SASIG White Paper

Model Based Enterprise

SASIG
strategic automotive product
data standards industry group

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FOREWORD

The Automotive Industry is expanding the use of 3D CAD systems and related technology from engineering and product design to tooling, process development, manufacturing operations, and many other downstream business areas. The goal is to produce 3D models that can represent a complete product model in the context of the downstream operation. Each of these models offers an opportunity to greatly enhance efficiency throughout the entire value chain, including the extended enterprise of suppliers and partners. With this approach, 3D offers an opportunity to significantly promote reuse, improve design efficiency, reduce cost, and improve quality across the extended enterprise. The inclusion of Product Manufacturing Information (PMI) within CAD models is called 3D Model Based Definition (3D-MBD), and the inclusion of complete, in-context product information within a Digital Package of Information and use of the complete definition throughout the extended enterprise is called Model Based Enterprise (MBE). A more complete definition of 3D-MBD and MBE appears in Section 1 of this paper.

This paper describes the current and future states of MBE in the automotive industry, promotes the implementation of the 3D-MBD model and provides guidance to successfully shift from a drawing-based to a model-based enterprise.

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SASIG MBE BACKGROUND

The Strategic Automotive Standards Industry Group (SASIG) is a global consortium of standards organizations. Active members of this consortium include Japan Automobile Manufacturers Association (JAMA) in Japan, Groupement pour l'Amelioration des Liaisons dans l'Industrie Automobile (GALIA) in France, and Automotive Industry Action Group (AIAG) in the U.S. Liaison members include Japan Automobile Parts Industry Association (JAPIA), ODETTE-Sweden, ODETTE International, and ProSTEP iViP.

This paper is the latest in a series of publications begun in 2003 by the Digital Engineering Visualization Workgroup (DEV) of the Strategic Automotive Product Data Standards Industry Group (SASIG) aimed at standardizing 3D CAD and Visualization. Previous publications include “Guideline for Digital Engineering Visualization,” “Guidelines for Combining 3D Models and 2D CAD Documentation,” and the “3D Annotated Model Standard.”

SASIG has worked since 2003 on the 3D data deployment, visualization, and management processes. The Digital Engineering Visualization Workgroup (DEV) started, in a first phase, with Digital Engineering Visualization tools in order to improve collaboration and project review for automotive companies. Key automobile industry global players including OEMs and Tier 1 suppliers have made a concentrated effort to identify the tools and technologies that can significantly enhance the industry’s ability to reduce costs and improve time to market. The SASIG DEV published guideline has addressed when, where, and why Digital Engineering Visualization tools are used.

The first phase also focused on the need to convey the information needed to manufacture a product from product development. Product information usually includes a combination of 3D models and 2D drawings. This is a more effective process than the traditional 2D drawings alone because digital manufacturing processes today need the 3D model in order to develop tooling and fixtures, perform analysis, build prototypes, and so forth. This is the result of product, process, and resources model integration. The concept is for technical data to incorporate a complete 3D Annotated Model containing all the information necessary to manufacture a part and drive the inspection of the result. This raised the question of how to apply existing standards for 2D drawings to 3D models. The result of that work is the SASIG 3D Annotated Model Standard recommendation, which covers the information not included in ISO 16792 “Digital Product Definition Data Practices.”

The current or second phase of this initiative is the enabling of the Model Based Enterprise. The SASIG 3D - MBE Workgroup was formed to address this industry need. The mission of the 3D - MBE Workgroup is to promote the implementation of the 3D-MBD Model to enable seamless sharing of product information within the extended enterprise and the automotive industry.

The workgroup’s vision is to move the automotive industry from current state to MBE. To do so, the 3D-MBE Workgroup is focused on:

- 3D Model-Based Definition penetration and maturity in the automotive industry
- Elimination of the obstacles to achieving 3D-MBD
- Exchange and consumption of 3D-MBD data across the extended enterprise to support specific business areas and their workflows

The MBE SASIG initiative will allow the automotive industry worldwide to work toward globally common digital product lifecycle processes and standards. The initiative will also provide a common voice in representing interoperability and functionality issues with MBE.

1 INTRODUCTION TO MBE

1.1 SASIG defines 3D-MBD and MBE as follows:

- 3D Model Based Definition (3D-MBD) - is the practice of using 3D models (such as solid models, 3D PMI, and associated metadata) within 3D CAD software to define (provide specifications for) individual components and product assemblies. The types of information included are geometric dimensioning and tolerancing (GD&T), component level materials, assembly level bills of materials, engineering configurations, design intent, etc.
- Model Based Enterprise (MBE) - is a fully integrated and collaborative environment founded on 3D product definition (3D-MBD) detailed and shared across the enterprise; to enable rapid, seamless, and affordable contextual consumption of engineering data.

Historically, the automotive industry used 2D drawings to represent product design intent. Drawings were once used at every step in the engineering process and at every level of the value chain, but that has changed. Enterprises that focus primarily upon 2D drawings are referred to as "Drawing Centric." With the introduction of 3D CAD over several decades, 3D models became the new industry standard for designing products, tooling, and manufacturing processes. The majority of original equipment manufacturers and large suppliers are now "Model Centric," where 3D models are developed and used downstream, but these firms and their value chains still rely heavily upon 2D drawings as the master authority. This is largely because PMI is not fully embedded within 3D models. In Model Centric enterprises, neither 3D CAD models nor CAD-generated 2D drawings alone provide enough information to successfully engineer, manufacture, and inspect parts for production. So 2D drawings are still required to augment 3D CAD models to more fully communicate design intent, product characteristics, and requirements. Model Centric firms continue to view the drawings as the master authority of the product definition, despite inherent weaknesses.

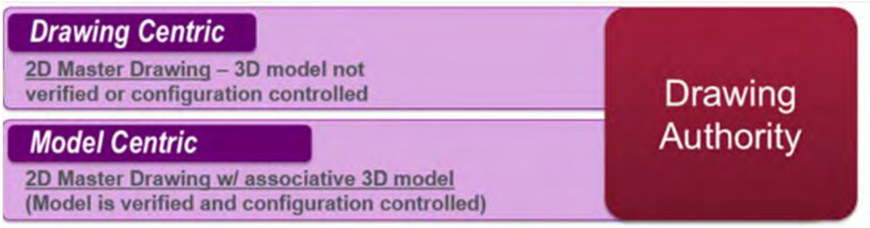


Figure 1.1 The Pre-MBE State – Drawing Authority

Using 2D drawings is no longer necessary or desirable. Leading automotive industry firms are beginning to demand fully annotated 3D models. 2D drawing-based practices severely limit the definition of complete design intent and complicate the sharing and reuse of product information throughout the extended enterprise. Maintaining both 3D CAD and related drawings datasets has proven to be an impediment to design collaboration. Often 3D content and drawing release levels are out of sync with one another, which casts doubt as to what is actually the master data.

Today, modern technology allows us to connect the many stakeholders responsible for the production of automotive products by more effectively incorporating the complete product definition in the appropriate configuration for downstream operations. By unlocking the potential for MBE, OEMs and suppliers now have the ability to create more informative 3D-MBD CAD models, better manage the change of those models, and improve communication to and from the supply chain. This document is intended to provide the reader with information regarding 3D-MBD and MBE and to make a case for the adoption of these processes throughout the extended automotive value chain to improve quality and increase efficiency.

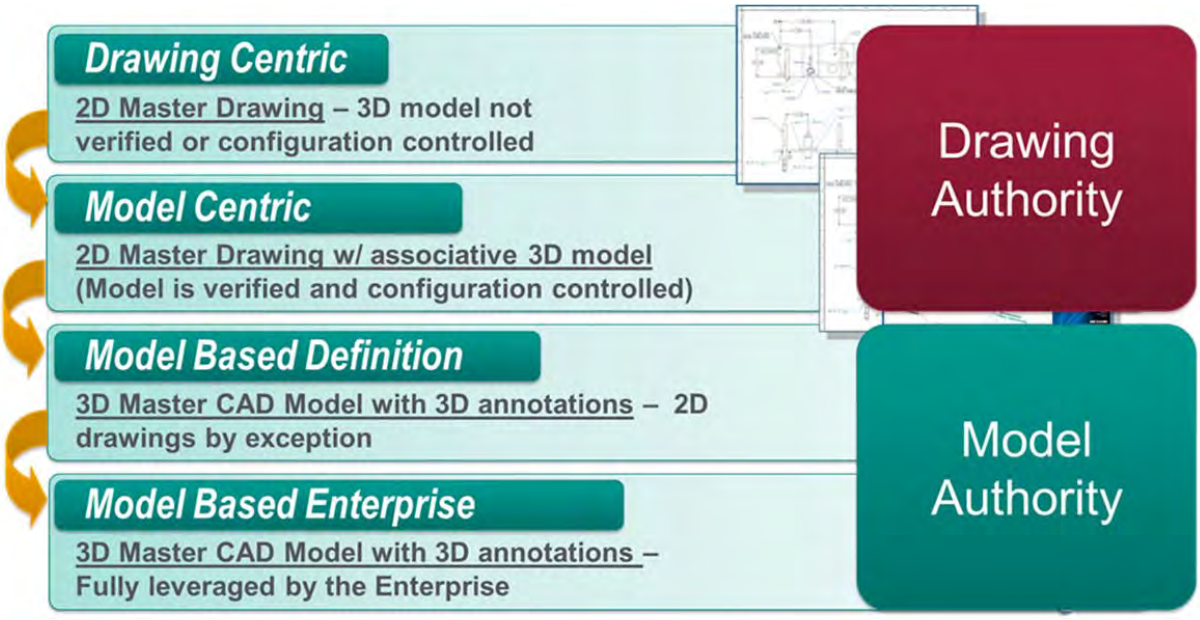


Figure 1.2 The 3D-MBD and MBE States - Model Authority

1.2 PMI Annotations within the 3D Model

In Model Based Definition, the process of creating and associating PMI annotations to features and geometry occurs as the CAD model is being developed. Linking the annotations and features together helps to provide clarity of design intent and promotes the use of 3D-MBD CAD files as a single authoritative source of the product definition. For more details, refer to the SASIG 3D Annotated Model Standard.

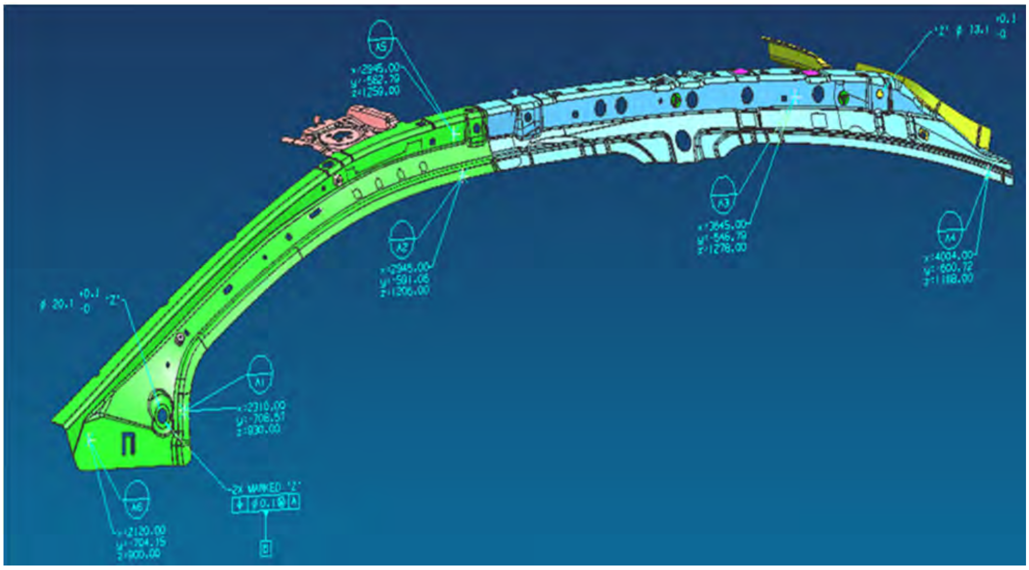


Figure 1.3 Model with Embedded PMI

1.3 MBE Drives Reuse and Downstream Consumption

Viewed broadly, MBE is an approach in which product lifecycle information is collected and repurposed for product definition and downstream consumption. MBE promotes the reuse of this information within enterprises and across their extended value chains. The reuse of information results in improved product quality and efficiency gains within the product lifecycle, driven by use of in-context, complete product definition throughout the extended enterprise.

Transitioning to a business configuration that applies MBE will enable downstream processes (including suppliers) to directly access and consume the complete digital definition. Stamping and Formability, Weld Study and Instructions, Manufacturing, and Inspection are examples described in detail in Section 4. As a result, benefits such as facilitating automation, shortening development lead time, reducing costs, improving quality, etc. are expected.

1.4 Semantic Consumption and Visual Communication for Downstream Processes

Downstream and concurrent consumption of 3D-MBD data is typically divided into two broad categories:

1) Semantic consumption = Suggests that the PMI annotations within the 3D-MBD model are machine readable for use in operations such as machining and inspection.

2) Visual communication (consumption) = The idea that the PMI annotations or other information that is associated to geometry within the 3D-MBD model is readable for human consumption. Examples of related operations include process planning, service, work instructions, supplier collaboration, and so forth.

For semantic consumption, both native CAD and certain derivative formats support machine readability for operations like inspection and machining. ‘Derivative formats’ are taken to mean: Formats based on another source, in MBE 'neutral' and/or visualization file format such as 3D-PDF, JT, STEP AP242-compliant, etc. Improvements in the capability to directly import or export 3D-MBD information continue to grow in many areas of engineering, manufacturing, and inspection. Since native CAD is truly the authoritative source of product definition, it is natural to look only for opportunities to use the 3D-MBD data contained within the native CAD file itself. However, this is neither desirable nor practical in many cases. Visual communication is generally a stepping stone for enterprises wishing to gain experience with MBE, largely because applications are less complex, involve less risk, and provide a test bed for later semantic consumption.

Both Semantic Consumption and Visual Communication may involve the use of derivative formats. These derivative formats promote 2D drawing elimination because they make 3D content and associated 2D information more widely available and consumable. If a derivative file is used, then it must be properly validated with the CAD to ensure 100 percent replication of the native CAD, PMI, and embedded non-CAD content as described below.

1.5 Interoperability Considerations

Because many enterprise operations do not necessarily require the use of native CAD and because value chain partners often use different CAD formats and follow differing design practices, interoperability is both necessary and desirable. A strong interoperability strategy can be essential in MBE to ensure that 3D-MBD information is shared accurately and completely with the entire value chain without requiring expensive CAD licenses or CAD expertise to consume needed information.

Both derivative and neutral formats help drive MBE success but also embody certain risks that must be addressed as part of deployment. The success of interoperability strategies for 3D-MBD is highly dependent upon accurate, automated replication of 3D content, especially PMI, that preserves the association between model features and annotations. Also, well designed interoperability strategies require validation of neutral and derivative file output to ensure accuracy and completeness of 3D representations. Automation improves quality by eliminating manual input errors and increasing efficiency, but perhaps most importantly, ensures that content is updated when any changes to CAD master data occur.

1.6 The Digital Package of Information

The Digital Package of Information is a complete, in-context virtual representation of the product or process supporting specific business areas. The Technical Data Package, the VDA drawing-free process (Zeichnungslos Prozess - ZLP), and the JIS DTPD (Digital Technical Product Documentation) are examples of the Digital Package of Information. SASIG believes that this Digital Package of Information will be a critical element of MBE and is discussed in the Appndix A.

2 MBE CURRENT STATE

As mentioned in Section 1, a model-based enterprise journey involves first mastering 3D-MBD. Much of this section will concentrate on the adoption of 3D-MBD, leading to MBE. We will begin with a short review of available standards. Standards defining annotated 3D model requirements have existed for over a decade. Even though the 3D Annotated Model Standard and ISO 16792 standards have existed for many years, implementation of these standards varies significantly across the automotive industry and among technical solution providers' (such as CAD, translators, etc.) offerings. Leading automotive enterprises have recognized the value of implementing 3D-MBD and have begun the process of adopting new business practices to leverage MBE's many benefits.

The transition to MBE, of course, requires the re-engineering of various business processes and the adoption of emerging technologies. OEMs and many large suppliers have begun authoring annotated 3D-MBD models for release to downstream operations and suppliers. Some also mandate that suppliers provide annotated 3D-MBD models. According to a 2014 survey conducted by the Japan Automobile Manufacturers' Association, Inc. (JAMA), the use of 2D drawings has been reduced by 7 percent each year since 2008. In the Americas, Europe, and elsewhere in Asia, similar progress has been made.

