manage data at more detailed level of abstraction (e.g., FEA model component parts [mesh, loads, properties, targets, results])*
- ☐ *There is a need to manage data at a fine level of detail (element-level data)*
- ☐ *Other (describe your view and provide examples of the level of data abstraction that need to be handled by an SDM system)*
  a text box was provided

Number of responses: 69

Three levels of granularity were offered:

1. A high level of granularity or abstraction was described to be things like files, documents, and object relationships;

2. A more detailed, or medium level, of data abstraction was described as items such as subcomponents of a model -- such as groups of loads, properties, or a finite element mesh. Also included were analysis targets and results;

3. Finally, a fine level of detail was described as individual parameters, name/value pairs, element-level data for finite element models, and detailed geometric design parameters.

The responses are shown in Figure 20 using report group 2.

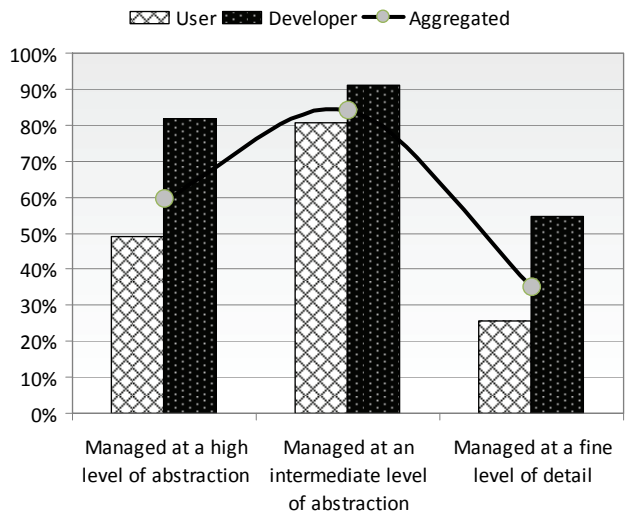


Figure 20: Granularity of SDM data representation

User respondents indicated that data at every level of granularity should be managed. The medium level of granularity or abstraction, such as model components, was the most popular response, selected by 80% of the respondents in the User group. Next, 50% of the respondents indicated that data at a high level of abstraction (such as files) should be managed. This indicates that more Users are interested in managing component-level data than objects at a file or document level. Data at a very fine level of abstraction, detailed data, was selected by 25% of the respondents.

Developers also indicated that data at every level of detail should be managed, and with even higher percentages than User respondents. The medium level of granularity was the most frequent selection among Developers.

In terms of the "Other" response option, several written comments were provided (which may be paraphrased) regarding level of granularity of the data to be managed

OEM comments

1. The level of detail is probably connected to the amount of data and the maturity of organization regarding SDM. At this preliminary stage of evaluation of SDM, a high level is probably most relevant.

2. There is no need to manage objects like files and folders because they are best dealt with by the O/S. However when data is managed in a distributed environment, there is a need to show links identifying out-of-data/update info (there may be dependencies).

Developer comments:

1. All are required

8.2 Structuring of data objects

8.2.1 Hierarchical representation

This question sought to determine the importance of organizing data in an ordered hierarchical representation based upon parent-child relationships to produce a folder or file-like tree structure.

Survey section 3.0 question 2:

An ability to create an ordered hierarchical representation of data objects based upon parent / child relationships to produce a folder/file-like tree structure is: [Select one]

Response options:

- ☐ *Very important*
- ☐ *Somewhat important*
- ☐ *Not very important*
- ☐ *No opinion*
- ☐ *Don't know*

Number of responses:70

The responses are shown in Figure 21 using report group 2.

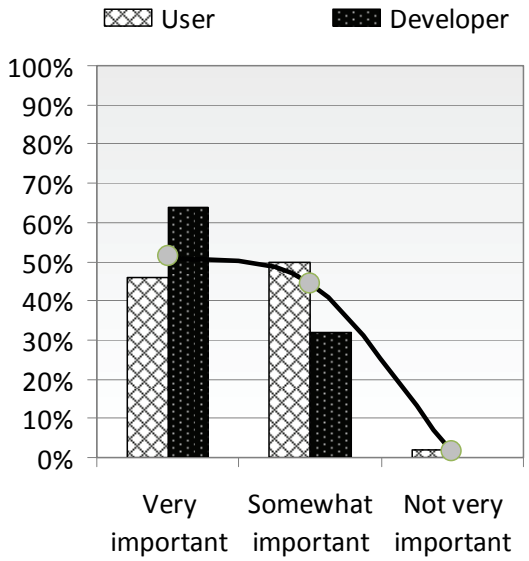


Figure 21: Hierarchical representation of data objects

Nearly all of the User respondents (95%) indicated that it is either very important or somewhat important that there be the ability to order the data in a hierarchical structure.

Likewise, nearly all of the Developers (93%) indicated that it was either very important or somewhat important.

It was rated very important more often by Developers (63%) than Users (46%).

8.2.2 Multiple inherited object classification

This question sought to determine the importance of having the ability to derive a data structure out of object classifications, in other words a semantic approach to data organization.

Survey section 3.0 question 3:

An ability to use a semantic approach in which a data structure is derived out of multiple object classifications is: [Select one]

Response options:

- ☐ *Very important*
- ☐ *Somewhat important*
- ☐ *Not very important*
- ☐ *No opinion*
- ☐ *Don't know*

Number of responses: 70

The responses are shown in Figure 22 using report group 2.

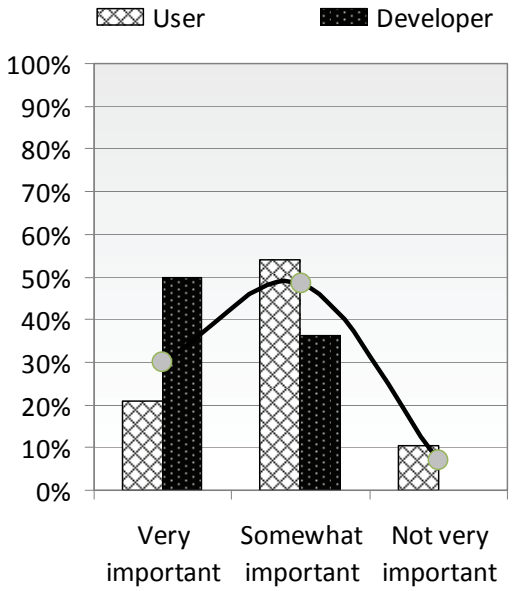


Figure 22: Multiply-inherited classification

Most of the User respondents (76%) indicated that it is either very or somewhat important, with the majority classifying it as just somewhat important (54%).

The majority of Developers also rated the capability either very or somewhat important, but they were significantly more likely to rate it as very important (50%) than did Users (21%).

The Developer community appears to place greater importance upon the semantic structuring of data objects than does the user community. This may simply be because they have a deeper understanding of data management theory.

8.2.3 Additional approaches for classifying data

This question was optional and asked respondents to describe other approaches to classifying data, and about a third of them (36%) choose to answer the question.

Survey section 3.0 question 4:

Optionally describe one or more additional approaches for classifying data, and then indicate the importance of the method. *[NOTE: Please respond using the comment box first and then select the importance of the method from the three available choices.]*

Response options:

- ☐ *Very important*
- ☐ *Somewhat important*
- ☐ *Not very important*
- ☐ *Please specify approach:*
  a text box was provided

Number of responses: 33

Written responses (16% of the respondents) indicated the need for a wide variety of methods for organizing data. Some of them would seem to be reliant on applying key descriptive metadata to the objects, and then being able to use that metadata in classifying and locating the data.

Written comments included:

Users:

Consultancy:

1. Organize in relation to projects
2. An ordered schematic representation with dependency links

OEM:

3. Based on product
4. Based on criteria selected by the User group
5. In relation to a physical part (number & version) with link to relevant FE model
6. Based on potential cost benefit and simulation type
7. Manage or classify by results that are used to make design decisions
8. Via search for material or date
9. By life cycle stage, project, subsystem and analysis type
10. Last modified. Show data last edited or modified.

Tier1:

1. By part function, part materials & processes, type of analysis
2. Configurable and flexible so that it can be adjusted to suit different customer needs

Developers

Developer

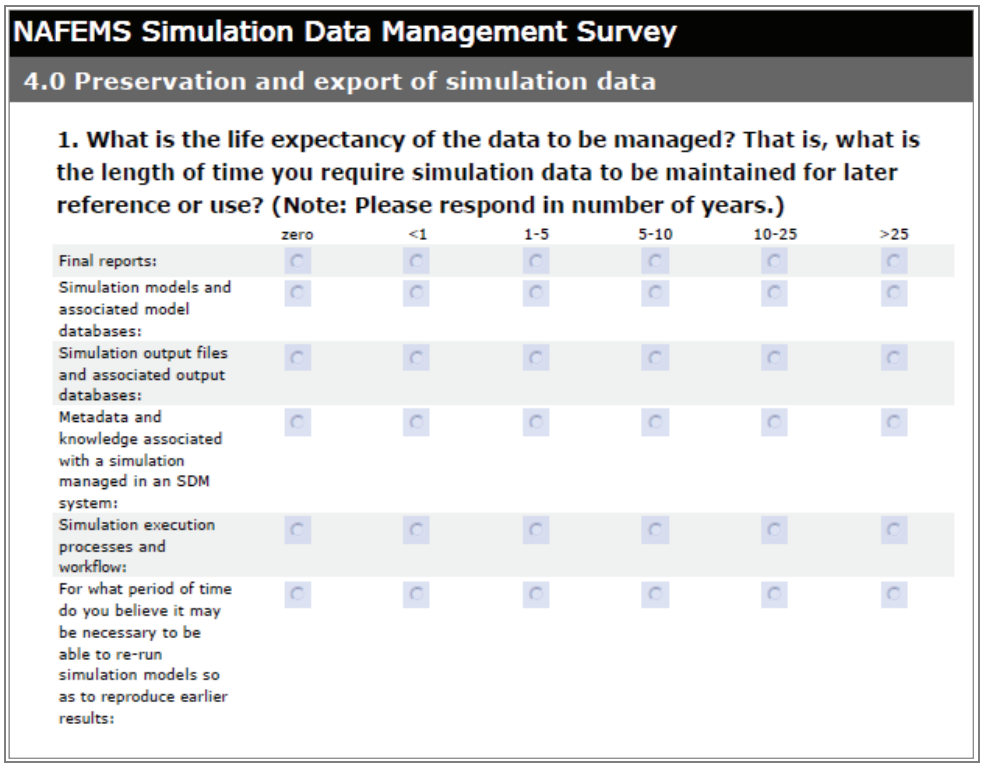
1. Based on project context, since the same data could be a part of different projects
2. Based on currently available products. Also by which products are considered successful, and which are not.
3. Discipline-based approach

In summary, respondents indicated a need to manage data objects at all levels of granularity. They also indicated a need to view data objects based on the relationships between them, and that a semantic approach is important. There is also a requirement to view and organize data based on the attributes (metadata) of the objects themselves, in addition to relationships between the objects.

9. Life Expectancy of the Data to be Managed

The survey sought to determine the number of years it is required for simulation data to be maintained for later reference or use. It provided the respondent with the ability to assign different retention requirements to various types of simulation data.

The question as it appeared in the survey is shown Figure 23 below.



NAFEMS Simulation Data Management Survey

4.0 Preservation and export of simulation data

1. What is the life expectancy of the data to be managed? That is, what is the length of time you require simulation data to be maintained for later reference or use? (Note: Please respond in number of years.)

	zero	<1	1-5	5-10	10-25	>25
Final reports:	○	○	○	○	○	○
Simulation models and associated model databases:	○	○	○	○	○	○
Simulation output files and associated output databases:	○	○	○	○	○	○
Metadata and knowledge associated with a simulation managed in an SDM system:	○	○	○	○	○	○
Simulation execution processes and workflow:	○	○	○	○	○	○
For what period of time do you believe it may be necessary to be able to re-run simulation models so as to reproduce earlier results:	○	○	○	○	○	○

Figure 23: Image of survey question

Note: Due to the length of the question, the plot labels used throughout this chapter are abbreviated:

Final reports = Final reports

Metadata = Metadata and knowledge associated with a simulation managed in an SDM system

Models = Simulation models and associated model databases

Process = Simulation execution processes and workflow

Output = Simulation output files and associated output databases

Re-run = For what period of time do you believe it may be necessary to be able to re-run simulation models so as to reproduce earlier results

Figure 24 shows a stacked plot of the retention requirements for all of the different types of data from the User group perspective.

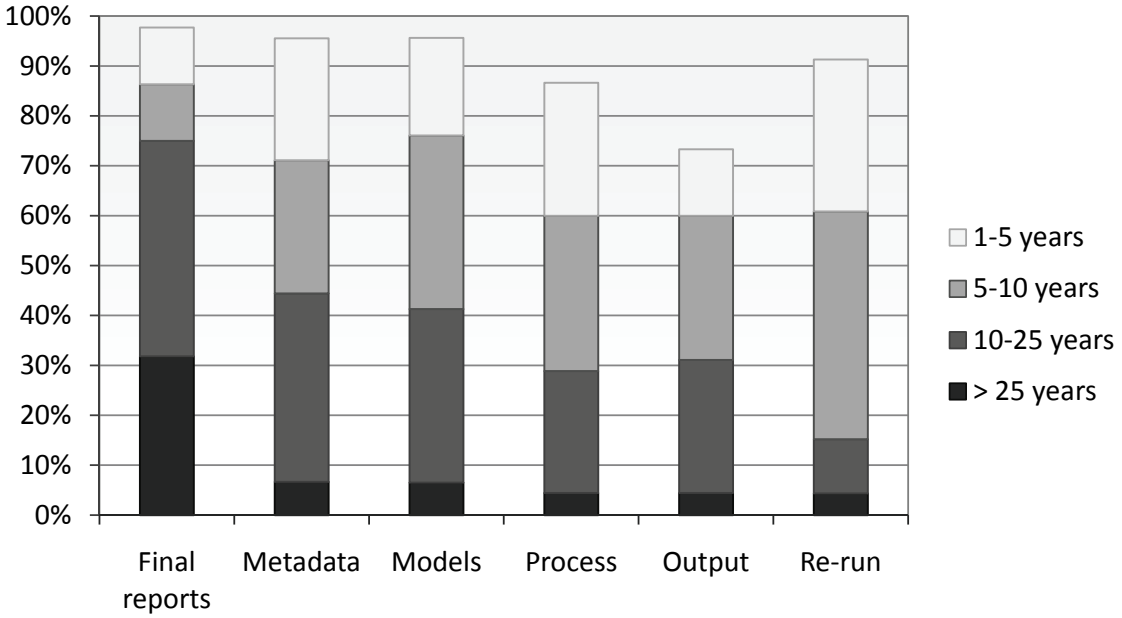


Figure 24: Timescales for data retention by data category

Most Users felt that Final Reports would need to be retained for at least 10 years, with many requiring 25 years or longer retention. At the other end of the scale, the requirement to re-run models in 10 years' time or more, drops down to 15% of the respondents, but a large number (45%), felt the need to be able to rerun models after 5 years or more.

In Figure 25 and also in chapters 9.1-9.6, report group 2 was used.

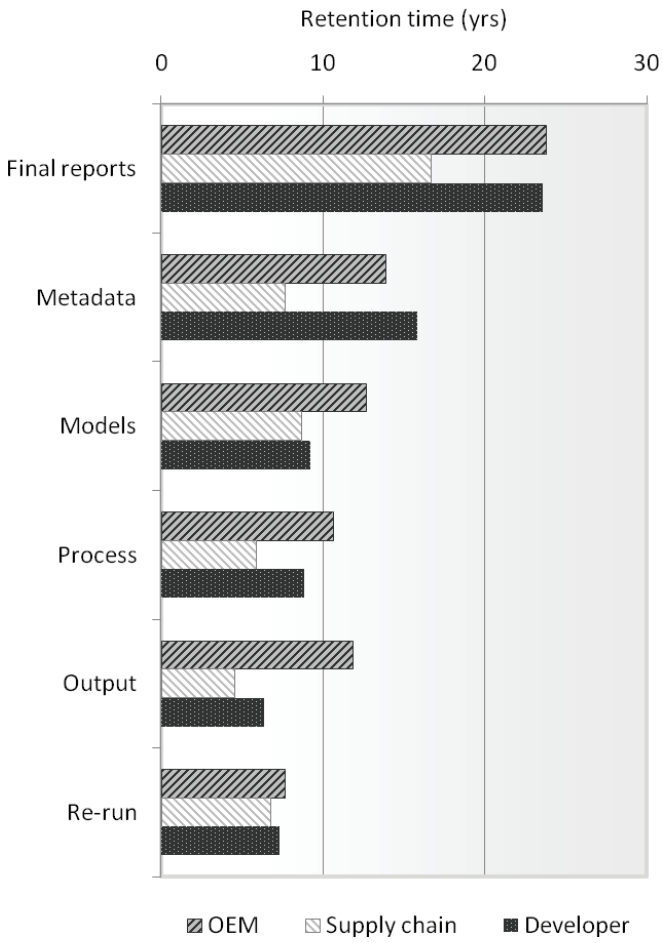


Figure 25: Characteristic timescales for data retention by report group

To compare the opinions of the respondents associated with the OEM, Developer, and Supply Chain groups, but avoiding the complexity of the stacked bar chart of Figure 24, a weighted average of the responses was calculated and plotted in Figure 25. It should be noted that the average times shown in Figure 24 provide only rough indications as to the intended retention period for the various categories of simulation data, and conceal variations within each category of respondents.