2.1 Current Automotive Industry Awareness and Penetration

In order to develop a better understanding of the current state of 3D-MBD use and to determine the readiness of the automotive industry to take this direction, in late 2015 SASIG began gathering information on the industry's adoption of MBE. Companies that responded represent a cross section of the automotive industry.

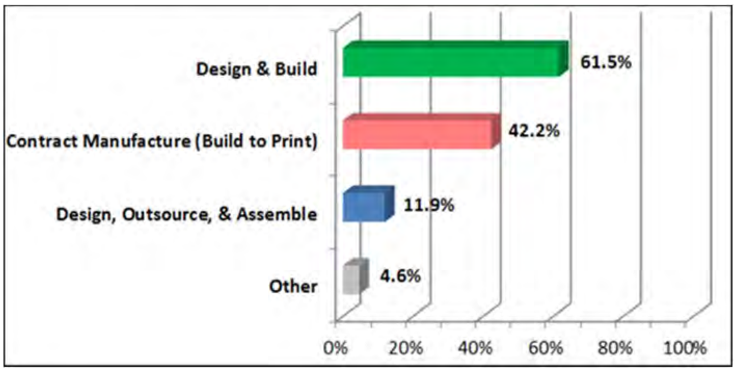


Figure 2.1 Company Profiles

Companies are currently using CAD for a variety of purposes across numerous functional areas (Figure 2.1). CAD and derivative formats are used not only in engineering but also downstream in areas such as work instructions, N/C programming, inspection, and testing.

Companies are currently using not only native CAD formats, such as NX or CATIA V5, but also neutral file formats, such as IGES and STEP and visualization formats, such as JT and 3D-PDF for data exchange, visualization, image creation, documentation, customer delivery, collaboration, CNC, and analysis (Figure 2.2).

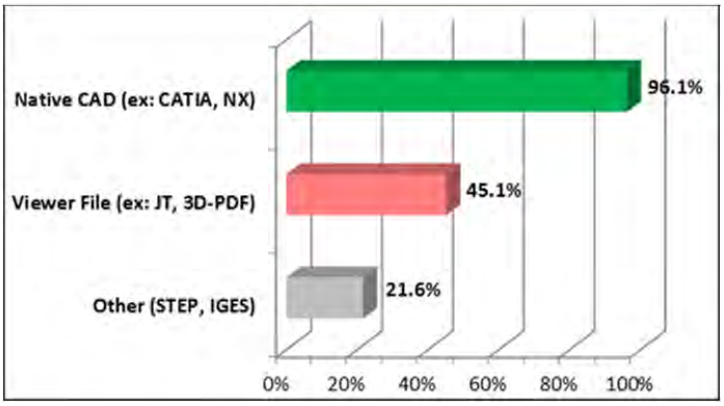


Figure 2.2 Data File Formats

Survey results also show a large percent of respondents are familiar both with the concept of 3D-MBD (Figure 2.3) and the direction OEMs are taking to move away from the use of 2D drawings (Figure 2.4). Roughly two-thirds of the respondents are familiar with 3D-MBD, while almost 80 percent of the respondents are familiar with OEMs' direction to eliminate 2D drawings.

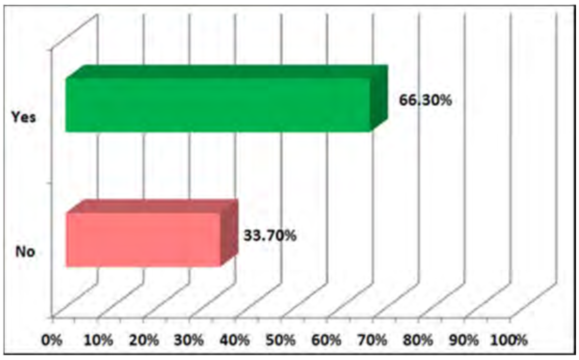


Figure 2.3 Familiarity with the 3D-MBD Concept

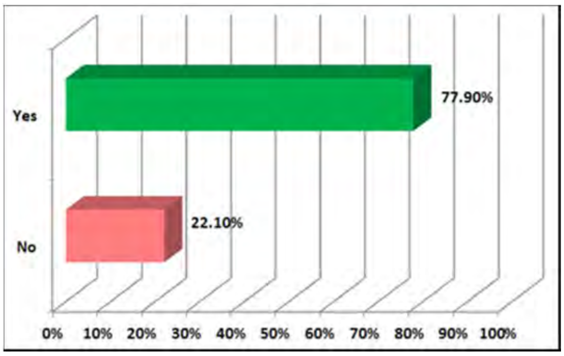


Figure 2.4 Familiarity with 2D Drawing Elimination Direction

However, even though these companies are aware of 3D-MBD and the emphasis upon 2D drawing elimination, a large percentage (almost 75 percent) of the companies do not yet use 3D-MBD (Figure 2.5). The key obstacles preventing companies from implementing 3D-MBD include cost/resources, existing processes, resistance to change, and lack of supplier readiness.

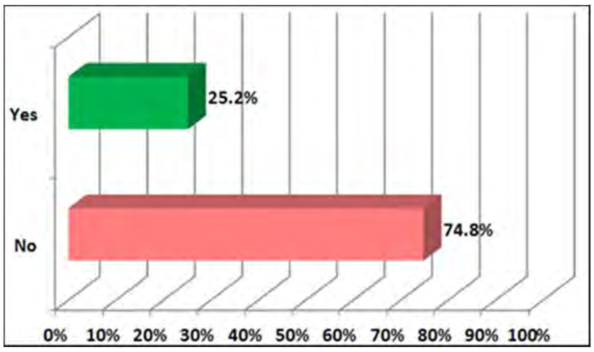


Figure 2.5 Companies Using 3D-MBD

Although roughly 75 percent of the companies that responded to the survey are not currently using 3D-MBD, a large percentage reported interest in taking this direction (Figure2.6).

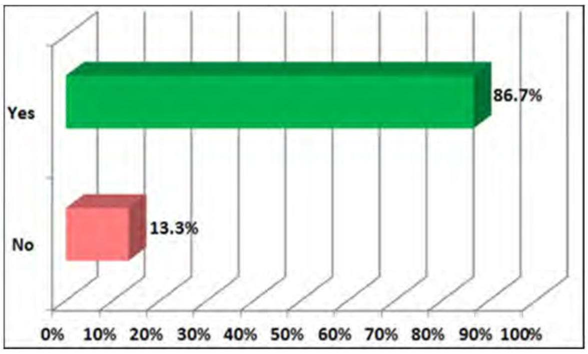


Figure 2.6 Companies Interested in 3D-MBD

No companies reported using 3D models in their production process 100 percent of the time. In fact, more than 77 percent of the respondents reported that less than 10 percent of their products are produced using only 3D-MBD. Only 4.5 percent reported using 3D-MBD greater than 70 percent of the time.

All companies moving to MBE experienced improved quality, better communication, and higher efficiency within the development process, including reduced lead times. However, these same findings showed that downstream use of 3D content is still generally limited.

In conclusion, even though the results show a small percentage of companies currently practicing MBE, it appears the automotive industry is ready to move more aggressively in this direction. In many cases, in order to expand the use of MBE, a more definitive definition of the future state and a roadmap for implementation are necessary for success. Sections 3 and 6 of this paper address the future state vision and transformation to MBE, respectively.

3 MBE FUTURE STATE AND BENEFITS

3.1 Evolution of Model-Based Representations

Two critical factors give MBE significant advantages over drawing- and document-based engineering: 1) computer interpretability and 2) data associativity. A growing number of downstream software applications can directly consume semantic model data. Complete unambiguous content, including associativity of 3D and non-CAD information, is also available for visual communication across virtually all parts of the value chain. Contrast this with 2D document-based environments where humans must interpret the engineering documents and then manually enter the information into the specific user interface of each engineering or downstream application. Whether semantic consumption or visual communication is the goal, MBE ensures that complete product definition is captured electronically and according to industry standards so that these processes can be driven digitally and without data re-entry. The progression from the current state to the future MBE state, depicted in Figure 3.1 below, ultimately results in the use of models across all disciplines and company boundaries.

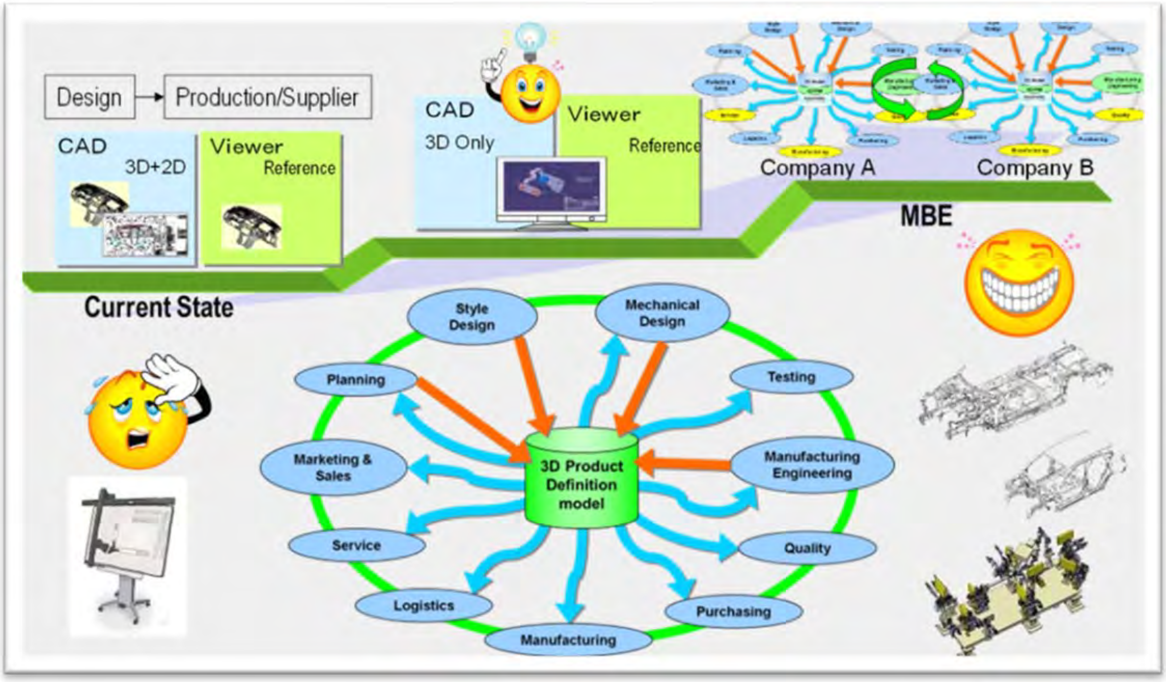


Figure 3.1 Progression from the Current State to the Future MBE State

Like the automotive industry, other industries such as aerospace, defense, and shipbuilding also realize that MBE practices are imperative to sharing product and processes information across organizations and the extended enterprise. This is the vision for MBE. MBE processes beyond 3D-MBD will describe complete product definition using the Digital Package of Information. This Digital Package of Information can potentially represent shape, behavior, and context for almost all products and processes. MBE will drive a standards-based communication process across the industry. 2D drawings and paper-based engineering will be things of the past. (See Appendix A for a more complete explanation.)

Ultimately, MBE will drive the transition from outmoded drawings and document-based engineering to complete, in-context product definition, aimed at efficient and effective enterprise-wide consumption and reuse of information. The MBE transformation is based upon the merger and sharing of data among historical PDM, ERP, and other systems. The Digital Package of Information concept ultimately represents a mash-up of data from these many domains to fully represent the shape, behavior, and context of products and processes. Digital Packages of information will accurately and dynamically carry fit-for-purpose engineering information across all functional domains.

3.2 Expected MBE Business and Financial Benefits

Financial benefits associated with the transition to MBE have been well documented across other industries, such as aerospace and defense. Initial results within the automotive industry are very consistent with results experienced in other industries. Clearly, results will vary from company to company due to numerous factors such as CAD and PLM expertise, customer and supply-chain policies, operational efficiency, and business practices.

Table 3.1 represents potential savings based on estimates identified by other industries and initial automotive studies.

Table 3.1 Potential MBE Business and Financial Benefits

Category	Key Enablers	Estimated Savings Range
Designer Efficiency	•GD&T advisor supported GD&T information added to 3D model	10 - 30%
Engineering Efficiency	•Reduced involvement in repeat drawing creation iterations for GD&T information checking and validation	5 – 10%
Engineering effectiveness improvement	•Productivity gains to effectiveness	10 – 20%
Reduced need for manufactured part checking	•Access to correct GD&T information for manufacturing process planning	15 - 25%
Reduced Rework and Scrap	•Access to correct product information	10 – 20%
Reduced Cost of Quality	•Access to correct GD&T information for manufacturing process planning	2 – 10 %
Improved win rate (and margins) through higher quote confidence	•Sufficient time for cost estimation and sourcing based on timely and accurate PMI data availability	TBD
Quality of Life Improvement	•Eliminate non-value work	Intangible but Significant
Risk mitigation against significant product fulfillment error	•Single source of product information •Access to correct product information to all stakeholders	Significant

4 MBE DOWNSTREAM USAGE

This section describes four different use cases targeted for development by the SASIG 3D-MBE Workgroup. For each use case an "As Is" and "To Be" description has been developed to serve as a roadmap to capture functional requirements. (See Section 5 and Appendix C for more details.)

4.1 Business Operations Improvement (Use Case Examples)

Transitioning to a business configuration that applies MBE will enable downstream processes (including suppliers) to directly access and consume the complete MBE digital definition (Figure 4.1). As a result, benefits such as facilitating automation, shortening development lead time, reducing costs, improving quality, etc. are expected. In this section, specific semantic and visual communication use cases are described. Use cases for Stamping and Formability, Weld Study and Instructions, and Manufacturing and Inspection are highlighted with projected benefits that could be expected with MBE. Refer to Appendix B for a more detailed description of each use case.

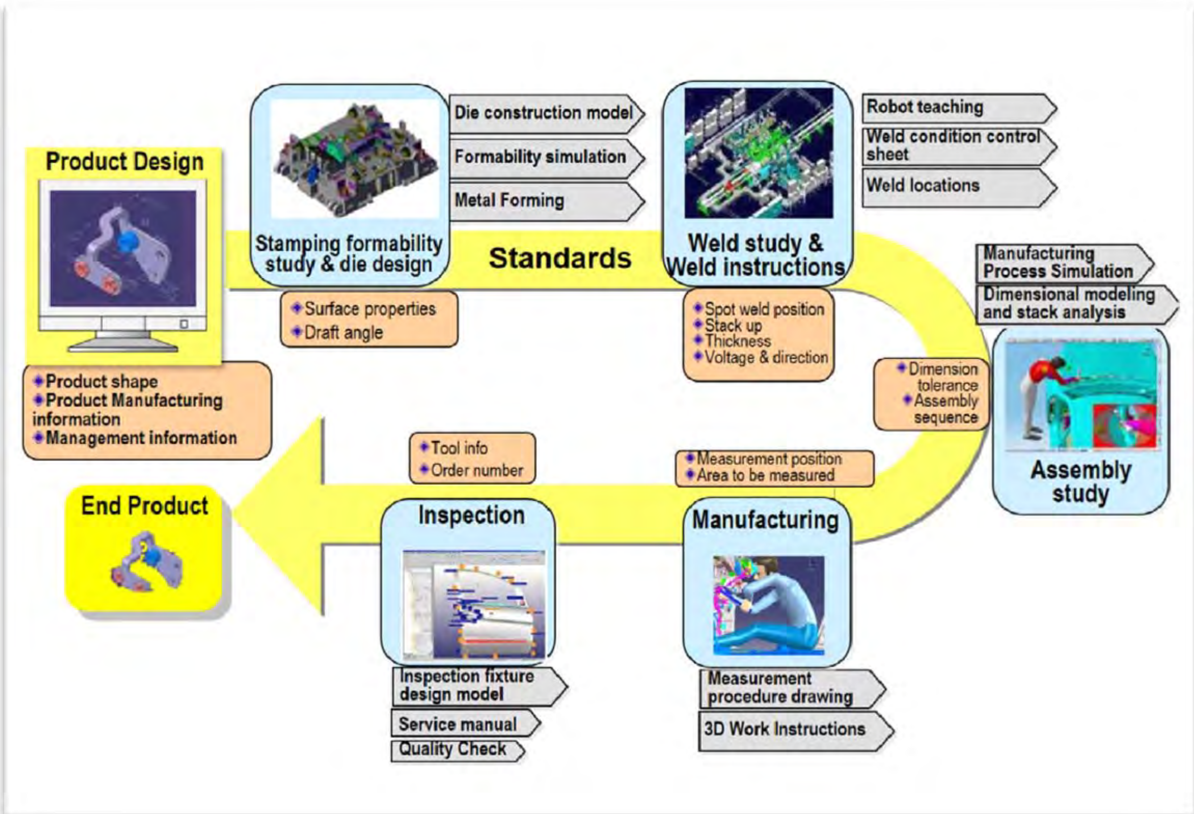


Figure 4.1 Examples of Downstream Usage

To demonstrate the benefits of MBE, the 'As Is' and 'To Be' state of select downstream operations (Die Engineering, Spot Welding, Inspection, Service Manual) have been captured. In the 'As Is' state, the current issues of consuming the 3D-MBD model are investigated. In the 'To Be' state, the business operations/practices to resolve the current issues have been identified.

Benefits of applying MBE for the four use cases are listed below.

Table 4.1 Examples of the Benefits of Applying MBE on the Four Use Cases

	Quality	Cost	Delivery
Die Engineering	Design quality improvement of die surfaces	Cost reduction by reducing number of die revision iterations	3D-MBD-enabled forming simulations will lead to fewer design iterations and quicker die surface design. Also results in a reduction of the number of physical trials
Spot Welding	Eliminates manual entry of data which prevents human error	Cost reduction by automatically setting the weld conditions	3D-MBD-enabled data preparation will lead to quicker weld robot simulations.
Inspection	Eliminates manual entry of data (dimensions, tolerances, etc.), which prevents human error	Reduced design and manufacturing costs of inspection tools, jigs, and fixtures	Expedited part inspection and pass/fail process
Service Manual	Improved level of understanding for operators by providing operator instructions that use 3D Models, videos, and image.	Reduced cost by using 3D-MBD for automating the creation of manuals	Quicker service manual creation and better design for serviceability (installation/ removal trajectory paths)

4.2 Select Functional Area Use Cases (Issues and Resolution)

4.2.1 Die Engineering (Stamping and Formability)

MBE will enable the association and availability of all the 2D and 3D information needed for forming operation simulations to the analysis systems. By doing this, manual operations such as transcribing and reading information from drawings will be eliminated and numerous iterations involving rework due to errors/mistakes will be eliminated. Benefits include cost reduction by reducing the number of die revision iterations and improved die surface quality improvement (Figure 4.2.1).

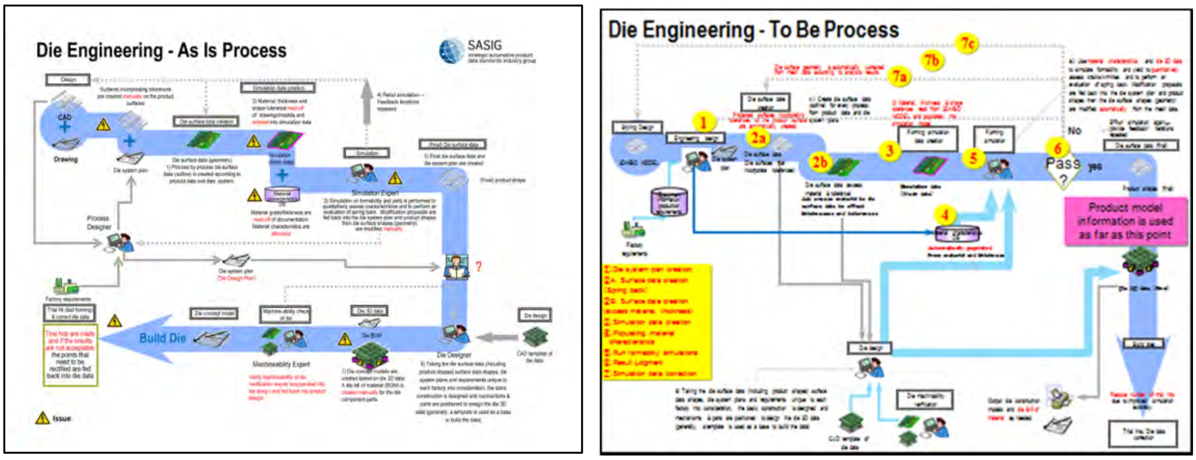


Figure 4.2.1 Die Engineering "As Is" and "To Be" Processes

4.2.2 Spot Welding

MBE will allow the automatic setting of spot weld information (part numbers, material, thickness, stack-ups) needed in weld robot simulations, will eliminate manual processes transcribing and reading information, and will prevent iterations of rework due to errors/mistakes. MBE significantly improves time to market, reduces rework, and greatly reduces cost of prototype and production operations (Figure 4.2.2).

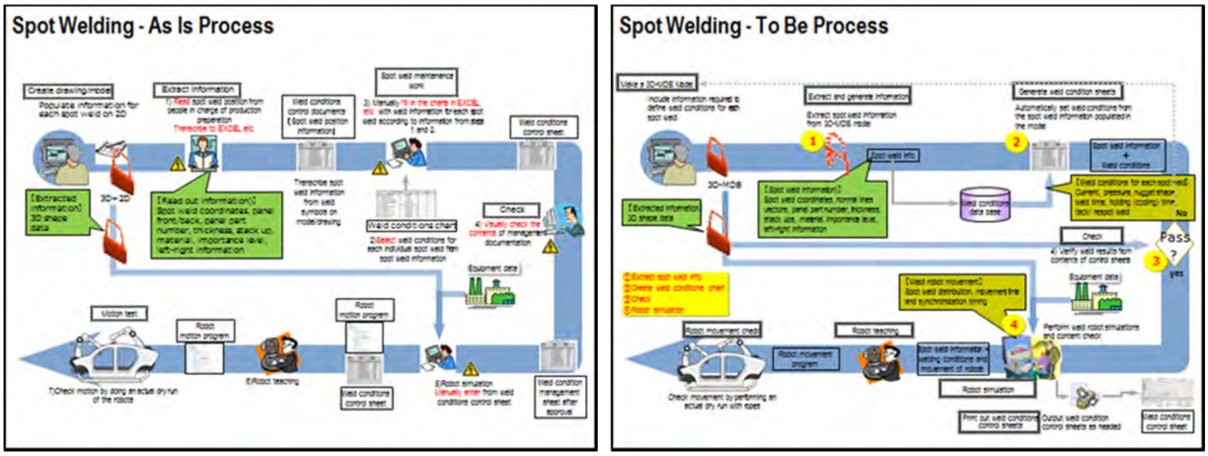


Figure 4.2.2 Spot Welding "As Is" and "To Be" Processes

4.2.3 Inspection

In the MBE Inspection Process, measurement results of physical products are compared with 3D-MBD content (shapes, measurement datum, dimensions, tolerances, etc.) and pass/fail judgments are made. Performing this process reduces variation in inspection results and also shortens inspection time. MBE prevents misreading information such as dimensions and tolerances, and reduces overall design and manufacturing costs (Figure 4.2.3).

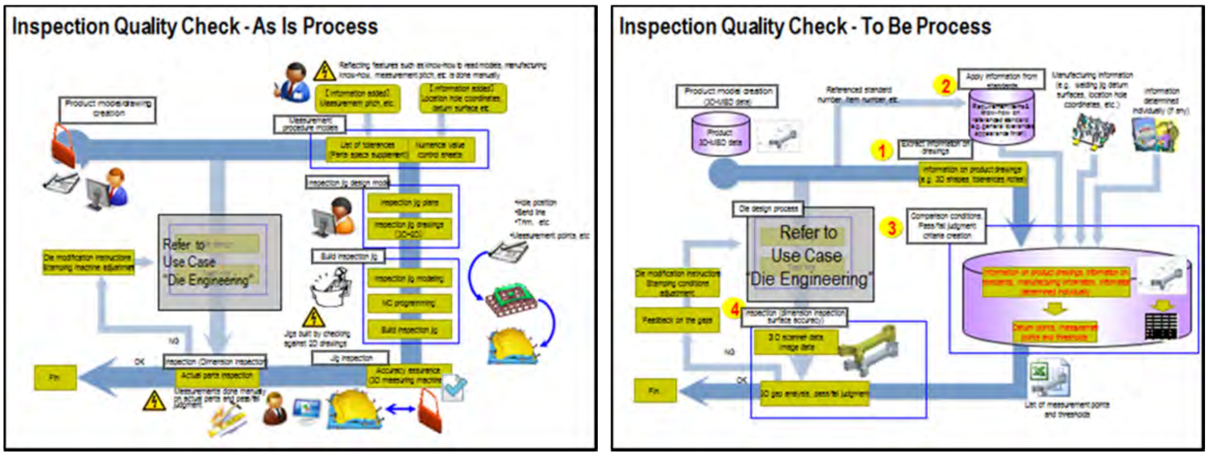


Figure 4.2.3 Inspection "As Is" and "To Be" Processes

4.2.4 Service Manuals

In order to develop effective service manuals and avoid serviceability issues related to product changes, installation/removal trajectory paths, etc. need to be analyzed for service operations. This requires federation of information from multiple sources including PLM, ERP, and MES environments. By moving to an MBE approach, 3D visual process plans and work instructions are updated automatically with changes to source data from any of these sources, significantly reducing cost and time. By moving to superior, interactive 3D instructions, workers are better prepared, improving new product launch quality and lead time (Figure 4.2.4).

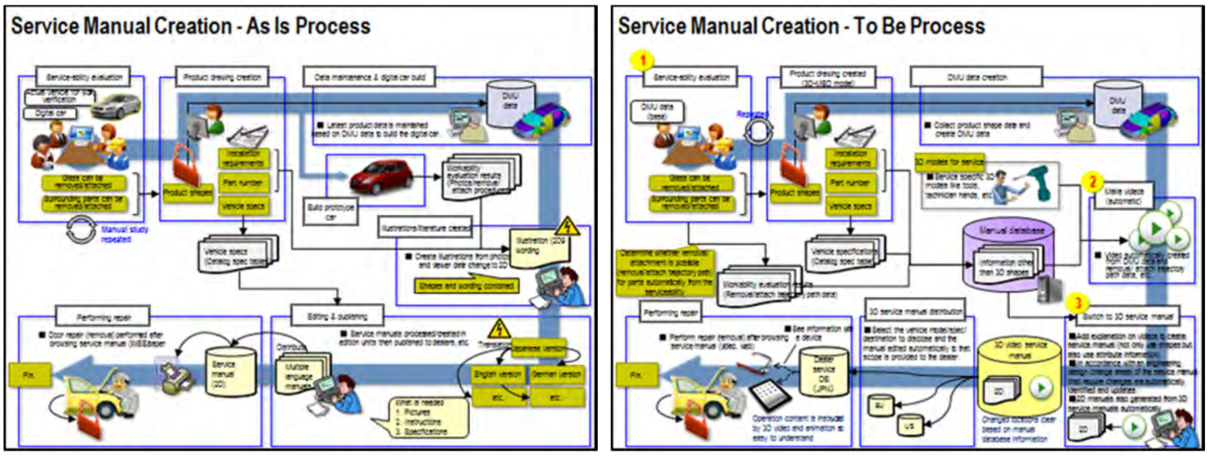


Figure 4.2.4 Service Manual "As Is" and "To Be" Processes

5 3D-MBD FUNCTIONAL REQUIREMENTS

The SASIG 3D-MBE Workgroup created and documented the 3D-MBD technical functional requirements needed to achieve the future "To Be" state for the use cases introduced in Section 4. The workgroup then conducted a gap analysis with a subset of MBE Software Providers (SP), initially focusing on CAD and Translation SPs, to investigate current MBE capabilities with respect to the documented requirements. Table 5.1 below shows a sample of the functional requirements. The full set of functional requirements is listed in Appendix C.

Table 5.1 Sample of the 3D-MBD Functional Requirements

	Category	Sub-category	Description/Detail information	Type of data	On 3D-MBD Model?	Requirement for Data Creation	Requirement for Consumption
13	Information related to holes	Hole symbol	Hole application (fastening hole, clearance hole, locator hole)	Annotations (text, symbols, color…)	X	Should be able to input as a hole feature (Input of application, etc. should be drop down select, etc. done easily)	Should be able to recognize each type of information regarding the hole Moreover, should also be able to recognize shapes of original surface before making hole.
10	Information related to holes	Hole shape	Hole opening direction	Shapes/vectors	X	Should be able to enter as hole element component information	Should be able to recognize each type of information relevant to holes Moreover, should also be able to recognize shapes of original surface before making hole. .
9	Information related to holes	Hole shape	Hole position	Shapes/coordinates	X	・Should be able to input as a hole feature (Input of application, etc. should be drop down select, etc. done easily. For ServiceManual) ・Should be able to enter as hole element component information.(for DieEng)	・Should be able to recognize each type of information regarding the hole plus should be able to also recognize the shape information of the original surface (for ServiceManual) ・Should be able to recognize each type of information relevant to holes Moreover, should also be able to recognize shapes for the front face of the opened hole(for DieEng)
11	Information related to holes	Hole shape	Hole diameter	Shapes/numbers	X	Should be able to enter as hole element component information	Should be able to recognize each type of information relevant to holes Moreover, should also be able to recognize shapes of original surface before making hole.

Results from the CAD and Translation SPs' demos and surveys demonstrated that most of the technical functional requirements are implemented in the SP's proprietary products; therefore, most of the "To Be" use cases are feasible to implement. Both the CAD and Translation SPs continue to work on developing tools to support the MBE transformation per market demand.

6 MBE TRANSFORMATION

The SASIG 3D-MBE Workgroup has developed a simple, mostly visual way of assessing an organization's progress towards 3D-MBD and MBE realization. Initial emphasis has been placed on embedded 3D PMI.

6.1 Navigating the MBE Maturity Model

An enterprise cannot be said to be a Model Based Enterprise until models are available for and used in downstream operations, generally as part of a Digital Package of Information representing the complete product description. The transition to MBE, however, requires adopting 3D-MBD design practices. In this section, the maturity model is described and can be thought of as a measuring stick to assess progress toward the ultimate MBE vision.

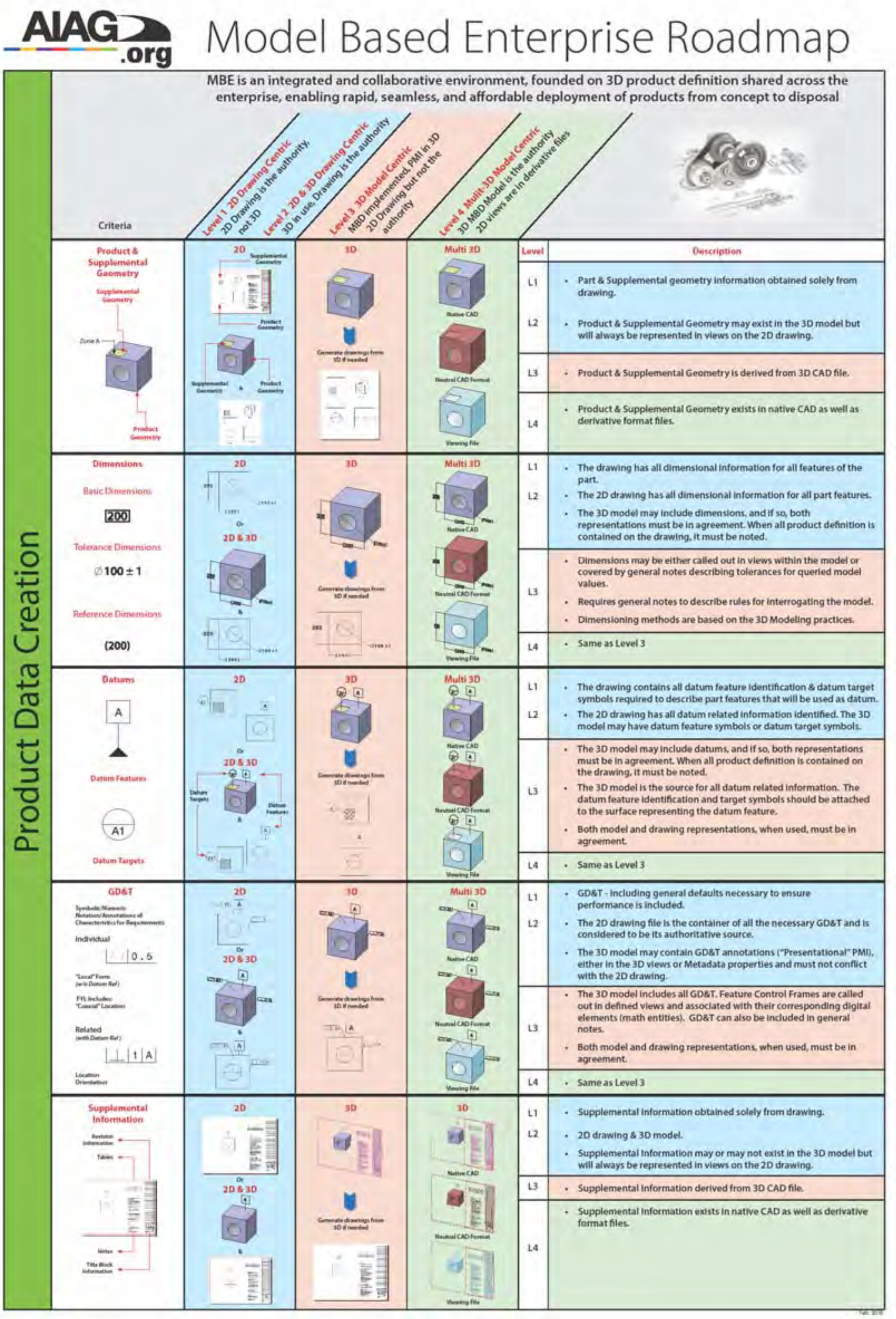


Figure 6.1 The Automotive MBE Maturity Model

6.2 Assessing Readiness through 3D-MBD Criteria

Level 3, as depicted in the maturity model above, is the level at which an enterprise can be said to employ Model Based Definition because all PMI is completely embedded within the 3D model and drawings are necessary only by exception. The following are specific criteria that must be addressed to successfully transition to 3D-MBD.