Despite that, it is evident that OEMs reported a requirement to retain all categories of data for a substantially longer period of time than their suppliers. Broadly, the Developer vision lies somewhere in between the other categories except for the case of metadata and knowledge, which Developers tend to see as more critical to the functioning of SDM systems than do their clients.

The other major area of difference involves the retention of simulation output and associated databases. These are potentially huge datasets and it is of interest that, whereas OEMs suggest a retention period of 10-15 years, vendors appear to have something closer to seven years in mind. Perhaps OEMs place greater reliance upon output data to support long-term access to detailed results whilst their suppliers would prefer to re-run any such analysis.

Chapters 9.1-9.6 provide expanded details for each of the data types. Chapter 9.7 breaks down the responses by industry.

9.1 Completed analysis work including final reports

This chapter presents the data retention requirements for final reports.

Survey section 4.0 question 1:

What is the life expectancy of the data to be managed? That is, what is the length of time you require simulation data to be maintained for later reference or use? (Note: Please respond in number of years.)

Final reports:

Response options:

- ☐ *Zero*
- ☐ *<1*
- ☐ *1-5*
- ☐ *5-10*
- ☐ *10-25*
- ☐ *>25*

Number of responses: 64

The responses to the question are shown in Figure 26 using report group 1, in which OEM, Developer, and Supply Chain responses are shown separately.

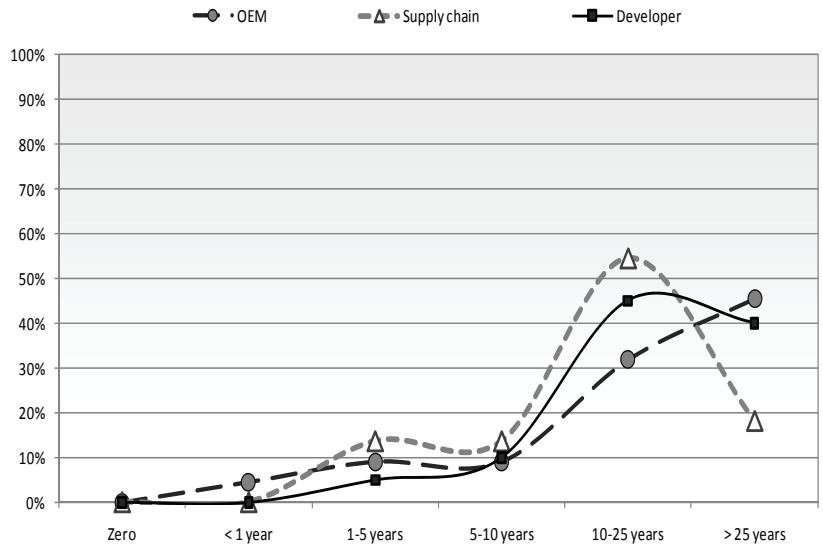


Figure 26: Retention periods for final reports

According to the respondents, final reports need to be retained for 10 years or longer, with many requiring 25 year or longer. Both OEM and Developer groups are in agreement with their opinion of 25 year or longer retention; the Supply Chain group doesn't feel the same level of need for very long retention periods. Only about 20 % of respondents specified retention needs for less than 10 years.

9.2 Metadata and knowledge

This chapter presents the data retention requirements for metadata and knowledge for simulations managed in an SDM system.

Survey section 4.0 question 1:

What is the life expectancy of the data to be managed? That is, what is the length of time you require simulation data to be maintained for later reference or use? (Note: Please respond in number of years.)

Metadata and knowledge associated with a simulations managed in an SDM system:

Response options:

- ☐ *Zero*
- ☐ *<1*
- ☐ *1-5*
- ☐ *5-10*
- ☐ *10-25*
- ☐ *>25*

Number of responses: 65

The responses to the question are shown in Figure 27 using report group 1.

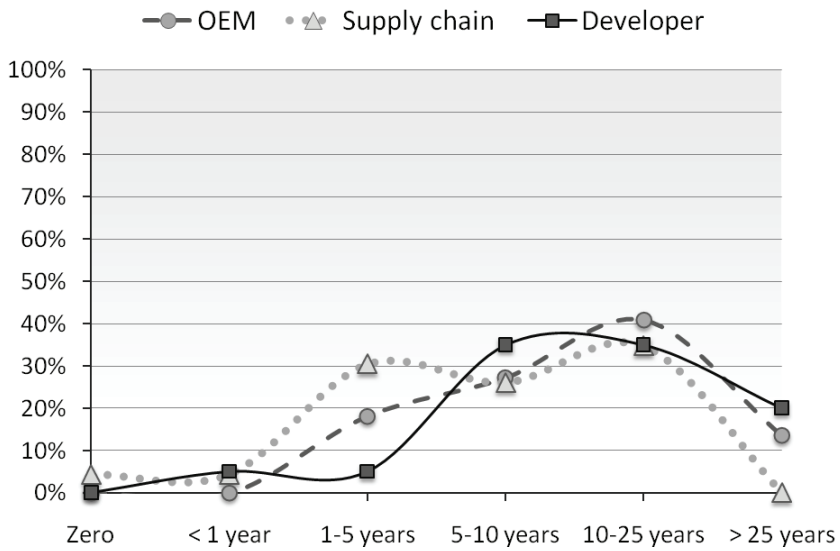


Figure 27: Retention periods for metadata and knowledge

Respondents generally specified a minimum of five years for data retention. Most specified more than 10 years.

Developer and OEM groups appeared to place similar requirements for metadata retention in the period of five years and longer. There is an interesting (but unexplained) variation in the period of 1-5 years between the various groups.

As a side-bar comment, the authors of the survey report would expect metadata retention to track closely with the requirements of the retention of the other types of data, since the metadata provides the knowledge of "who, what, when, where, why" associated with each of the data types. It may be that the meaning of 'metadata' was not well understood by some of the survey respondents.

9.3 Models and associated databases

This chapter presents the data retention requirements for simulation models and associated model databases.

Survey section 4.0 question 1:

What is the life expectancy of the data to be managed? That is, what is the length of time you require simulation data to be maintained for later reference or use? (Note: Please respond in number of years.)

Simulation models and associated model databases:

Response options:

- ☐ *Zero*
- ☐ *<1*
- ☐ *1-5*
- ☐ *5-10*
- ☐ *10-25*
- ☐ *>25*

Number of responses: 66

The responses to the question are shown in Figure 28 using report group 1.

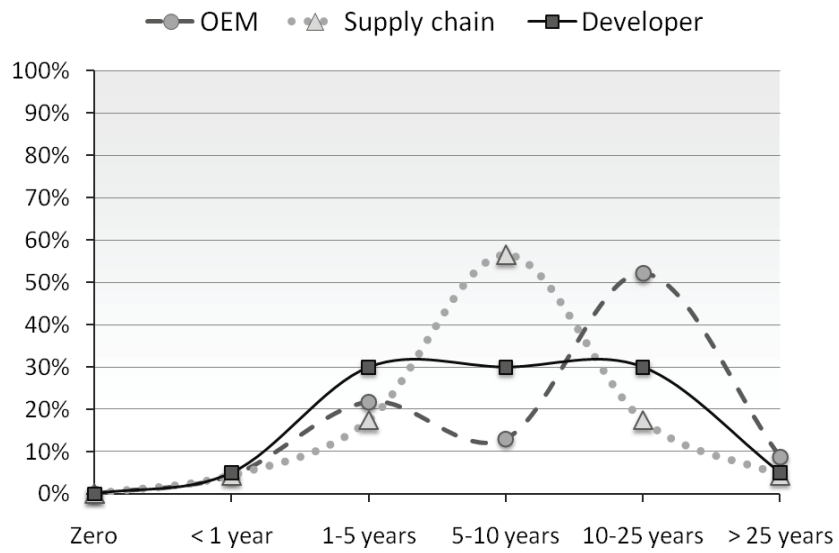


Figure 28: Retention periods for simulation models

Most respondents specified retention needs for more than five years. The peak retention period for models appears to be in the 5-10 year timeframe for the Supply Chain group, and in the 10-25 year timeframe for the OEM group. There appears to be fairly limited expectations for retaining models and model databases beyond 25 years.

Developers were pretty evenly divided at about 30% in each of the timeframes 1-5, 5-10, and 20-25 years. OEMs indicated significantly longer timescale requirements than anticipated by the Supply Chain or Developers

9.4 Execution processes and workflow

This chapter presents the data retention requirements execution processes and workflow.

Survey section 4.0 question 1:

What is the life expectancy of the data to be managed? That is, what is the length of time you require simulation data to be maintained for later reference or use? (Note: Please respond in number of years.)

Simulation execution processes and workflow:

Response options:

- ☐ *Zero*
- ☐ *<1*
- ☐ *1-5*
- ☐ *5-10*
- ☐ *10-25*
- ☐ *>25*

Number of responses: 65

The responses to the question are shown in Figure 29 using report group 1.

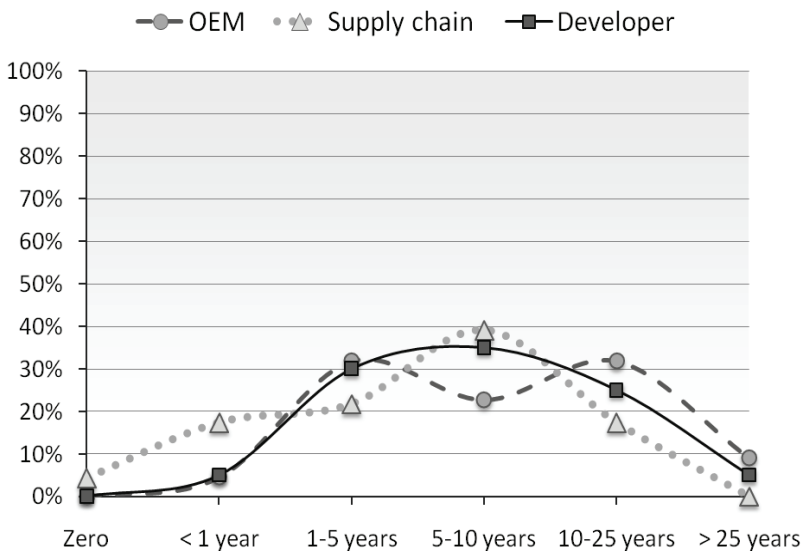


Figure 29: Retention periods for process and workflow definition

Most respondents specified a need to retain execution process and workflow data for 5 years or more, with many specifying more than 10 years.

9.5 Ability to re-run processes and workflow

This chapter covers the respondent's expectations for the ability to re-run simulation models as needed to reproduce earlier results.

Survey section 4.0 question 1:

What is the life expectancy of the data to be managed? That is, what is the length of time you require simulation data to be maintained for later reference or use? (Note: Please respond in number of years.)

For what period of time do you believe it may be necessary to be able to re-run simulation models so as to reproduce earlier results:

Response options:

- ☐ *Zero*
- ☐ *<1*
- ☐ *1-5*
- ☐ *5-10*
- ☐ *10-25*
- ☐ *>25*

Number of responses: 66

The responses to the question are shown in Figure 30 using report group 1.

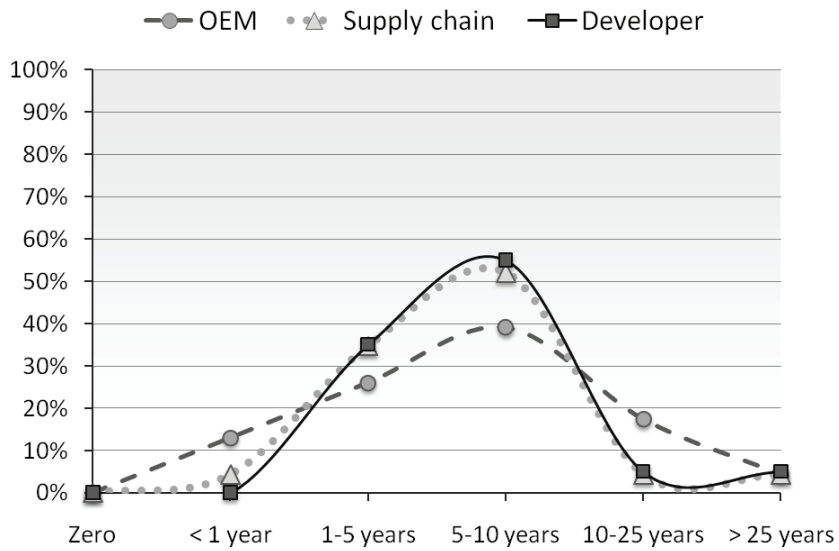


Figure 30: Timescales for retaining the ability to re-run processes and workflow

Over half of the respondents indicated a need to be able to re-run processes after more than five years. Though the requirement for more than 10 years is fairly low, it is still at 18% for the OEM group. The expectation for the ability to re-run processes peaks in the 5-10 year timeframe.

9.6 Output files and databases

This chapter presents the data retention requirements for output files and associated output databases from a simulation/analysis execution.

Survey section 4.0 question 1:

What is the life expectancy of the data to be managed? That is, what is the length of time you require simulation data to be maintained for later reference or use? (Note: Please respond in number of years.)

Simulation output files and associated output databases:

Response options:

- ☐ *Zero*
- ☐ *<1*
- ☐ *1-5*
- ☐ *5-10*
- ☐ *10-25*
- ☐ *>25*

Number of responses: 65

The responses to the question are shown in Figure 31 for Report group 1.

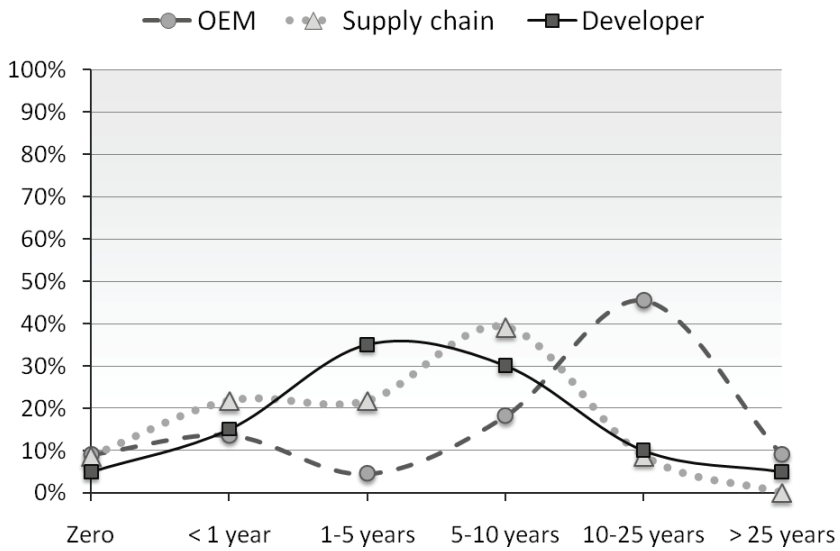


Figure 31: Retention periods for output files and databases

OEMs estimate retention timeframes for output files and databases that are much longer (10-25 years) than Developers appear to be planning for (1-5 years and 5-10 years). These tend to be very large datasets so options such as the regeneration of data (in the medium term, see Section 9.5) or discarding raw output may be considered. Moreover, the ability to open a database many years in the future may be a challenge due to technological changes and software obsolescence. It may be necessary to migrate data forward on a regular basis. However, solution approaches to address the challenge of long-term data retention and viability is not the subject of this survey.

9.7 Breakdown by industry sector

Additional analysis of the survey responses was done to see the differences in data retention requirements by the automotive and aerospace business sectors, especially as a function of the longevity of the products in each of these sectors.

9.7.1 Final reports

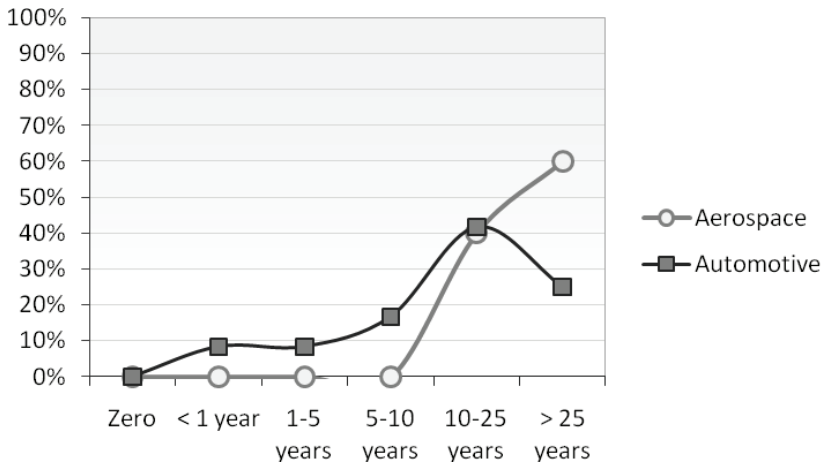


Figure 32: Retention period for final reports by sector

The survey responses bore out the hypothesis… the aerospace sector indicated a greater need for very long-term storage (25 years and more), than did the automotive sector.

It may be speculated that retention periods required from different industry sectors depend both upon the degree to which the industry is regulated and the typical lifecycle for the products within the sector.

It was also observed that OEMs have longer retention requirements than suppliers.