<u>Product & Supplemental Geometry</u>

- Specific digital elements are associated to those annotations that correspond to their purpose.
- Supplemental geometry must be distinct from model geometry.

<u>Dimensions</u>

- Annotated in 3D within associated (saved) Views
- Rules for interpreting values derived from interrogating (querying) the model are required.

<u>Datum's</u>

- Feature and Target annotations are associated to their corresponding digital elements and an associated Coordinate System.
- Sub-Datum schema require independent coordinate system (vectors) - appropriately labeled.

<u>GD&T</u>

- All Related Feature Control Frames must be associated to their corresponding (Datum) Coordinate Systems Supplemental Information.
  - General NOTES do not require associativity and may contain:
    - Approval / Revision History
    - CAD Application
    - Criticality Designation
    - Default Tolerances
    - Model Completeness

<u>Supplemental Information</u>

- Contains notes and tabular information such as:
  - General NOTES (Product specific)
  - Standard NOTES (describes the symbols)
  - Title block information
  - Bill of Material information
  - Change history column

6.3 Bridging the 2D to 3D Gap for 3D-MBD and MBE

In MBE, all required information for design and downstream processes is defined in 3D-MBD. The aim is to facilitate efficient product manufacturing by taking that information and disseminating it internally and/or from the automotive vehicle manufacturer or OEM throughout the supply chain to automotive parts suppliers. However, in terms of the current state of automotive manufacturing, the transition to an MBE environment can represent a significant cultural change that requires effective education, communication, and training for all parts of the enterprise, including the supplier. In addition, 2D documents may still be required for submission in certain instances (government regulations, areas of poor IT infrastructure, etc.). In these cases, for the time being, 2D drawings still remain a necessity. In this case, the 2D drawing is a temporary output generated from the 3D-MBD.

Migrating away from using 2D drawings toward implementing MBE is a choice that a company or organization must make. It is similar to the transition of moving from creating 2D drawings on the drafting board to 3D CAD. The path for migrating to MBE can be overwhelming, challenging, and frustrating but also exciting because of the opportunities to implement new emerging processes and technologies.

7 CONCLUSION

It is our hope that this paper has convinced you that the automotive industry is expanding the use of 3D-MBD and related technology from engineering and product design to tooling, process development, manufacturing operations, and many other downstream business areas. Progress is both real and accelerating. To accurately represent physical product, the 3D models should encompass much more definition than embedded PMI alone. This is becoming a reality primarily outside the automotive industry, but the automotive industry is making progress through the efforts of leading companies that have addressed 3D-MBD challenges and are now moving to make MBE a reality across entire value chains, including entire extended enterprises of suppliers and partners. This 3D approach offers an opportunity to significantly promote reuse, improve design efficiency, reduce cost, and improve quality across the extended enterprise.

This white paper has introduced both 3D-MBD and MBE, described the current and future states for MBE, and carefully outlined the transition process and pathway to success. SASIG member organizations will continue to drive for further progress in this important area. The authors of this paper strongly encourage you to take advantage of these opportunities to learn and grow your organization's MBE capabilities. Get involved to learn from other companies. Meet the people who are making it happen and get first-hand knowledge of their experiences you can leverage within your own organization.

8 REFERENCES

ISO 16792:2015 Technical product documentation – Digital product definition data practices

SASIG 3D Annotated Model Standard

SASIG Guideline for combining 3D models and 3D CAD Documentation

SASIG Guideline for Digital Engineering Visualization

U.S. Department of Defense Military Standard 31000-A

APPENDICES

Appendix A. Digital Package of Information

(Also referred to as: TDP-Technical Data Package, ZLP - Zeichnungslos Prozess - ZLP and DTPD - Digital Technical Product Documentation)

Digital Package of Information = Lifecycle Communication Enabler

Figure A.1 below illustrates the future communication spectrum, including human-to-human, human-to-machine, machine-to-human, and machine-to-machine. Information from disparate systems used within virtually all functional areas will be intelligently associated within MBE models and shared across the enterprise. The model-based approach eliminates "white-space" issues where information from MES, ERP, and other repositories must be associated, according to business logic, with 3D content from CAD and PLM systems for complete product definition.

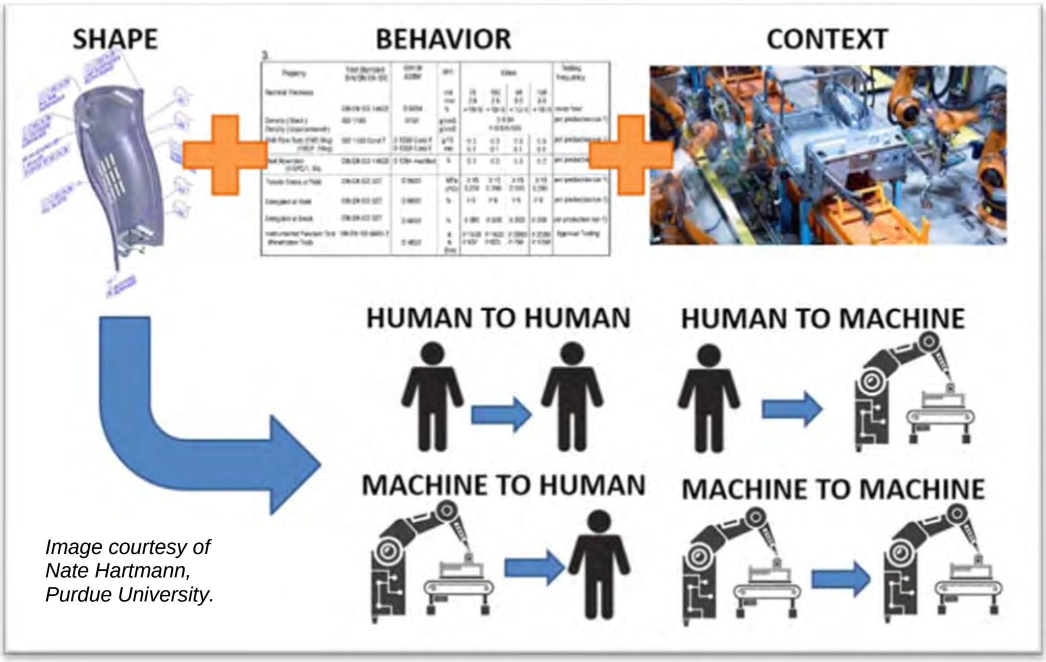


Figure A.1 Full Communication Spectrum

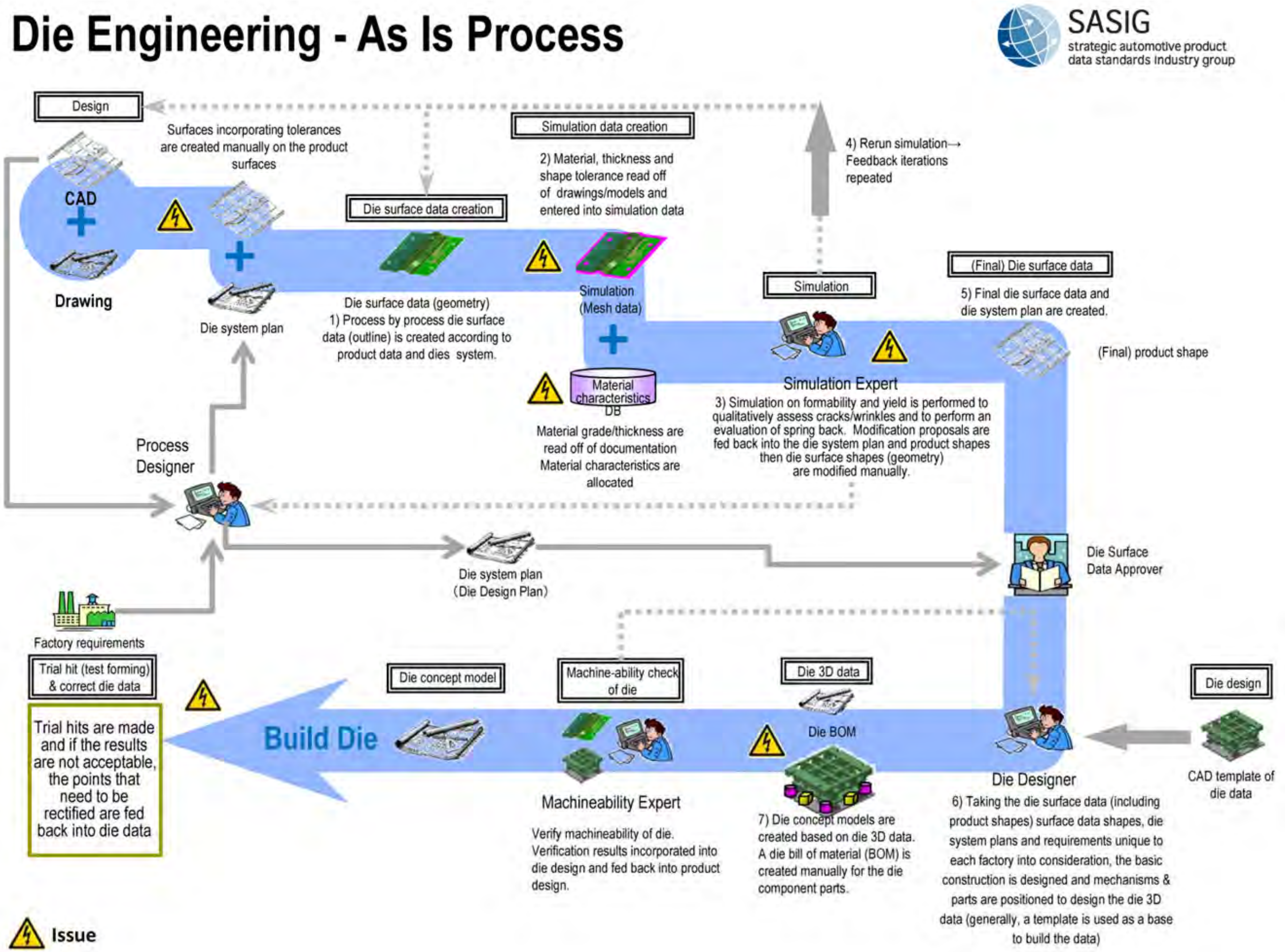
Wide-scale adoption and implementation of Digital Package of Information formats, including 3D-PDF and HTML5, to support all the shape, behavior, and context-based data exchanges using Digital Package of Information formats will transform and integrate operations by intelligently associating information.

As companies and their value chains progress from simpler process areas, like engineering release, to more complex areas such as procurement, process planning, and inspection, much of the information required for complete product definition exists outside of the CAD and PLM environments. Leading aerospace and defense companies have estimated that 40 percent of the required information comes from outside the CAD environments. For example, mBOM information required for process planning may exist in an ERP environment and needs to be associated with 3D content. To support these needs, where data must be federated and associated with 3D content, the Digital Package of Information is used to encapsulate the digital model for MBE. The Digital Package of Information concept and its uses are detailed in the U.S. Department of Defense Military Standard 31000-A, which can be a basis for further automotive industry adoption. This standard is available to non-defense firms as well and provides an excellent foundation for adopting the Digital Package of Information to support numerous business needs.

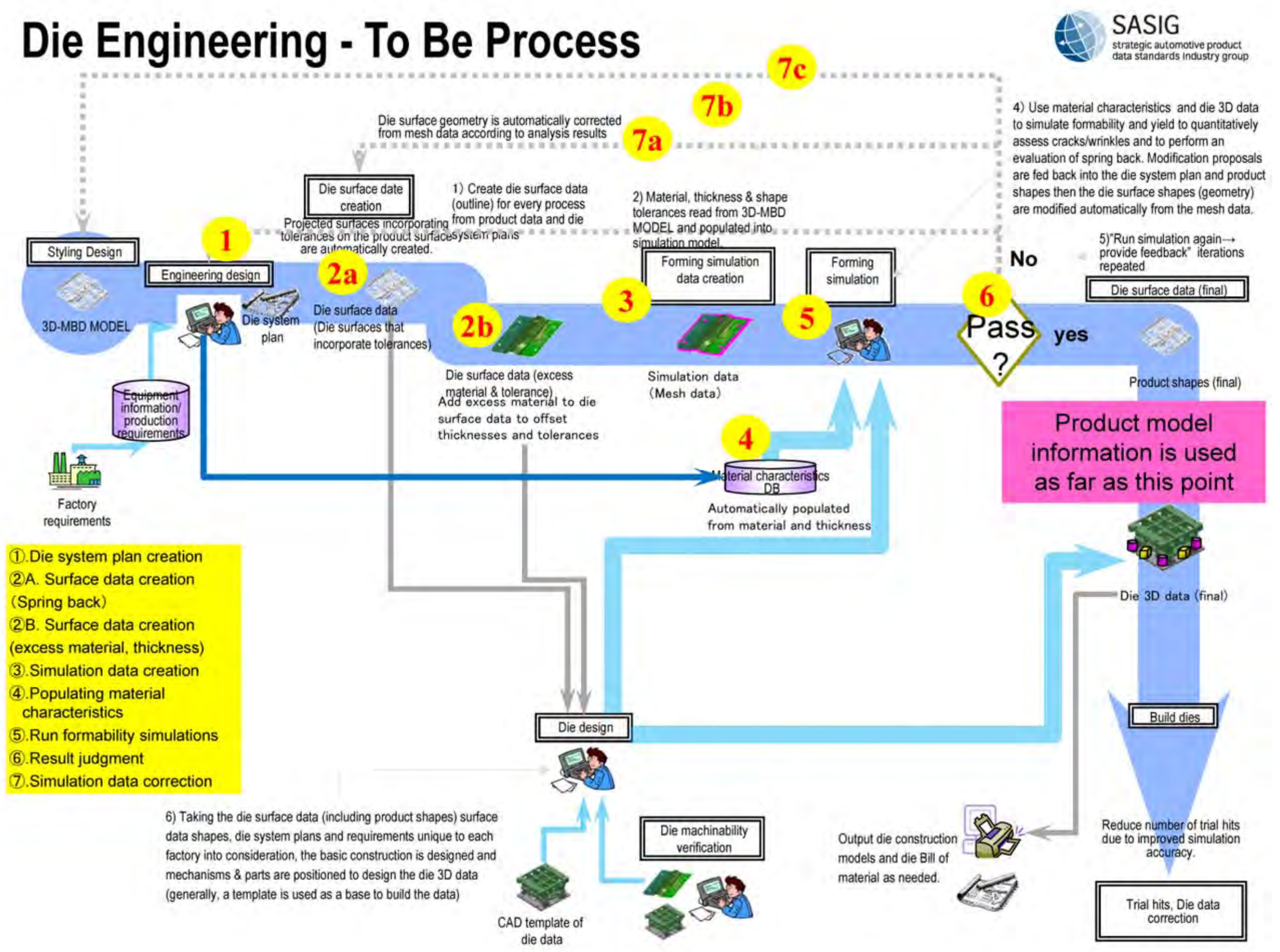
Appendix B. Downstream Use Cases and Benefits of MBE

This appendix shows the ‘’As Is Process’ and ‘To Be Process’ of the Select Functional Area Use Cases of Section 4.