9.7.2 Metadata and knowledge

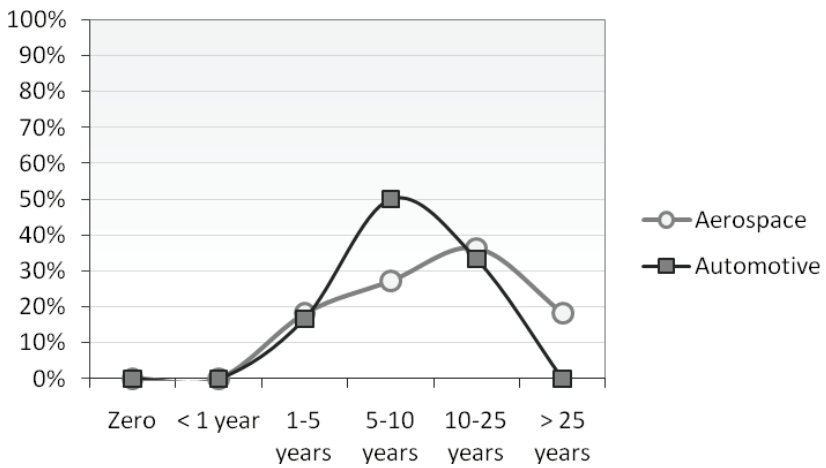


Figure 33: Retention period for metadata and knowledge by sector

In the case of metadata and knowledge information, again aerospace has longer retention requirements than automotive. Such a pattern was observed in all categories of data.

As a sidebar, and similar to the comments in Section 9.2, the report authors find it curious that metadata retention periods are not as great as for final reports. Perhaps the respondents feel final reports stand on their own and do not require separate 'who, what, why, who, and where' data?

9.7.3 Breakdown summary

The retention lifetime expectations for all of the data types are summarized below in comparing the aerospace and automotive business sectors.

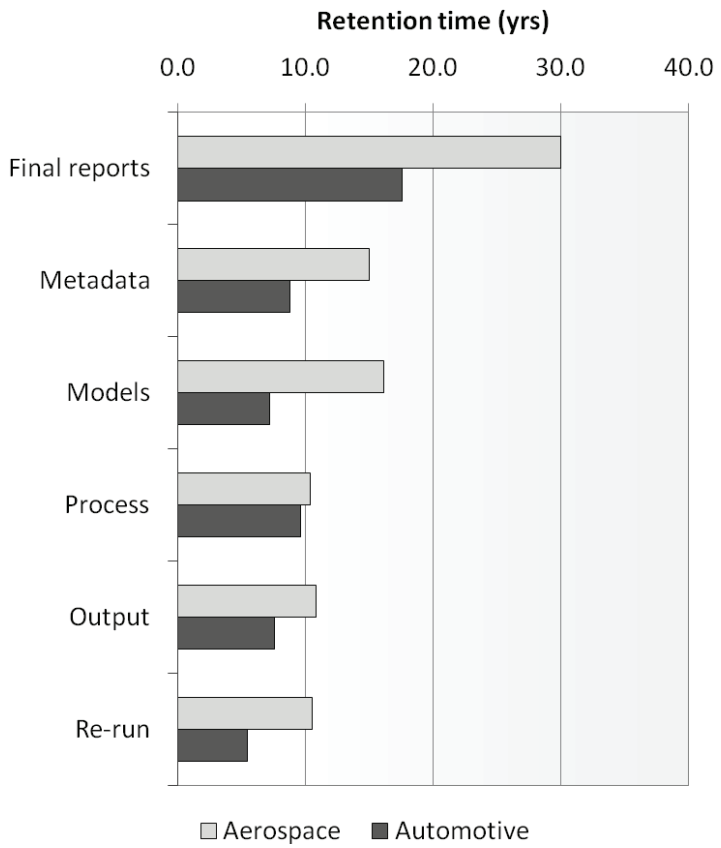


Figure 34: Characteristic timescales for data retention by sector

To compare the opinions of the respondents associated with the Aerospace and Automotive groups, but avoiding the complexity of the stacked bar chart, a weighted average of the responses was calculated and plotted in Figure 34. It should be noted that the average times shown in Figure 34 provide only rough indications as to the intended retention period for the various categories of simulation data and conceal variations within each category of respondent.

The aerospace sector consistently expressed a need for longer data retention, greater than 25 years for final reports.

In summary, significant data retention periods for all types of data were specified throughout. Approximately 60% of the User group expressed a need to retain all types of data for a period of five years or greater. 75% of the User group said that final reports need to be retained for 10-25 years, and 30% indicated a need for greater than 25 years.

A trend observed was that the OEM and Developer groups were in fairly close agreement on expectations of data retention, except in two areas: 1) analysis output and databases, for which OEMs expressed a need for longer retention times, and 2) analysis models, for which Developers opinions for retention were distributed across three of the retention periods, whereas OEM responses were more tightly grouped into the 10-25 yrs category. A second trend observed was that respondents in the Supply Chain group often indicated data retention periods that were one timeframe shorter than OEM and Developer -- perhaps this is because the Supply Chain does not have the ultimate ownership and support requirements for the final product as does the OEM group.

10. Data Integrity and Export to Neutral Formats

This chapter discusses the data integrity issues associated with managing simulations. It also describes the survey respondent's feedback on the need for export standards and what the NAFEMS role in developing these standards should be.

Chapter 10.1 addresses the types of data integrity functions that should be supported by a Simulation Data Management system, whereas Chapter 10.2 covers the reasons behind these requirements.

Chapter 10.3 is focused on the questions related to required support for export of data and the role of standards in this export. This chapter also explores the potential role of NAFEMS in developing standards related to Simulation Data Management formats.

10.1 Data integrity functions an SDM system should provide

The first question in this section of the survey was aimed at understanding the requirements for specific data integrity functions.

Survey section 6.0 question 1:

What types of data integrity functions should an SDM system provide? [Select all that apply]

Response options:

- ☐ *Provide data locks (change / access controls)*
- ☐ *Support data revisions, maintaining early revisions*
- ☐ *Support data versioning*
- ☐ *Provide data pedigree and an audit trail*
- ☐ *Record authorship*
- ☐ *None needed*
- ☐ *Other (please specify)*
  a text box was provided

Number of responses: 68

The results are presented in Figure 35 using report group 3. Respondents were asked to identify all of the data integrity functions that applied.

Most data integrity functions, including access control, versioning, and trailing features, appear to be deemed necessary by almost all of the respondents. The responses were evenly distributed across all the aspects of data integrity functions.

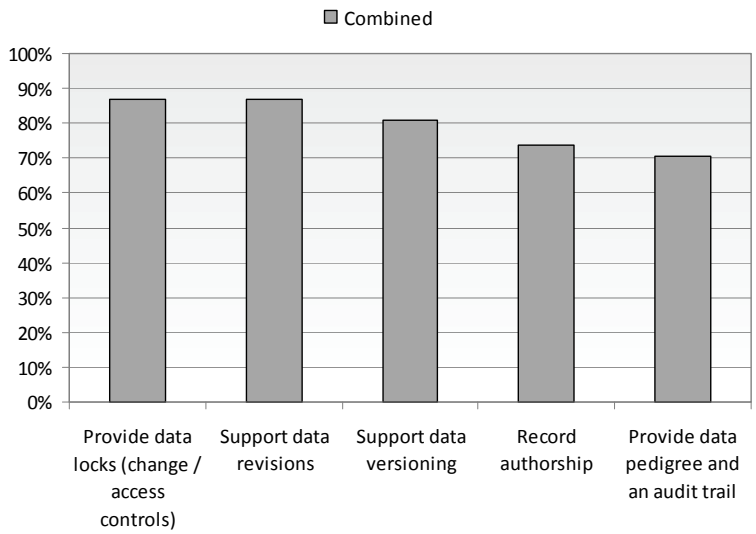


Figure 35: Data Integrity Functions

There were no responses indicating that no data integrity functions were required, and only a few indicated a need for data integrity functions that were not listed.

Developers appeared to place greater importance upon data integrity requirements than did the Users. This is also indicated in the widespread support for various data integrity functions in the available Simulation Data Management software.

The response from this question clearly indicated a strong requirement from all respondents for standard data integrity functions, including user access control, versioning, authorship, and pedigree/audit data.

10.2 Requirements for the data integrity

The first question in this section of the survey was aimed at understanding the justification and reasons behind the need for the requested data integrity functions.

Survey section 6.0 question 2:

What is the source or reason for the data integrity requirements? [Select all that apply]

Response options:

- ☐ *Company rules on data retention (ILM – Information Lifecycle Management)*
- ☐ *Legal proceedings*
- ☐ *Government regulations*
- ☐ *Product certification*
- ☐ *Compliance with standards (e.g., SAE, UL, …)*
- ☐ *Export controls (ITAR, EAR, …)*
- ☐ *Privacy policies and regulations*
- ☐ *Other (please explain)*
  a text box was provided

Number of responses: 67

Respondents were asked to identify all of reasons that applied. The responses are shown in Figure 36 using report group 2.