Die Engineering - As Is Process



Die Engineering - To Be Process

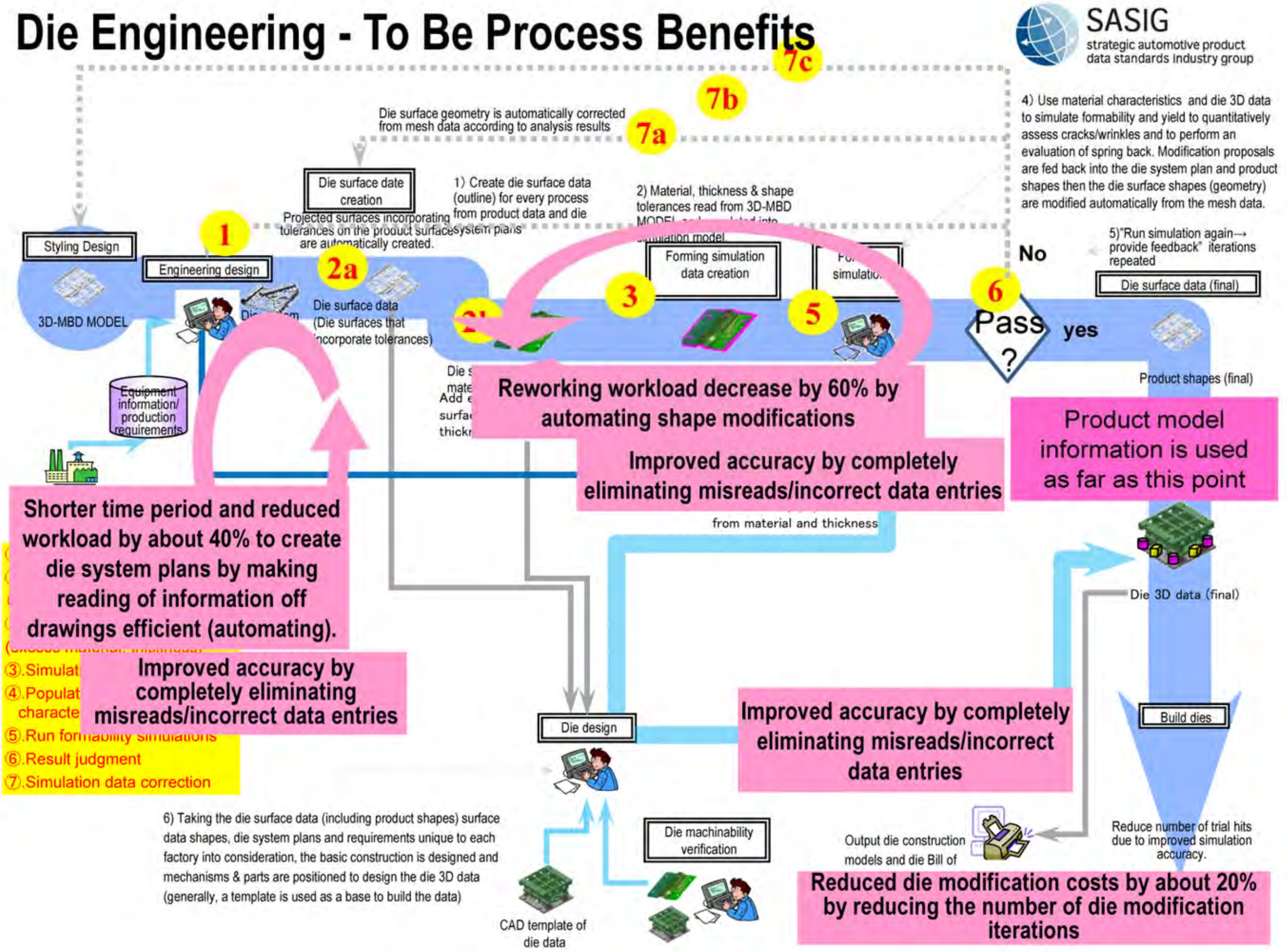


Detailed Processes for Die Engineering

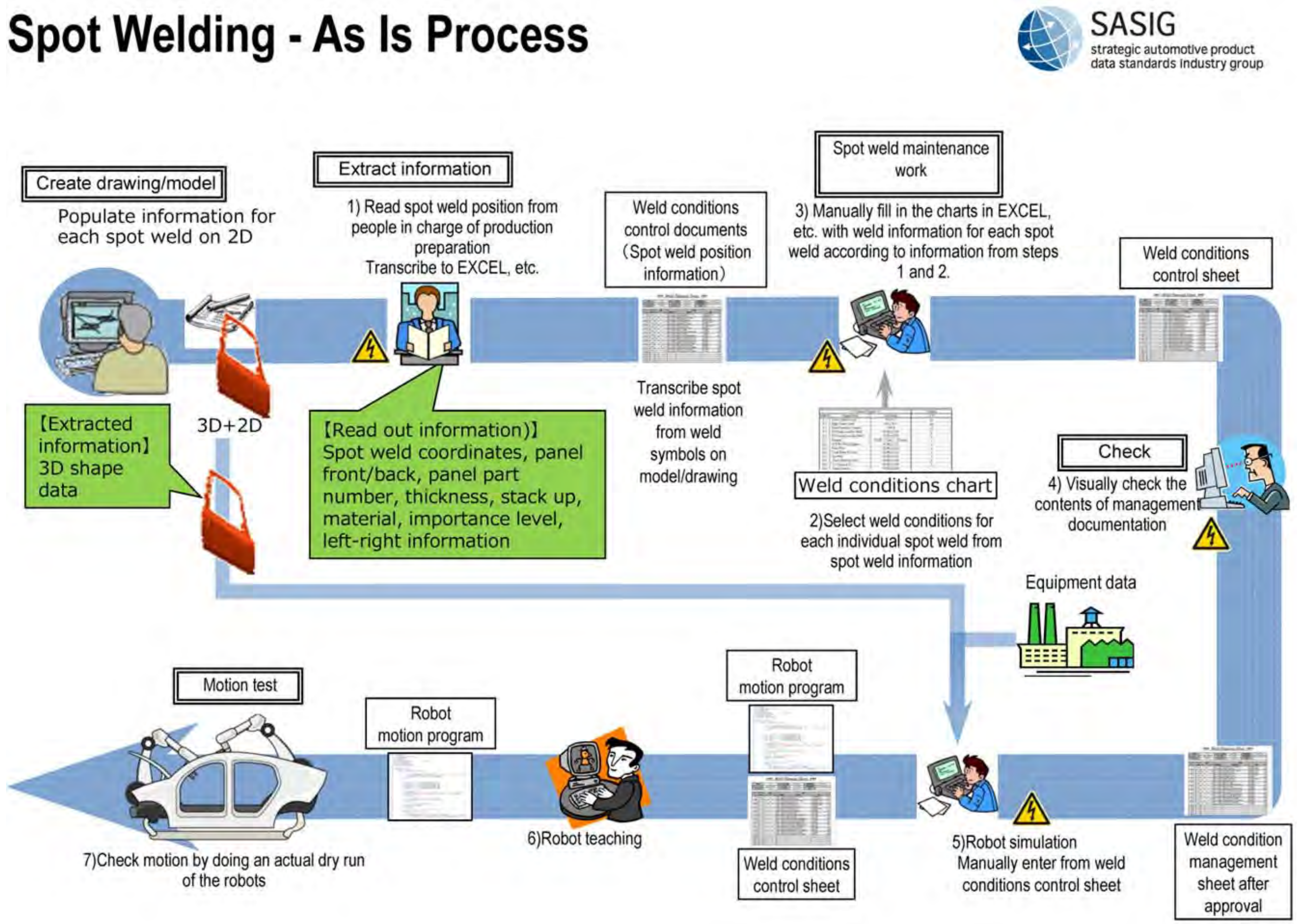
Detailed Processes for Die Engineering

Process name	Overview	Input	Output
①Die system plan creation	Create outline surfaces for each process and process proposal of the draws, bends, drafts, etc to form the shapes.	3D-MBD MODEL Equipment info/production requirements	Die outline surface data
②"A die surface" data creation (Spring back)	Take the spring back into consideration to reshape the die outline surface data to create the die surface datum data.	3D-MBD MODEL Die outline surface data	Die surface datum data
②"B die surface" data creation （excess material, thickness）	Create die surface data adding excess material and thickness to the die surface datum data	Die surface datum data, Die outline surface data 3D model data	Die surface data
③Simulation data creation	Create mesh data of simulation input based on die surface data	Die surface data	Mesh data
④Populating material characteristics	Obtain material characteristic data for simulation input from 3D model materials and thicknesses.	Materials, thicknesses	Material characteristics data （e.g. Young's modulus)
⑤Run formability simulations	Run analysis simulation on cracks, wrinkles, shrinking, spring back based on input data	Mesh data Material characteristics data	Simulation results mesh data
⑥Result judgment	Make a judgment on simulation results. （Check whether cracks and wrinkles occur or not)	Mesh data of simulation results	Good/no good judgment
⑦Simulation data correction	Correct die surface data and make changes to conditions for die system plan.	Mesh data 3D-MBD MODEL Die surface data Die outline surface data	（Corrected） Die surface data

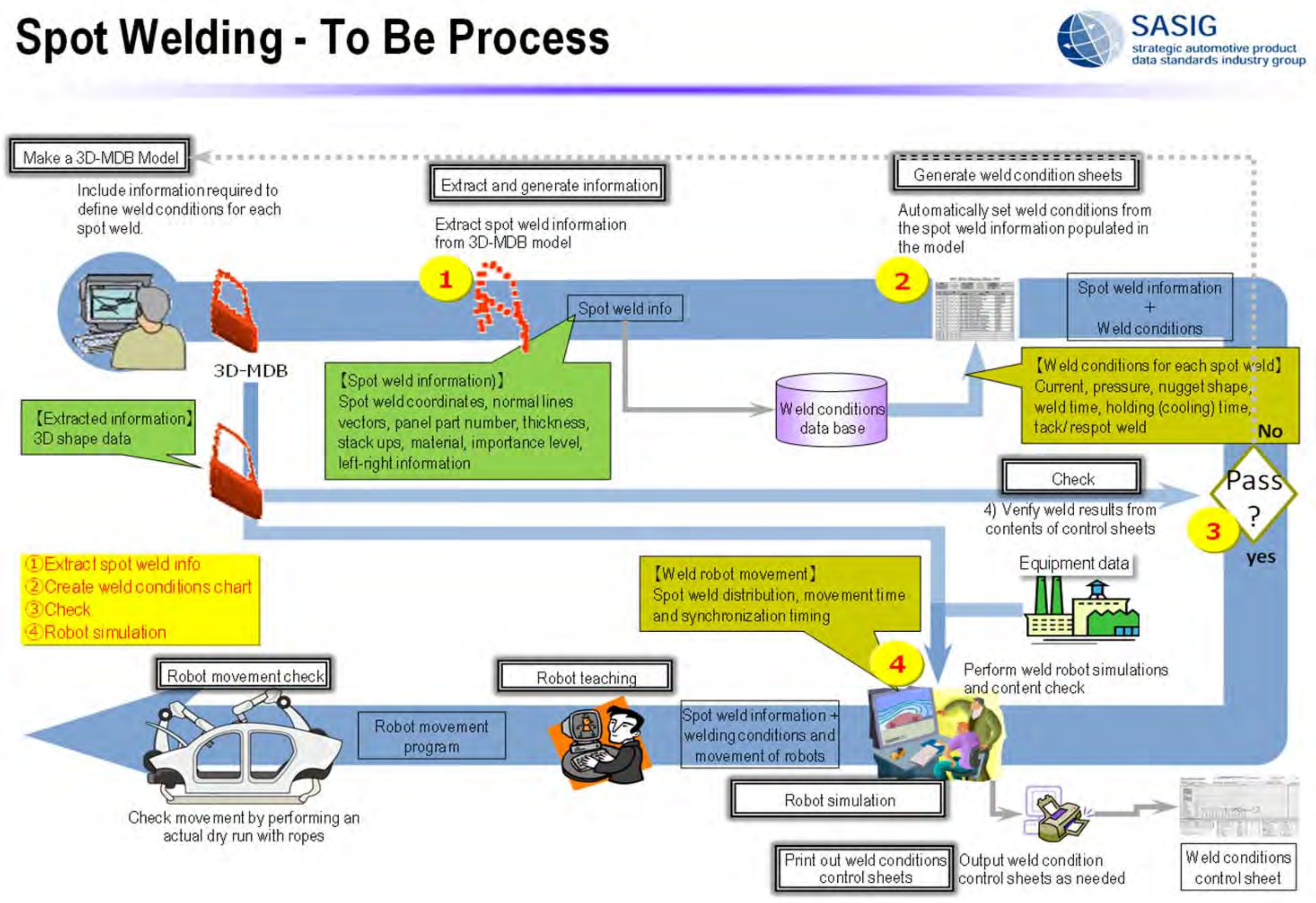
Die Engineering - To Be Process Benefits