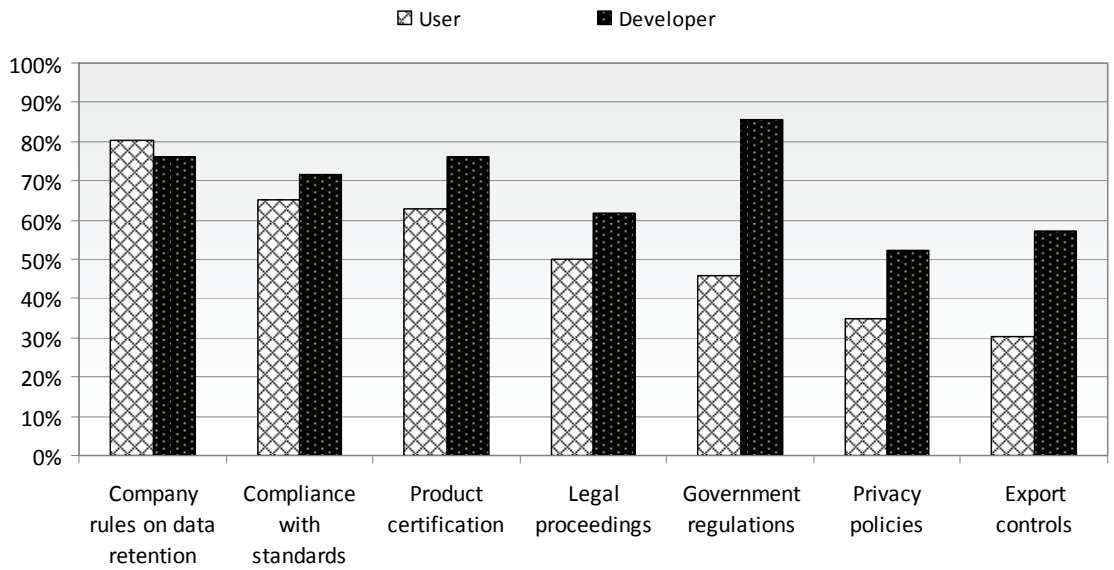


Figure 36: Reasons for Data Integrity Functions

For Users, the major drivers for data integrity requirements were company policy on record retention, product certification requirements, and compliance with standards.

For Developers, the major drivers are similar, but with much stronger requirements on almost all aspects other than company rules. Both government regulations and export controls ranked almost twice as high in the Developer's perspective than the Users.

The responses to this section revealed that the major concern among Users was clearly focused on meeting internal company policies and data requirements. This differed significantly from the Developers' perspective which was much more focused on meeting external requirements.

10.3 Standards and data formats

This section deals with understanding the respondent's expectations regarding support for data types and objects (ability to save to and export out of the data management system) and what should be NAFEMS responsibility for defining standards for data formats, taxonomy, data models, meta-data, object classes, ontology and the like for managing simulation data and processes

The first question related to this topic asked if an investment should be made to create standards. A yes/no response was requested.

Survey section 5.0 question 1:

Do you think investment should be made to create standards for data formats, taxonomy, data models, meta data, object classes, ontology and the like for managing simulation data and processes? [Select one]

Response options:

- ☐ *Yes*
- ☐ *No*

Number of responses: 67

There was a clear predication that an investment to create standards should be made.

The second question related to this topic asked what the role of NAFEMS should be in defining these standards.

Survey section 5.0 question 2:

If yes, do you believe NAFEMS should be responsible for defining the standards? [Select one]

Response options:

- ☐ *Yes, totally*
- ☐ *Yes, major contributor*
- ☐ *Yes, minor contributor*
- ☐ *No*
- ☐ *Comments (please specify)*
  a text box was provided

Number of responses: 63

The respondents were asked to select one of the contribution roles appropriate for NAFEMS. Those respondents who indicated "No" to the first question were grouped into the "Standards not required" response.

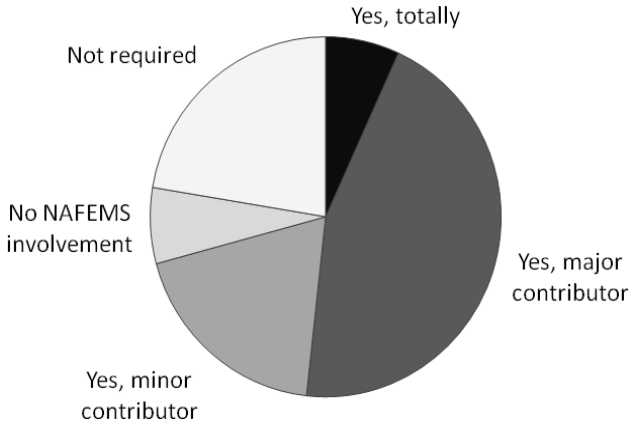


Figure 37: NAFEMS Role in Defining Standards

There was strong support exhibited for NAFEMS to have an active role in defining standards. Detailed analysis, however, showed that there was a marked difference between Users and Developers as to the extent of any NAFEMS contribution or responsibility, with Users being much more in favor of NAFEMS active involvement.

The next question related to this section addressed the data types and objects for which save export of the data management system in a neutral interpretable format is required. This question was focused on understanding the need to preserve simulation data and knowledge for future use, in a non-proprietary neutral interpretable format. The respondents were asked to select all data export requirements that applied.

Survey section 4.0 question 2:

To preserve simulation data and knowledge for future use, should it be possible to save the data or export it in a non-proprietary neutral interpretable format, such as STEP or XML (with well documented tags)? For which data types and objects should it be possible to save to and export out of the data management system in a neutral interpretable format? [Select all that apply]:

Response options:

- ☐ *Not needed*
- ☐ *All managed files and documents*
- ☐ *All meta-data that is associated with individual files or documents*
- ☐ *All meta-data that has been captured and associated with a simulation package*
- ☐ *File / document pedigree*
- ☐ *Other (please specify)*
  a text box was provided

Number of responses: 66

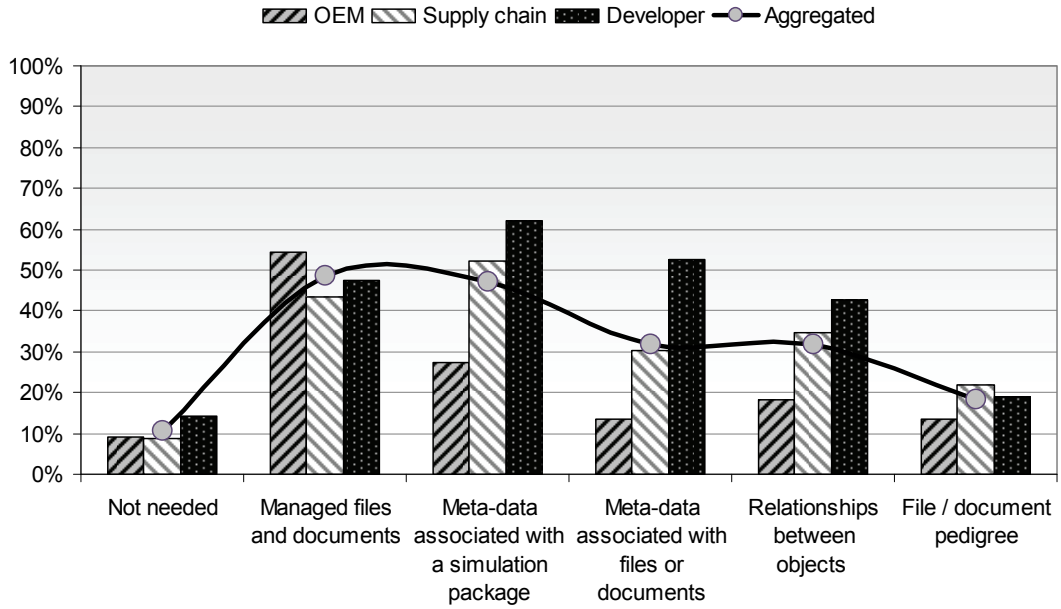


Figure 38: Export of data objects

About half of the respondents specified a requirement to export all files and documents, and about half had the same requirement for meta-data. Developers expressed a higher requirement to export a wide range of data types showing a strong focus on preserving files and documents. The Developers placed a far higher importance than Users on the ability to export metadata. Amongst the Users those in the Supply Chain indicated a much higher need to export Meta-data and relationships in a neutral format than was indicated by the OEMs.
A strong requirement for the support of exporting a wide range of data was indicated by the respondents. However, the User respondents were clearly focused on the basic files and documents while the Supply Chain and Developers had a much stronger interest in associated data such as Meta-data being exported in a neutral format.