Spot Welding - As Is Process



Spot Welding - To Be Process



Detailed Processes for Spot Welding

Detailed Processes for Spot Welding

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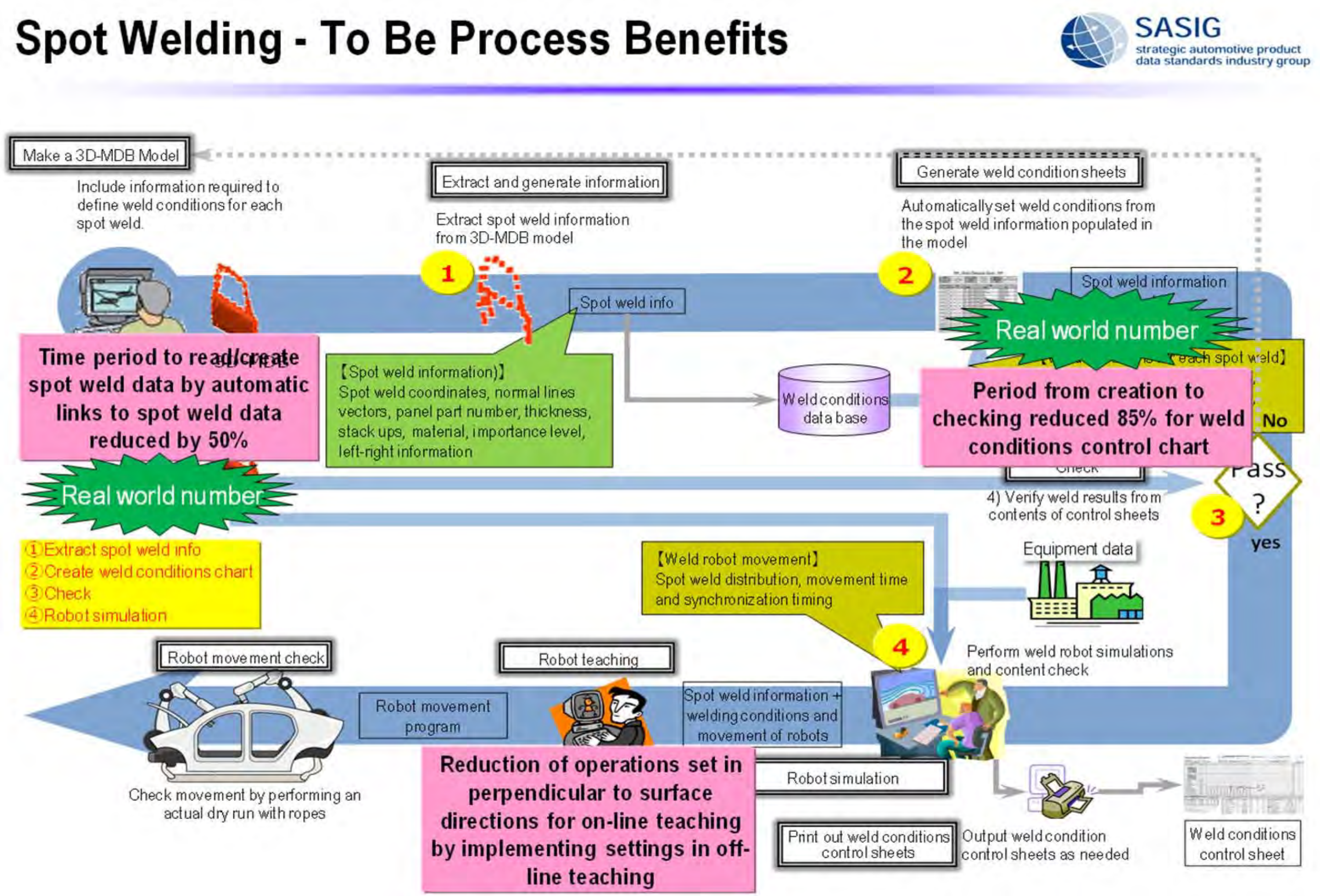
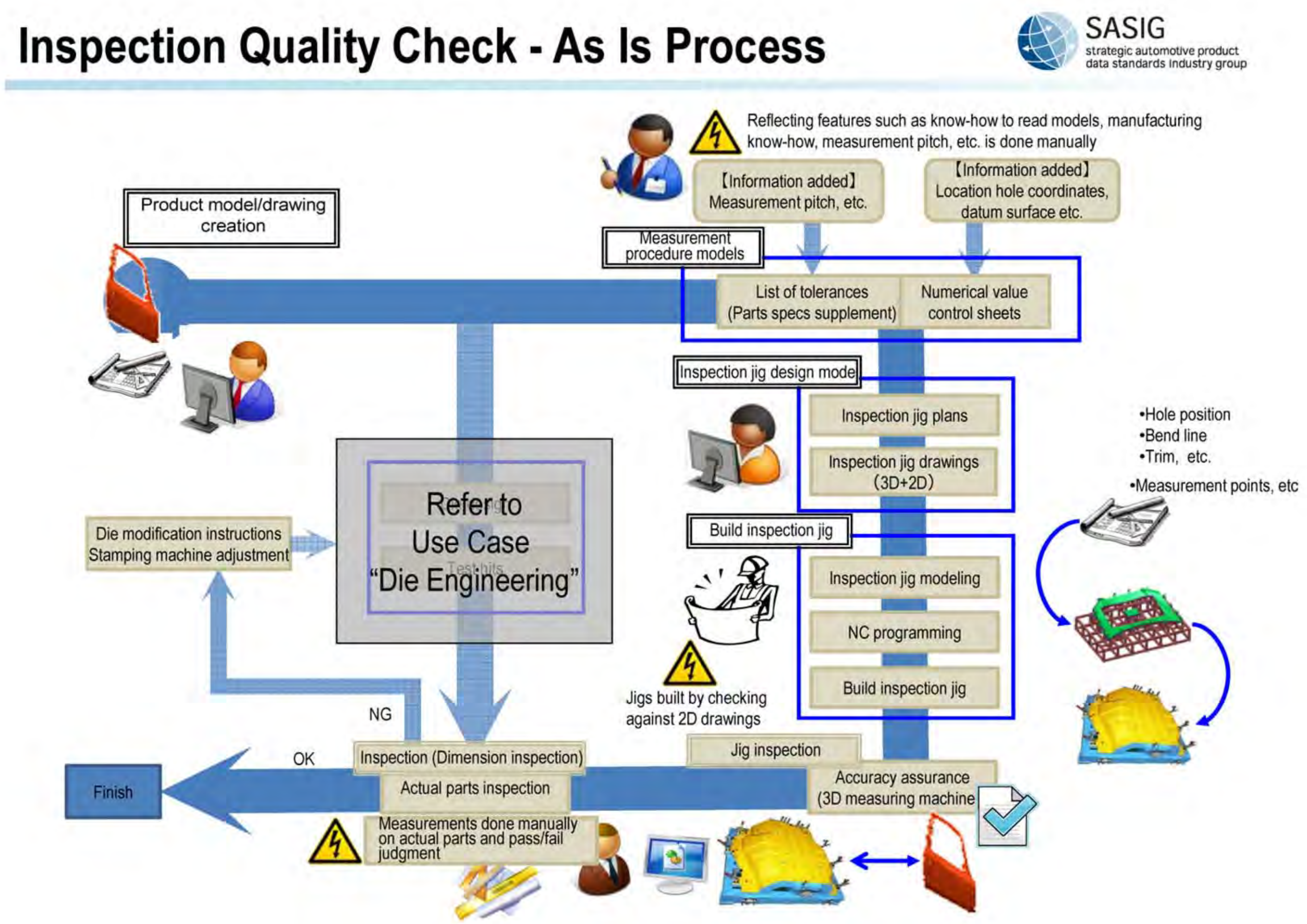
Process Name	Overview	Input	Output
① Extract spot weld information	Extract spot weld information from the weld symbols provided in the drawing information.	Weld symbols	Spot weld information
② Create weld condition table	Set weld conditions automatically for every spot weld individually from the spot weld information populated in the model.	Spot weld information (Determined based on thickness, stack up and material)	Spot weld information + weld conditions (Current, pressure, nugget shape, weld time, holding (cooling) time, tack/ respot weld
③ Check	Verify feasibility of welds with weld conditions and 3D shapes together for each individual spot weld.	Spot weld information + weld conditions 3D shapes	Good/No good judgment
④ Robot simulation	Determine the movement and spot weld distribution of robots along with equipment.	Spot weld information + weld conditions 3D shapes Equipment data	Movement for each robot individually (Spot weld distribution, movement, time, synchro timing, spot weld number)
Robot teaching (offline)	Program the movement of robots.	Movement robot by robot Spot weld information + weld conditions	Data entered into robots
Robot movement check (offline)	Check movement with the actual robots that will be used.	Data entered into robots	Good/No good judgment

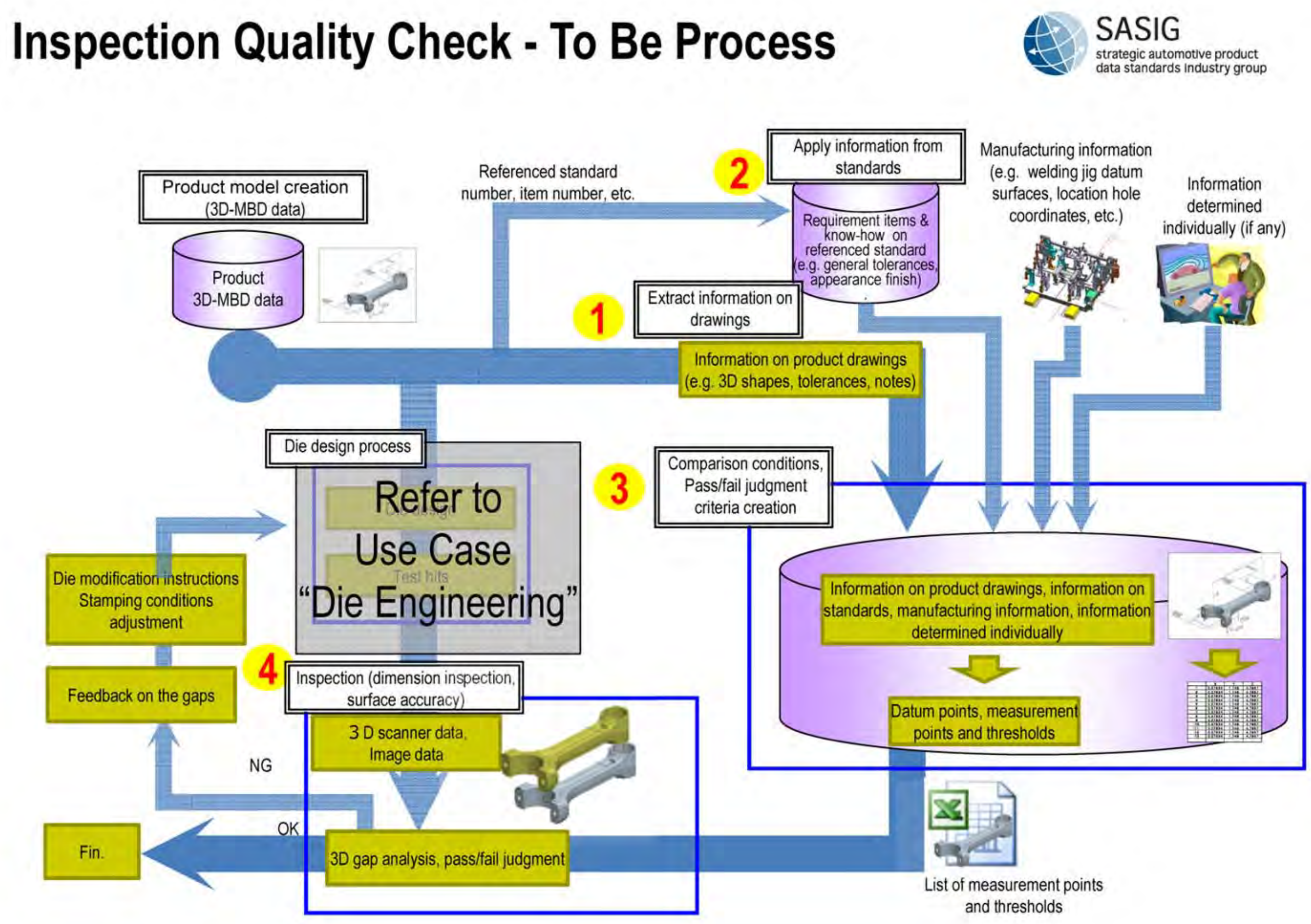
Spot Welding - To Be Process Benefits



Inspection Quality Check - As Is Process



Inspection Quality Check - To Be Process



Detailed Processes for Inspection Quality Check

Detailed Processes for Inspection Quality Check

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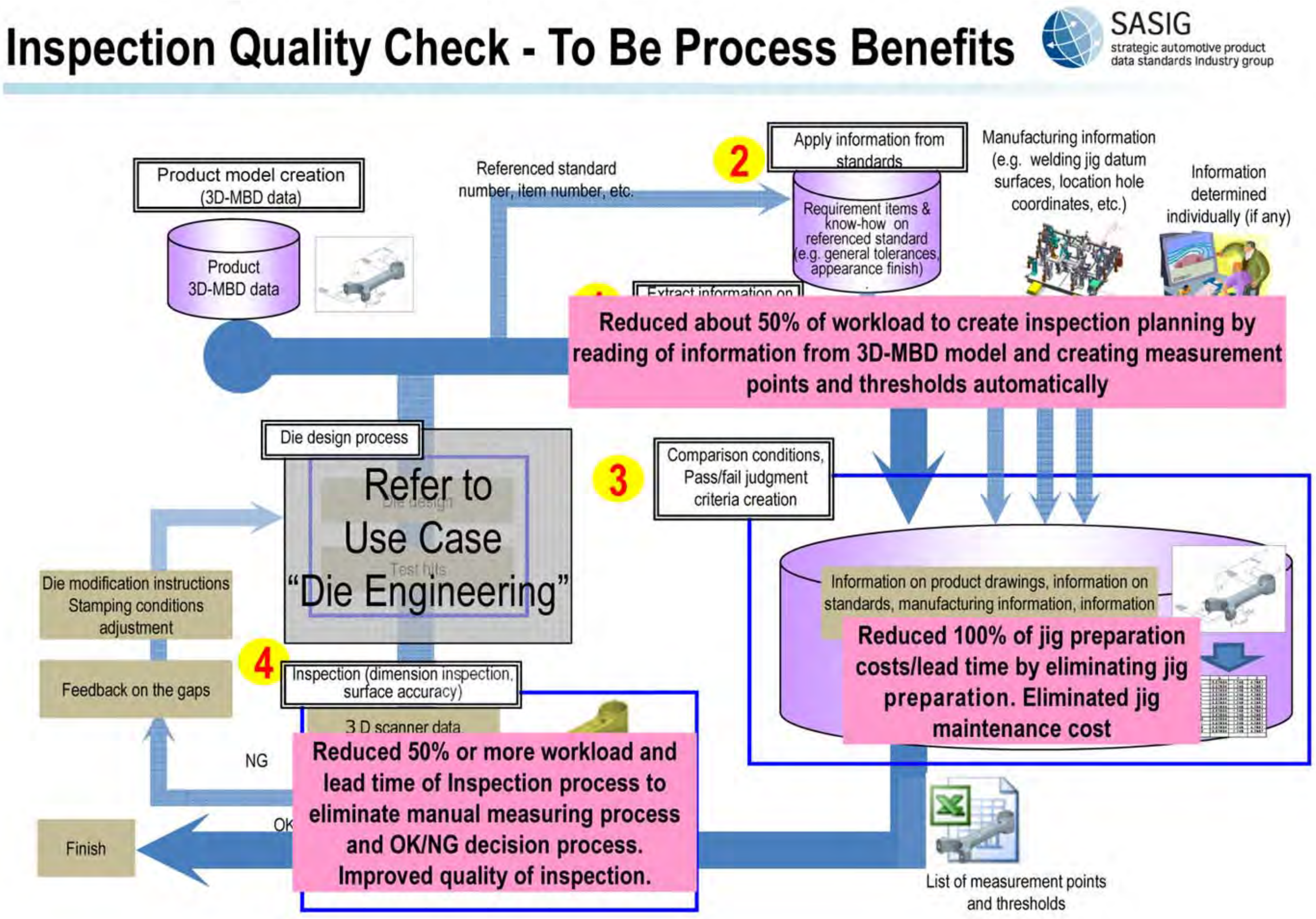
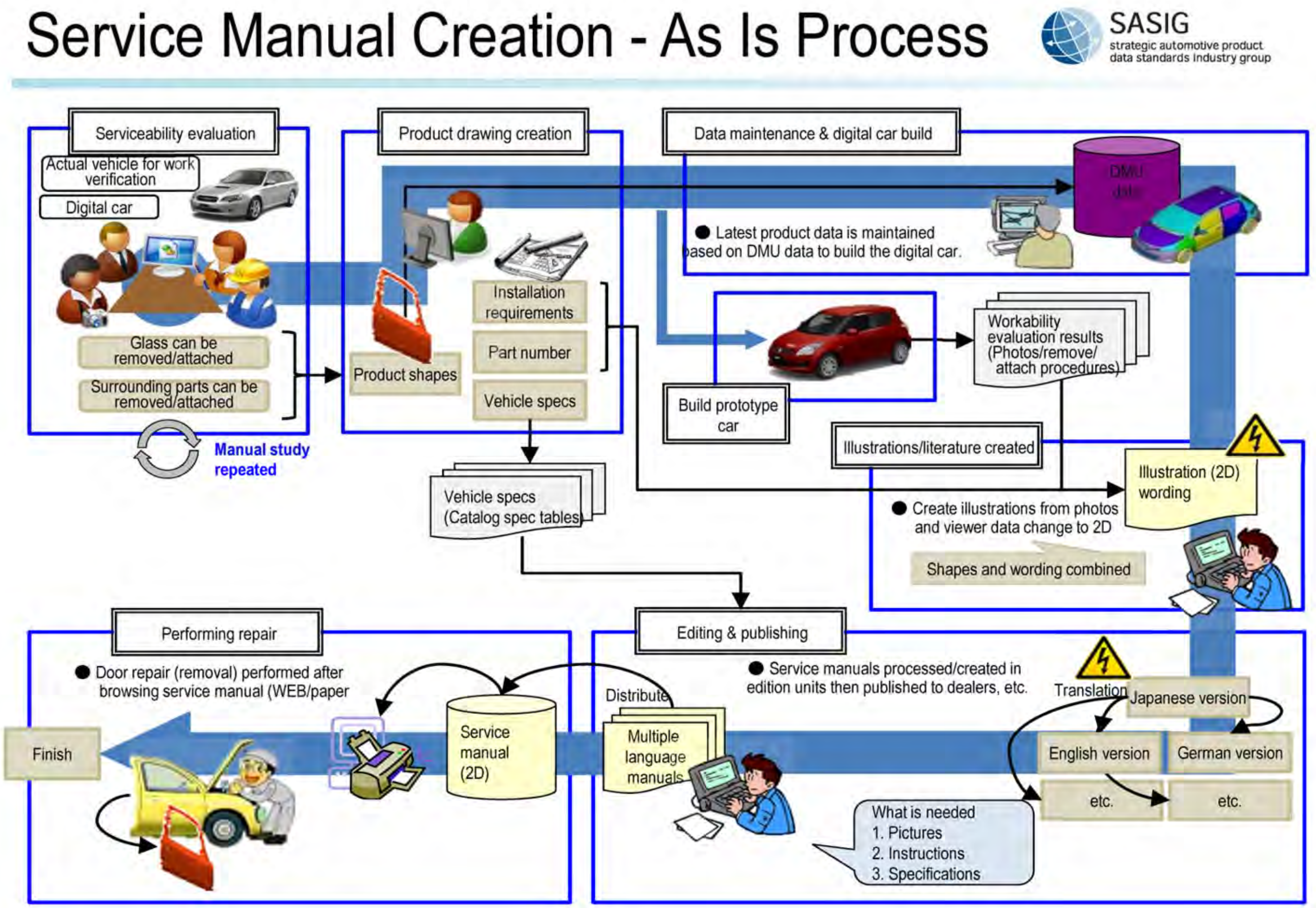
data standards industry

Process name	Overview	INPUT	OUTPUT
①Extraction of information on 3D-MBD model	Extract the information needed to check dimension surface accuracy and for dimension inspection from the 3D-MBD model information.	・３D-MBD Model Data	・Information on product models (example 3D shapes, tolerances, notes)
②Applying the information on standards	Apply informationof standards, etc. for the part based on the information about the parts on the drawings.	・３D-MBD Model Data (Referred standard number, item number, etc.)	・Know how and requirement items on applied standards, (e.g. general tolerances, measurement pitch)
③Comparison conditions, pass/fail judgment criteria creation	Convert the measurement values and thresholds list in order to compare information on the product drawing, requirement items on the standard, manufacturing information, individually determined infromation against the measured information.	・Information on the 3D-MBD product drawing (e.g. shapes, tolerances, notes.) ・Know how and requirement items on referenced standards (e.g. general tolerances, measurement pitch) ・Manufacturing information (examples weld jig datum surface, location hole coordinates, etc.) ・Individually determined information (If any)	・List of measurement points and thresholds
④Inspection (Dimension inspection, surface accuracy)	Compare the actual parts measured group of points data with the measurement points and threshold list to make data on any differences while making a pass/fail judgment at the same time.	・Measured information (group of points data) ・List of measurement points and thresholds	・OK/NG judgment ・Information on gaps/differences.