10.4 Approach for exporting data to be provided by an SDM system

The next question related to this section investigated the approaches for data export that should be supported from a Simulation Data Management system. The respondents were asked to select all data export approaches that applied.

Survey section 4.0 question 3:

What approach for exporting data should be provided by an SDM system? [Select all that apply]

Response options:

- ☐ *None*
- ☐ *Files and documents should be exported in their original native format (e.g., original binary, text)*
- ☐ *Files and documents should be converted to and exported in an enduring neutral format such as STEP*
- ☐ *Meta-data shall be exported in a neutral, non-proprietary interpretable format such as XML*
- ☐ *Object relationship information shall be exported in a neutral non-proprietary interpretable format such as XML*
- ☐ *Other (please specify)*
  a text box was provided

Number of responses: 69

The results are presented in Figure 39 using report group 3.

For Meta-data export, there was a slight preference indicated for using a neutral, non-proprietary format. However, there was a similar slight preference for files and documents to be exported in their original native format. Export of files and documents to an enduring neutral format was of interest but not as strong as native export. It is also interesting to note that less than half the respondents were concerned about export of object relationships.

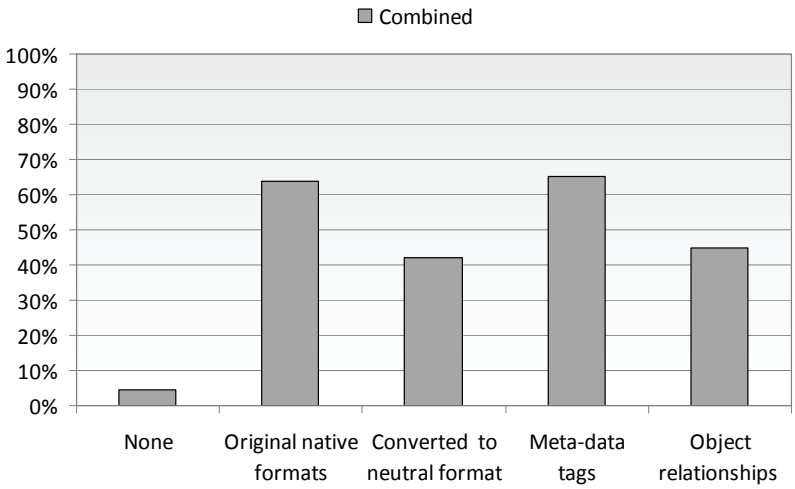


Figure 39: Approaches to the export of data

Moderately strong support was illustrated from the respondents for some form of neutral format export, but no clear preference was indicated as to the approach for the data export.

The responses to the questions in this section indicated that data integrity functions are a major concern and expected functionality of a Simulation Data Management system. The need for data export standards also received strong support with most respondents indicating that NAFEMS should be a major contributor to defining these standards. There was strong support across the board for neutral format export of files and documents and strong support for neutral export of Meta-data amongst Developers and Users and Supply Chain. There was, however, no clear indication of a required approach for this export.

11. Technological Approach

This chapter discusses the understanding of mandated technological approaches for data management systems. It also describes the survey respondent's feedback on the need for export standards and what NAFEMS role in developing these standards should be.

Chapter 11.1 addresses whether or not the respondent's company has a mandated technological approach for data management systems.

Chapter 11.2 addresses whether or not the respondent has a personal preference related to technological approaches for data management systems.

11.1 Company approved

This question address whether or not the respondent's company has a mandated technological approach for data management systems. The respondents were asked to choose one answer that applied.

Survey section 8.0 question 1:

Does your company have a mandated technological approach for data management systems (databases, web services, service oriented architecture, user authentication, etc.)? [Select one]

Response options:

- ☐ *No*
- ☐ *Don't know*
- ☐ *Yes (please specify)*
  a text box was provided

Number of responses: 63

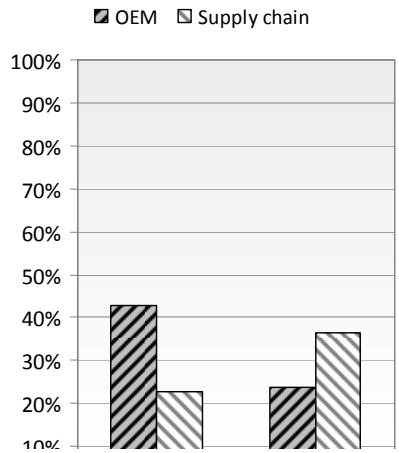


Figure 40: Mandatory company approach

The responses to the question are shown in Figure 40 using report group 1. Developers were excluded from the graph.

OEMs are markedly more likely to have a mandated technological approach to data management systems than other companies within the Supply Chain. Even that - is only a minority and some of those have multiple strategies in place simultaneously.

Most of the User respondents did not indicate awareness of a mandated technological approach within their company.

11.2 Individual preference

This question address whether or not the respondent has a personal preference regarding a technological approach for data management systems

Survey section 8.0 question 2:

Do you have a preferred technological approach? [Select all that apply]

Response options:

- ☐ *Relational database*
- ☐ *Object-oriented database*
- ☐ *Web-based navigation (thin client)*
- ☐ *Resource description framework (RDF)*
- ☐ *No preference*
- ☐ *Don't know*
- ☐ *Other (please specify)*
  a text box was provided

Number of responses: 64

The responses are shown in Figure 41 using report group 1.

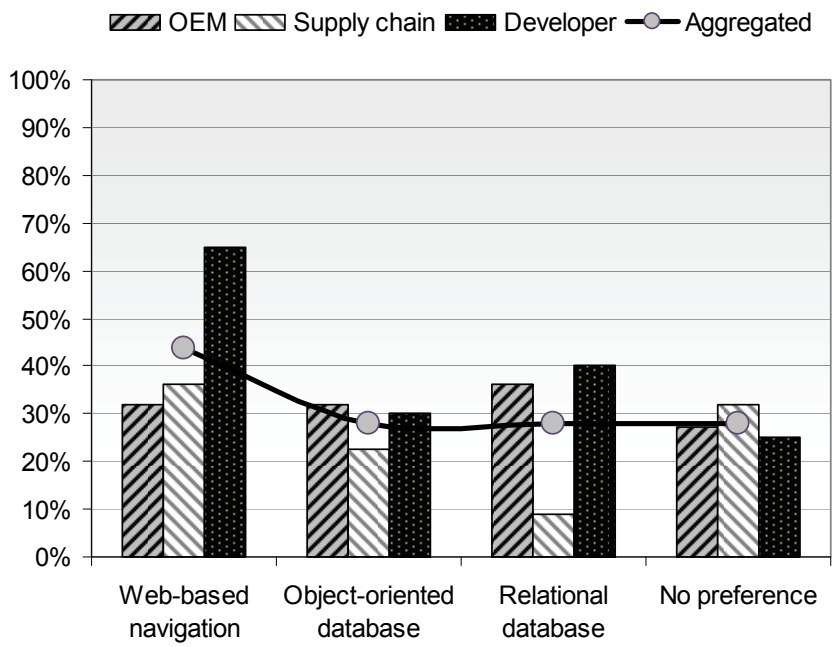


Figure 41: Personal preferences for technological approach

Of those that expressed an opinion, Developers were more likely to prefer relational databases while Users favored object-oriented databases. The most marked difference however was the strong interest in web-based navigation expressed by Developers which was not shared to the same extent by the Users. Other than the Developers strongly expressed desire for web-based navigation, there was not a strong preference toward any specific technological approach. A further option of 'Resource Description Framework' was provided in the survey but there was almost no interest expressed in at this time.

The responses to the questions in this section indicate clearly that there is more interest illustrated in the 'what' of Simulation Data Management rather than the 'how'.

12. Additional Input

This section reports on responses to three general information questions seeking input on additional capabilities desired but not covered by other survey questions, on improvements in coverage of the survey, and asking for final thoughts on any topic related to the survey or SDM.

12.1 Other services to be provided by an SDM system

This section discusses what other services should be provided by a Simulation Data Management system that were not covered by the other survey questions.

Survey section 9.0 question 1:

What other services should be provided by an SDM system?
[Select all that apply]

Response options:

- ☐ *A capability to "open" files using the application that created the file, and "open with ..." using another application*
- ☐ *A generic viewer (cf. VCollab, Acrobat3d, JT viewer) that is able to display geometry and results for a wide range of simulation applications*
- ☐ *A generic post-processor that is able to manipulate and display results for a wide range of simulation applications*
- ☐ *Text editor*
- ☐ *Search: data objects by name, metadata, object relationships*
- ☐ *Search: file contents*
- ☐ *Facilities for analytics which can aggregate various data from a range of selected simulations, perform operations on the data, and present the results in graphical and tabular representations for decision making*
- ☐ *Be able to create, display and export a structured view of analysis data objects (analogous to a PDM product structure / product configuration)*
- ☐ *None*
- ☐ *Other (please specify)*
  a text box was provided

Number of responses: 65

A list of possible additional services was provided, plus respondents could add other items in an open text box. The results are presented in Figure 42 using report group 3.