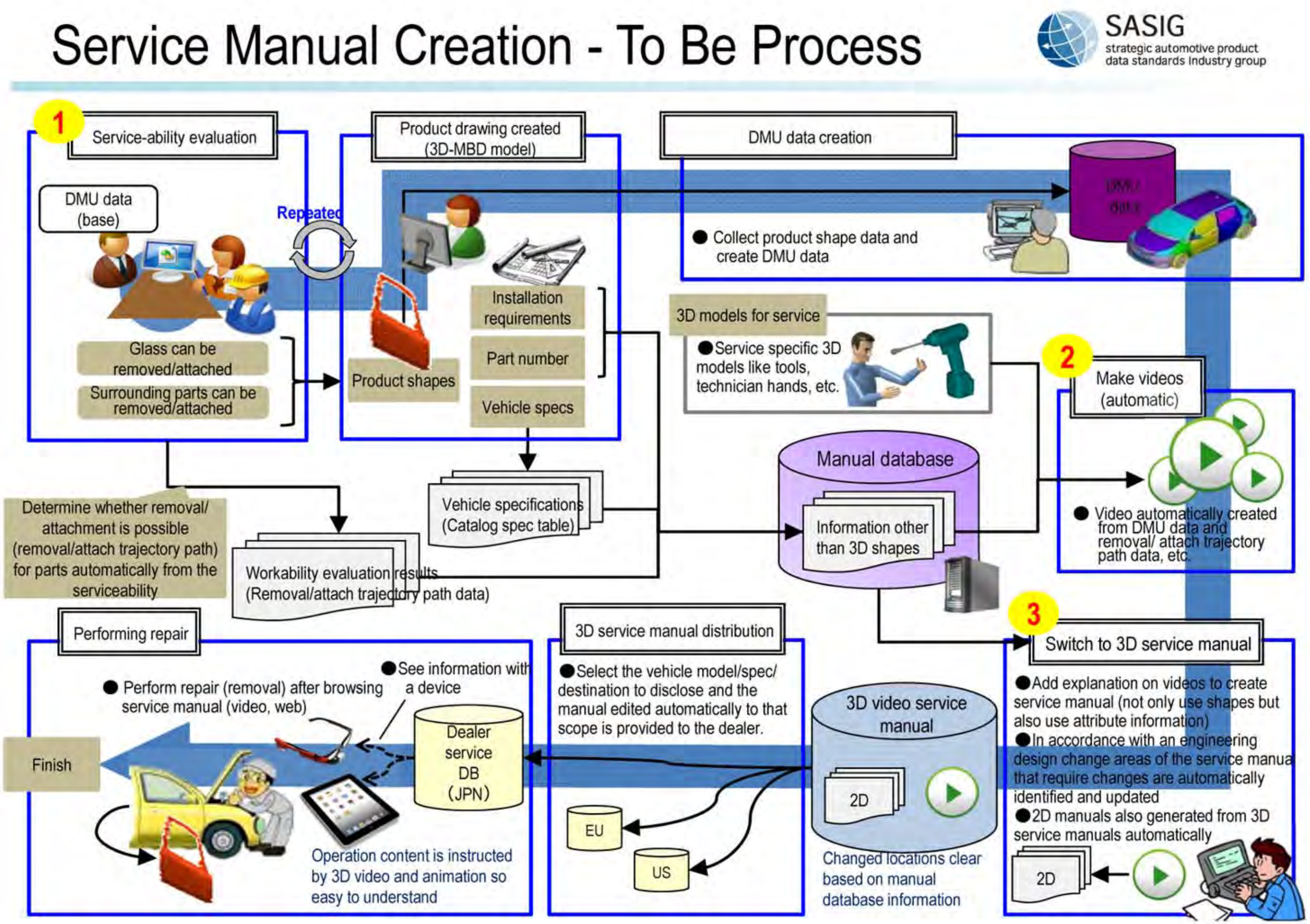
Inspection Quality Check - To Be Process Benefits



Service Manual Creation - As Is Process



Service Manual Creation - To Be Process



Detailed Processes for Service Manual Creation

Detailed Processes for Service Manual Creation

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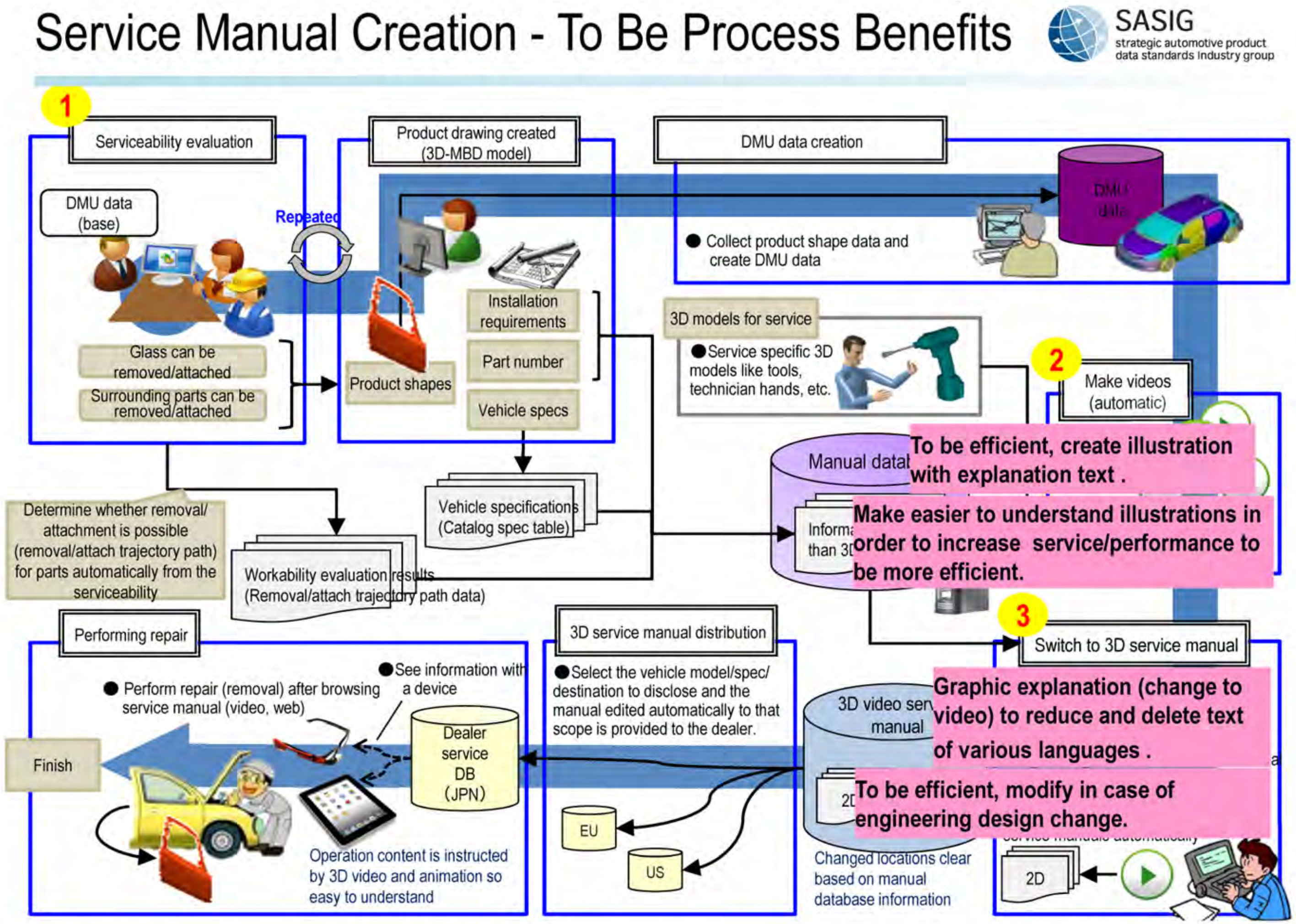
Process name	Overview	INPUT	OUTPUT
①Service-ability evaluation	・Evaluate service-ability of dismantling, repair, assembly, etc.	・DMU data (base) (Position and angle when installed on the vehicle, quantity, etc.) ・3D-MBD model data (shapes) ・Tool information	・Workability evaluation results (removal/attachment trajectory data, etc.)
②Making videos	・DMU data and workability evaluation results automatically create video from (removal/attachment trajectory path data, etc)	・ＤＭＵ data ・3D-MBD model data (shapes) ・3D models for service (tools/technician hands, etc.)	・3D video
③Switching to 3D service manuals	・Create service manuals by adding explanations to video ・Identify the parts of the service manual that require corrections in conjunction with an engineering design change and update ・Automatically generate 2D service manuals from the 3D service manual.	・３D video ・Explanation information ・Vehicle specifications (parts configuration, etc for every destination) ・Engineering design change information	・3D service manual ・2D service manual

Service Manual Creation - To Be Process Benefits



Appendix C. 3D-MBD Functional Requirements List

This appendix shows the 3D-MBD Functional Requirements list mentioned in Section 5.

How to read the Functional Requirements list

In the “Description Detail Information” in each use case, “X” is indicated in the column of applicable use case, and the number of the process in the use case is also described. Items that overlap are merged into one item. In the drawing elimination use case, if 2D printed documentation is required, all functional requirements should be supported to enable automatic creation of the documentation.

The information that each line contains is described below:

- Category：General category of the item
- Sub-category： Sub-category under the category
- Description Detail Information：Detailed explanation of the item
- Type of data：The type of data
- On 3D-MBD Model?： Is the information 3D-MBD-specific or not?
- Requirement for Data Creation：Requirements for when the data are created
- Requirement for Consumption：Requirements for when the data are consumed

Category	Sub-category	DescriptionDetail information	Type of data	On 3D-MBD Model?	Requirement for Data Creation	Requirement for Consumption	DRW Elimintion	SPOT	Die Engineering	Inspection	Service Manual
Information related to holes	Hole symbol	Hole application (fastening hole, clearance hole, locator hole)	Annotations (text, symbols, color...)	X	Should be able to input as a hole feature (Input of application, etc. should be drop down select, etc. done easily)	Should be able to recognize each type of information regarding the hole Moreover, should also be able to recognize shapes of original surface before making hole.	X				X-①
Information related to holes	Hole shape	Hole opening direction	Shapes/vectors	X	Should be able to enter as hole element component information	Should be able to recognize each type of information relevant to holes Moreover, should also be able to recognize shapes of original surface before making hole.	X		X-①/②B		
Information related to holes	Hole shape	Hole position	Shapes/ coordinates	X	・Should be able to input as a hole feature (Input of application, etc. should be drop down select, etc. done easily. For ServiceManual) ・Should be able to enter as hole element component information.(for DieEng)	・Should be able to recognize each type of information regarding the hole plus should be able to also recognize the shape information of the original surface (for ServiceManual) ・Should be able to recognize each type of information relevant to holes Moreover, should also be able to recognize shapes for the front face of the opened hole(for DieEng)	X		X-①/② B		X-①
Information related to holes	Hole shape	Hole diameter	Shapes/ numbers	X	Should be able to enter as hole element component information	Should be able to recognize each type of information relevant to holes Moreover, should also be able to recognize shapes of original surface before making hole.	X		X-①/②B		
Information related to holes	Sealer information	Number of holes		N/A	N/A	No need to retain this as an item but should be able to count the number of features recognized as holes	X			X-①/③	
Management information and notes on 2D	Management information, notes	Spec	Text	X	Should be able to input this as specs	Should be able to recognize this as specifications and should be able to get detailed specification contents.	X			X-②	
Management information and notes on 2D	Management information, notes	Referenced standards	Text	X	Should be able to input this as referenced standards	Should be able to recognize the referenced standard and should be able to get the standard number that should be checked.	X			X-②	
Management information and notes on 2D	Management information, notes	Materials	Text	X	Should be able to input this as material and should be able to link this to the applicable shape	Should be able to recognize this as materials and a standard may be applied as the need arises. Should be able to extract material symbols/material grade as numbers.(for DieEng)	X		X-④	X-②	X-①
Management information and notes on 2D	Management information, notes	Number of referenced drawings	Text	X	Should be able to input this as numbers for reference drawings and should be able to specify the items that should be referred to	Should be able to recognize this as numbers for reference drawings and should be able to get the items that should be referred to	X			X-②	
Management information and notes on 2D	Management information, notes	Cross check numbers & representative item numbers	Text	X	Should be able to input this as cross check numbers or representative item numbers	Should be able to recognize this as cross check numbers or representative item numbers	X			X-②	
Management information and notes on 2D	Management information, notes	Specifications tables	Text	X	Should be able to input this as a specifications table	Should be able to recognize this as a specifications table and should be able to get each item and value on the table.	X			X-②	
Management information and notes on 2D	Management information, notes	Standard number of standard parts	Text	X	Should be able to input this as standard numbers of standard parts	Should be able to recognize this as standard numbers of standard parts and should be able to get the standard number in a way that is linked to the applicable parts.	X			X-②	
Management information and notes on 2D	Management information, notes	Information to identify if there details are on another model/drawing	Text	X	Should be able to specify that details are on another model/drawing	Should be able to specify that details are on another model/drawing and should be able to identify the other drawing/model	X			X-②	
Management information and notes on 2D	Title	Modification date & calender revision date	Text	X	Should be able to input as attributes	Should be able to recognize modification date	X				X-③
Management information and notes on 2D	Title	Location of design change (design change address, back circle)	Text	X	Should be able to input as attributes	Should be able to recognize engineering design change locations	X				X-③

Category	Sub-category	DescriptionDetail information	Type of data	On 3D-MBD Model?	Requirement for Data Creation	Requirement for Consumption	DRW Elimintion	SPOT	Die Engineering	Inspection	Service Manual
Management information and notes on 2D	Title block information, management information	Assembly parts structures	Text	X	Should be able to specify assembly parts structures with links to the assembly shapes	Should be able to recognize assembly structures	X			X-①/③	
Management information and notes on 2D	Title block information, management information	Same drawing item numbers	Text	X	Should be able to input this as the same drawing item number and should be able to link with the applicable shapes	Should be able to recognize this as the same drawing item number and should be able to link with the applicable shapes	X			X-①/③	
Management information and notes on 2D	Title block information, management information	Item numbers or part numbers	Text	X	Should be able to input this as an item number or part number	Should be able to recognize this as an item number or part number	X			X-①/③	X-①
Management information and notes on 2D	Title block information, management information	Item names or part names	Text	X	Should be able to input this as item names or part name	Should be able to recognize this as item names or part name	X			X-①/③	X-①
Information related to dimensions and torrerances	Datums, dimensions and tolerances	Dimensions	Coordinate values, numbers	X	Should be able to input dimensions easily as well as should be able to retain the applicable shape information and datum points/lines/surfaces	Should be able to recognize dimensions as well as be able to recognize the countermeasure shape information and datum points/lines/surfaces	X		X-②a	X-①/③	
Information related to dimensions and torrerances	Datums, dimensions and tolerances	Dimensional tolerances	Text	X	Should be able to input tolerance easily as well as should be able to retain the applicable dimensions information	Should be able to recognize tolerance as well as be able to recognize the countermeasure dimensions information	X		X-②a	X-①/③	
Information related to dimensions and torrerances	Datums, dimensions and tolerances	Geometrical tolerances	Text	X	Should be able to input type of tolerance/tolerance zone/tolerance value easily as well as should be able to retain the applicable shape/datum information	Should be able to recognize type of tolerance/tolerance zone/tolerance value as well as be able to recognize the countermeasure shape/datum information	X			X-①/③	
Information related to dimensions and torrerances	Datums, dimensions and tolerances	Datum targets	Annotations (numbers/ symbols/ text,)	X	Should be able to input points/lines/surfaces for datum easily as well as should be able to retain the applicable shape/datum information	Should be able to recognize points/lines/surfaces for datum -as well as be able to recognize the countermeasure shap/datum e information	X			X-①/③	
Information related to dimensions and torrerances	Datums	Machining/assembly datums	Coordinates, lines, surfaces	X	Should be able to specify this as machining datums and assembly datums on the 3D model	Should be able to recognize this as machining datums and assembly datums on the 3D model	X			X-①/③	
Information related to spot welding	Spot weld symbol	Thickness	Numbers	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Spot weld symbol	Material/material grade	Text	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Spot weld symbol	Left-right information	Symbol (flag)	X	Should be able to retain multiple pieces of related information by creating one weld symbol	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Spot weld symbol	Spot weld position	Coordinates	X	Should be able to retain multiple pieces of related information by creating one weld symbol	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Spot weld symbol	Spot weld number	Numbers/text	Automatically created when extracting spot weld	Should be set as a unique number when data is output	Once the number has been determined, it is used without being changed.	X	X-①			
Information related to spot welding	Spot weld symbol	Spot weld direction	Vectors	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			

Category	Sub-category	DescriptionDetail information	Type of data	On 3D-MBD Model?	Requirement for Data Creation	Requirement for Consumption	DRW Elimintion	SPOT	Die Engineering	Inspection	Service Manual
Information related to spot welding	Spot weld symbol	Indicating spot welds requiring special care	Symbol (flag)	X	Should be able to retain multiple pieces of related information by creating one weld symbol	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Spot weld symbol	Weld applicable item numbers	Text	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Spot weld symbol	Weld applicable item numbers	Text	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Spot weld symbol	Specificaitons of weld (type)	Symbol	X	Should be able to retain multiple pieces of related information by creating one weld symbol	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Spot weld symbol	Specifications of weld (temporary set assembly)	Numbers	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-①			
Information related to spot welding	Weld information	Weld nut positions	Shapes/ coordinate values	X	Should be able to create this as a weld nut and should be able to specify positions and screw diameters	Should be able to recognize this as a weld nut and should be able to get the position and screw diameter	X			X-①/③	
Information related to spot welding	Weld information	Weld bolt positions	Shapes/ coordinate values	X	Should be able to create this as a weld nut and should be able to specify positions, screw diameters and lengths	Should be able to recognize this as a weld bolt and should be able to get the position, screw diameter and length	X			X-①/③	
Information related to spot welding	Weld information	Spot weld positions	Shapes/ coordinate values	X	Should be able to create this as a spot weld point and should be able to specify positions	Should be able to recognize this as a spot weld and should be able to get the position	X			X-①/③	
Information related to spot welding	Weld information	Other weld positions	Shapes/ coordinate values	X	Should be able create this as weld information and should be able to specify characteristics, shapes, positions and lengths	Should be able to recognize this as weld information and should be able to get the characteristics, shapes, positions, lengths, etc.	X			X-①/③	
Information related to spot welding	Weld information	Cautionary spot weld instructions	Symbols (flags)	X	Should be able to specify this with a link to a specific spot weld as a cautionary spot weld.	Should be able to recognize this as cautionary spot welds	X			X-①/③	
Information related to spot welding	Weld information	Item numbers applicable to welding	Text	X	Should be able to specify this with a link to spot weld positions or other weld positions	Should be able to recognize this with a link to spot weld positions or other weld positions and should be able to get item numbers of applicable parts	X			X-①/③	
Information related to spot welding	Weld information	Item names applicable to welding	Text	N/A	Should be able to specify this with a link to spot weld positions or other weld positions	Should be able to recognize this with a link to spot weld positions or other weld positions and should be able to get item names of applicable parts	X			X-①/③	
Information related to spot welding	Weld information	Specifications of welds (stack ups)	Numbers	X	Should be able to specify this with a link to spot weld positions or other weld positions	Should be able to recognize this with a link to spot weld positions or other weld positions and should be able to get stack up information	X			X-①/③	
Information related to spot welding	Spot weld information + weld conditions	Thickness	Numbers	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			
Information related to spot welding	Spot weld information + weld conditions	Left-right information	Symbol (flag)	X	Should be able to retain multiple pieces of related information by creating one weld symbol	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			

Category	Sub-category	DescriptionDetail information	Type of data	On 3D-MBD Model?	Requirement for Data Creation	Requirement for Consumption	DRW Elimintion	SPOT	Die Engineering	Inspection	Service Manual
Information related to spot welding	Spot weld information + weld conditions	Spot weld position	Coordinates	X (Obtain from section ②)	Should be able to retain multiple pieces of related information by creating one weld symbol	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-③			
Information related to spot welding	Spot weld information + weld conditions	Spot weld position	Coordinates	X	Should be able to retain multiple pieces of related information by creating one weld symbol	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			
Information related to spot welding	Spot weld information + weld conditions	Spot weld number	Numbers/text	Automatically created when extracting spot weld	Should be set as a unique number when data is output	Once the number has been determined, it is used without being changed.	X	X-④			
Information related to spot welding	Spot weld information + weld conditions	Spot weld direction	Vectors	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			
Information related to spot welding	Spot weld information + weld conditions	Indicating spot welds requiring special care	Symbol (flag)	X	Should be able to retain multiple pieces of related information by creating one weld symbol	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			
Information related to spot welding	Spot weld information + weld conditions	Diameter of nugget	Numbers	N/A	Automatically selected based on material, stack-up, shapes, etc.	Automatically selected based on material, stack-up, shapes, etc.	X	X-③			
Information related to spot welding	Spot weld information + weld conditions	Weld applicable item numbers	Text	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			
Information related to spot welding	Spot weld information + weld conditions	Weld applicable item numbers	Text	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			
Information related to spot welding	Spot weld information + weld conditions	Thickness direction	Vectors	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			
Information related to spot welding	Spot weld information + weld conditions	Specifications of weld (temporary set assembly)	Numbers	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-④			
Information related to spot welding	Spot weld information	Thickness	Numbers	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-②			
Information related to spot welding	Spot weld information	Material/material grade	Text	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-②			
Information related to spot welding	Spot weld information	Specifications of weld (temporary set assembly)	Numbers	Obtain from shape	Should be able to retain multiple pieces of related information by creating one weld symbol Additionally, modifications/editing of shapes should be traced and updated accordingly.	Should be able to extract various types of information related to spot welds from symbols as well as be able to recognize the shape information of the original face	X	X-②			

Category	Sub-category	DescriptionDetail information	Type of data	On 3D-MBD Model?	Requirement for Data Creation	Requirement for Consumption	DRW Elimintion	SPOT	Die Engineering	Inspection	Service Manual
3D shapes	3D shapes of the product	Thickness	Numbers	X	・Should be able to create & retain as attribute information (there are cases where 2 types exist. For ServiceManual) ・Should include thickness of surfaces and thickness direction information in faces.(for DieEng)	・Should be able to make removal/attaching trajectory path using thickness information.(for ServiceManual) ・Should be able to extract information on thickness as numbers.(for DieEng)	X	X-①	-①/②A/②B/(	X-①/③	X-①
3D shapes	3D shapes of the product	Thickness direction	Vectors	X	・Should be able to create & retain as attribute information.(for DieEng) ・Should include thickness of surfaces and thickness direction, material information in faces.(for DieEng / Spot)	・Should be able to make removal/attaching trajectory path using thickness information.(for ServiceManual) ・Should be able to recognize the direction of thicknesses relative to the product surface data, and extract thickness direction information as numbers. (for DieEng)	X	X-①	X-①/②A/②B	X-①/③	X-①
3D shapes	3D shapes of the product	3D shape of the product itself	Surfaces/(solid)	X	・Should be able to faithfully create shapes. ・Should include thickness of surfaces and thickness direction, material information in faces.(for DieEng / Spot)	・Should be able to faithfully reproduce shapes. (Even on viewers, etc.) ・Should be able to align shapes ・Should be able to take out edge lines by turning off fillets(for DieEng①/⑦b/⑦c) ・Trim lines should remain after turning off trims. Surfaces should remain in areas where they are needed. (for DieEng①/⑦b/⑦c) ・Should be able to extract Material & material grade information linked to the applicable shapes(for DieEng④) ・Should be able to express faces as elements that possess thickness.	X	X-①/③/④	-①/④/⑦B/⑦	X-①/③	X-①/②
3D shapes	3D shapes of the product (Wire frame)	Thickness difference position, tailored blank parting line	Shapes/text	X	Should be able to input as a thickness parting line feature Should be able to maintain a relationship to the thickness described above	Should be able to recognize as a thickness parting line plus should be able to recognize thicknesses for both parts	X			X-①/③	X-①
3D shapes	3D shapes of the product	Material/material grade	Text	X	Should be able to create and express faces as elements that possess thickness, thickness direction and materials	Should be able to extract material information from shape elements	X	X-①			
Other information	Die 3D shapes	Outline face data of die	Faces/solids	N/A (Made in DieEng section ①)	Should include face thickness and thickness direction information in faces	Should be able to modify shapes to those with added spring back based on thickness, thickness direction and material	X		X-②A/⑦B		

Category	Sub-category	DescriptionDetail information	Type of data	On 3D-MBD Model?	Requirement for Data Creation	Requirement for Consumption	DRW Elimintion	SPOT	Die Engineering	Inspection	Service Manual
Other information	Die 3D shapes	Die face datum data	Faces/solids	N/A (Made in DieEng section ②A)	Should include face thickness and thickness direction information in faces	Should be able to add excess material shapes Should be able to offset the amount for thickness	X		X-②B/⑦A		
Other information	Die 3D shapes	Die face data	Surfaces/ (solid)	N/A (Made in DieEng section ②B)	Should be able to add excess material shapes relative to the Die face datum data Should be able to offset the amount for thickness Should be able to correct based on the analysis results automatically	Should be able to translate to mesh data automatically	X		X-③/⑦A		
Other information	Die 3D shapes	Mesh data	Coordinates	N/A (Made in DieEng section ③)	N/A	N/A	X		X-⑤/⑥/⑦A		
Other information	Analysis results	Mesh data of analysis results	Coordinates	N/A (Result of DieEng section ④)	N/A	Should be able to caliculate the correction amount from the analysis results	X		X-⑥/⑦A/⑦B/⑦C		
Other information	Analysis results	Report on analysis results	Documents	N/A (Result of DieEng section ④)	N/A	N/A	X		X-⑦B/⑦C		
Other information	Equipment data	Specifications for robot and jig shapes	3D shapes, documents	N/A	N/A	N/A	X	X-④			
Other information	Service specific information	Workability evaluation results (Instructions, caution items, torque values and gap upper/lower limit, etc.)	Numbers/text	N/A	Should be able to efficiently obtain from information inside the manual database	Should also be able output 2D format as needed	X				X-③
Other information	Service specific information	Vehicle specifications	Text	N/A	Should be able to efficiently obtain from information inside the manual database	Should also be able output 2D format as needed	X				X-③
Other information	Service specific information	3D models for service	Surfaces/ (solid)	N/A	Should be able pair to 3D model for service from information in manual database	Should be able to faithfully reproduce shapes Should be able to align shapes	X				X-②
Other information	Service specific information	Workability evaluation results (removal/attachment trajectory path)	Text	N/A	Should be able to create automatically from DMU data	Should be able to make video linking the product 3D shapes and removal/attach trajectory path.	X				X-①/②
Other information	Sealer information	Sealer area	Surfaces	X	Should be able to input this as sealer information and should be able to specify the area	Should be able to recognize this as sealer information and should be able to get the area specified	X			X-①/③	
Other information	Sealer information	Sealer positions	Shapes/ coordinate values	X	Should be able to create this as sealer information and should be able to specify the characteristics and shapes	Should be able to recognize this as sealer information and should be able to get characteristics and shapes	X			X-①/③	
Other information	Measured information	Datum points of groups of points	Coordinates	N/A	(No requirements for creation)	The datum points on the 3D data and the datums should be made to match	X			X-④	
Other information	List of measurement points and thresholds	Datum points on 3D data	Coordinates	N/A	Should be able to create this by converting information on product drawings, information on standards, manufacturing information and/or information determined individually.	The measured groups of points and the datums should be made to match	X			X-④	
Other information	List of measurement points and thresholds	Groups of points to be measured on 3D data	Coordinates	N/A	Should be able to create this by converting information on product drawings, information on standards, manufacturing information and/or information determined individually.	Should be able to compare the measured groups of points and Should be able to output the results digitally	X			X-④	
Other information	List of measurement points and thresholds	Thresholds	Numbers	N/A	Should be able to create this by converting information on product drawings, information on standards, manufacturing information and/or information determined individually.	Should be able to compare the measured groups of points and Should be able to output the results digitally	X			X-④	
Other information	Hem flange information	Hem flange datum line	Shapes/ coordinate values	X	Should be able to create this as hem shapes.	Should be able to get the hem line and the line after the hem is developed as shapes	X			X-①/③	
Other information	Hem flange information	Hem flange area	Surfaces	X	Should be able to create this as hem shapes.	Should be able to get the hem line and the line after the hem is developed as shapes	X			X-①/③	

Category	Sub-category	DescriptionDetail information	Type of data	On 3D-MBD Model?	Requirement for Data Creation	Requirement for Consumption	DRW Elimintion	SPOT	Die Engineering	Inspection	Service Manual
Other information	Hem flange information	Hem shape fold back width	Shapes/text	X	Should be able to create this as hem shapes.	Should be able to get the hem line and the line after the hem is developed as shapes	X		X-①/②B	X-①/③	
Other information	Know-how and requirement items on referenced standards	General tolerances	Numbers/text	N/A	Should be able to specify the conditions of parts to apply tolerance values and tolerances to, the machining methods, location, area ,etc.	Should be able to get the tolerance values for applicable parts and positions	X			X-③	
Other information	Know-how and requirement items on referenced standards	Surface skin information/appearance finish datums	Numbers/text	X	Should be able to specify the parts to apply surface skin information/ appearance finish datum values and the conditions for parts to apply, location, area ,etc.	Should be able to get the appearance finish datum values/skin information for the surface regarding applicable parts, locations and area.	X			X-③	
Other information	Positions that jigs/fixtures should hold	Positions that jig/fixtures should hold	Surfaces/text	X	Should be able to specify this as the position that jig/fixtures should hold	Should be able to recognize this a positions that jig holds in place and be able to take out the area.	X		X-①	X-①/③	
Other information	Manufacturing information	Datum points of welding jigs	Shapes/ text/ numbers	N/A	Should be able to create this as the datum point of the weld jig/fixture	Should be able to recognize this as the datum points of the weld jigs/fixtures	X			X-③	
Other information	Manufacturing information	Datum surfaces of welding jigs/fixtures	Shapes/ text/ numbers	N/A	Should be able to create this as the datum surface of the weld jig/fixture	Should be able to recognize this as the datum surface of the weld jig/fixture	X			X-③	
Other information	Notes	R value (constant/changing)	Annotations（Numbers/ symbols/ text)	X	Should be able to retain the fillet creation area range and R value entry	Should be able to create and add required fillet shapes	X		X-①/②A		