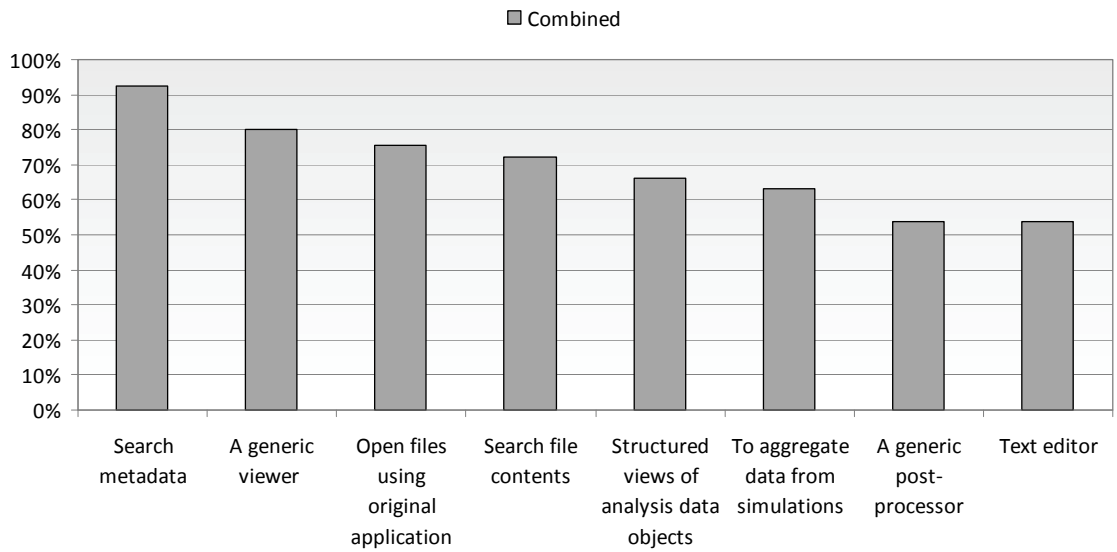


Figure 42: Other services

A strong desire was exhibited for a breadth of services, with no suggested service capability receiving lower than a 50% response rate. The strongest support was for advanced search capabilities. Visualization tools were also considered highly desirable by all respondents.

Just one text response was submitted; it requested integration with voice of the customer approaches (solvers, quality methods, and other customer practices).

> "Must integrate or need to have in account the relation or integration with FMEA, QFD, DFM/A, software or methods in order to be aware of the voice of the customer during the definitions of the simulation goals."

Clearly there are high expectations of services to be provided by the emergent Simulation Data Management systems.

12.2 Capabilities or needs not adequately covered by the survey

This question provided an open-ended opportunity for respondents to offer any information on simulation data management needs or capabilities that they felt were not adequately covered by the survey.

Survey section 10.0 question 1: ***Please provide any information on simulation data management needs or capabilities that you feel was not adequately covered by this survey?***
Response options: ☐ *a text box was provided*
Number of responses: 20

A variety of needs or capabilities were described and these are summarized in the list below.

- Knowledge capture and a knowledge DB; knowledge-based engineering coupled with simulation data management.
- Coverage for metal forming process and related data management.
- The need to be able to work with PDM/PLM systems, which are well entrenched, particularly in large companies.
- Items with regard to handing large data volumes, data pruning, selectivity about what is managed to avoid an overwhelming volume of information.
- Management of FEM batch meshing and model assembly.
- The purpose and role of SDM; what is the target demographic?
- Connections between an SDM system and high performance computing clusters (HPC's)
- Collaboration across disciplines, for example simulation/analysis, design, and testing.
- Connections between SDM and the analysis/simulation tools
- Learning curve, both for using an SDM system and for configuring one to the needs of the analyst; how can the user tweak the process to adapt to immediate needs without requiring a software developer.
- Process capture and automation provide the game changing real value, rather than simply management of data files.

The survey group thanks respondents for their comments.

12.3 General comments

The survey ended with an open text box that enabled respondents to submit general comments:

Survey section 10.0 question 3: ***Please write any general comments you would like to make here:***
Response options: ☐ *a text box was provided*
Number of responses: 16

Comments included:

- A request for the SDM business case, along with information about implementation costs, resources required, level of effort, and information on the cost/value of a COTS solution vs. an in-house created solution.
- A suggestion for the SDMWG to help educate on the pros / cons of the various vendor offerings.
- The name and focus of the 'simulation data management working group' is too limiting, and process and analysis process coupling are very important and should be included.
- The acronyms used in the survey were not adequately explained, and the 'scope' issue and questions were not clear.

The SDMWG thanks the respondents for their remarks and interest in the survey and subject area.

13. Suggestions for the NAFEMS SDMWG

Though not strictly in line with the core objective of the survey, the NAFEMS team used the survey as an opportunity to ask whether the respondents had recommendations or requests for future activities and deliverables of the NAFEMS Simulation Data Management Working Group (SDMWG).

Survey section 10.0 question 2:

Do you have any recommendations for the NAFEMS Simulation Data Management Working Group (SDMWG) in terms of future deliverables?

Some examples include, but are not limited to:

- ***General overview of SDM***
- ***Current/future technological developments***
- ***Gathering requirements***
- ***Standard data representation***

Response options:

☐ *a text box was provided*

Number of responses: 19

There were 19 responses with suggestions for the SDMWG.

- Several respondents submitted that NAFEMS and the SDMWG should provide education and awareness on the subject of simulation data management.
- Several respondents asked for information on the business case for SDM, including the risk/cost of NOT implementing an SDM system. There was a request for a survey of use cases to show what is possible with an SDM system, which could be counted as an item in both the education/awareness and business case columns.
- There were two requests for information on the relationships between PLM, SDM and PDM, and also the role and use of SDM as compared to PDM/PLM.
- One request was that the SDMWG review and evaluates SDM COTS software.
- One request was for the SDMWG to provide information on SDM for small businesses, and to collaborate with vendors in addressing this sector.
- One request was for the SDMWG to define best practices.
- Two respondents would like the SDMWG to put effort into standard data representations.

The SDMWG is already addressing several of the foregoing requests to provide information on the SDM business case culminating in a Business Value white paper, with publication expected to be early in 2011. The team thanks all respondents for suggestions about future activities of the SDMWG.

14. Conclusions

The NAFEMS Simulation Data Management Working Group had a number of goals in issuing the survey, where the four key objectives were to:

1) Develop a baseline understanding of Users awareness and adoption of the discipline
2) Understand the Users perception of the scope and requirements for SDM
3) Validate whether the User and Developer communities were on the same page
4) Bring to the surface any issues or topics that would help the SDMWG set directions for future activities

User's awareness and adoption of the discipline
Of the respondents who identified themselves as end-users, a fairly sizable number (40%) is familiar with the concepts of formalized data management and uses some system for it at least weekly in their regular work, whereas only a small percentage of the group (23%) has never used such a system. The majority of the User group is not using a software system that they would identify as being expressly designed for simulation data (57%). The Users identified themselves as being the most strongly associated with the analysis disciplines of aerodynamics, CFD, structures, thermal, and fatigue and are predominately from large companies which have an international presence.

User's perception of the scope and requirements for SDM
The User group had a rather broad vision for the scope of SDM. It included not only management of information at the level of simulation data files and reports, but extended to simulation processes and process execution. A wide range of data was expected to be handled. Some of the data was envisioned as being managed primarily by the SDM system, examples include simulation data, catalog and reference data, and process data. Other data, chiefly test, business and product data was envisioned as being handled primarily by other data management systems, but with links between the simulation data management and the other data types or repositories. The majority of Users replied that work-in-progress data needs to be managed (66%) in addition to data from completed analyses.

Are User and Developer communities on the same page?
For the most part, Users and Developers had a similar view of scope and capabilities for management of simulation data, and in many cases the vendors are actually leading the expectations for comprehensive capabilities for data management and coverage of data types. In terms of a technological approach to data management, vendors were more in favor of web-based thin client navigation systems (67%) than were the Users (35%). Users appeared to be ahead of the vendors in expectations in several areas; among them are management of in-work data and requirements for longer periods of time for data retention and use.

Issues or directions for NAFEMS SDMWG future activities
A number of respondents expressed suggestions for NAFEMS SDMWG future activities, including an interest in the SDMWG spending more time on providing education and increasing awareness of simulation data management; on implementations or requirements for SDM systems that would be appropriate to small businesses; and on comparisons of SDM systems

Final thoughts
The NAFEMS SDMWG, and particularly the survey team, wishes to thank the respondents for taking the time to complete the survey, their answers, and in many cases for providing additional input in text window fields. The SDMWG will also use the submitted comments to improve the survey prior to the next time one is released.