Nathan W. Hartman, Jesse Zahner, Tom Hedberg, Allison Feeney

Extending and Evaluating the Model-based Product Definition

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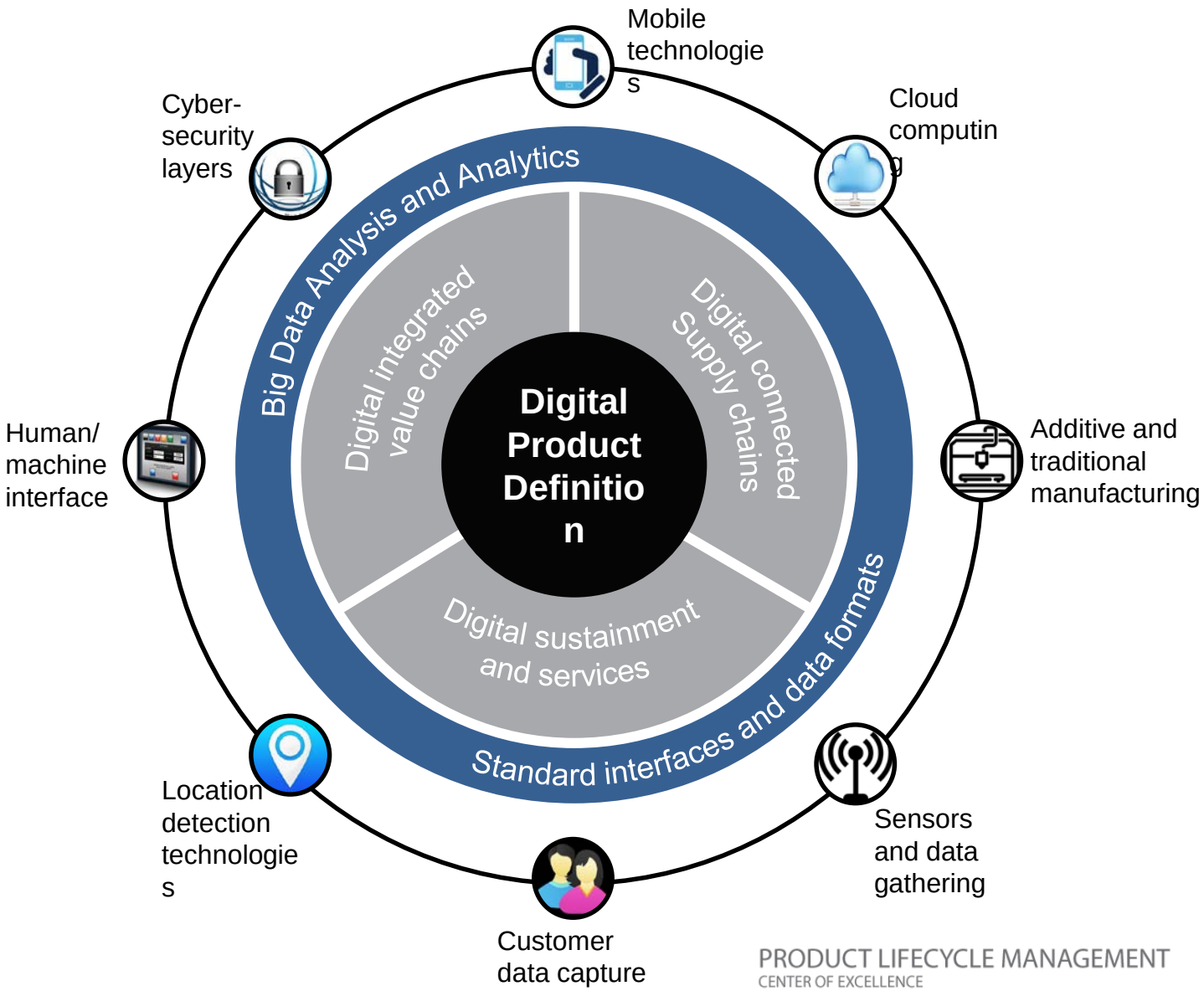
Introduction

- This research focused on information elements required in different workflows within an organization.
- The information elements that we sought to capture were called the minimum information elements.
- Industry has begun to adopt Model-based definition, but the creation and dissemination processes vary widely.
- A better understanding of model-based definition requirements is needed for robust MBD adoption and dissemination.

What is a digital enterprise?

- A digital enterprise changes the way people work and how they use information



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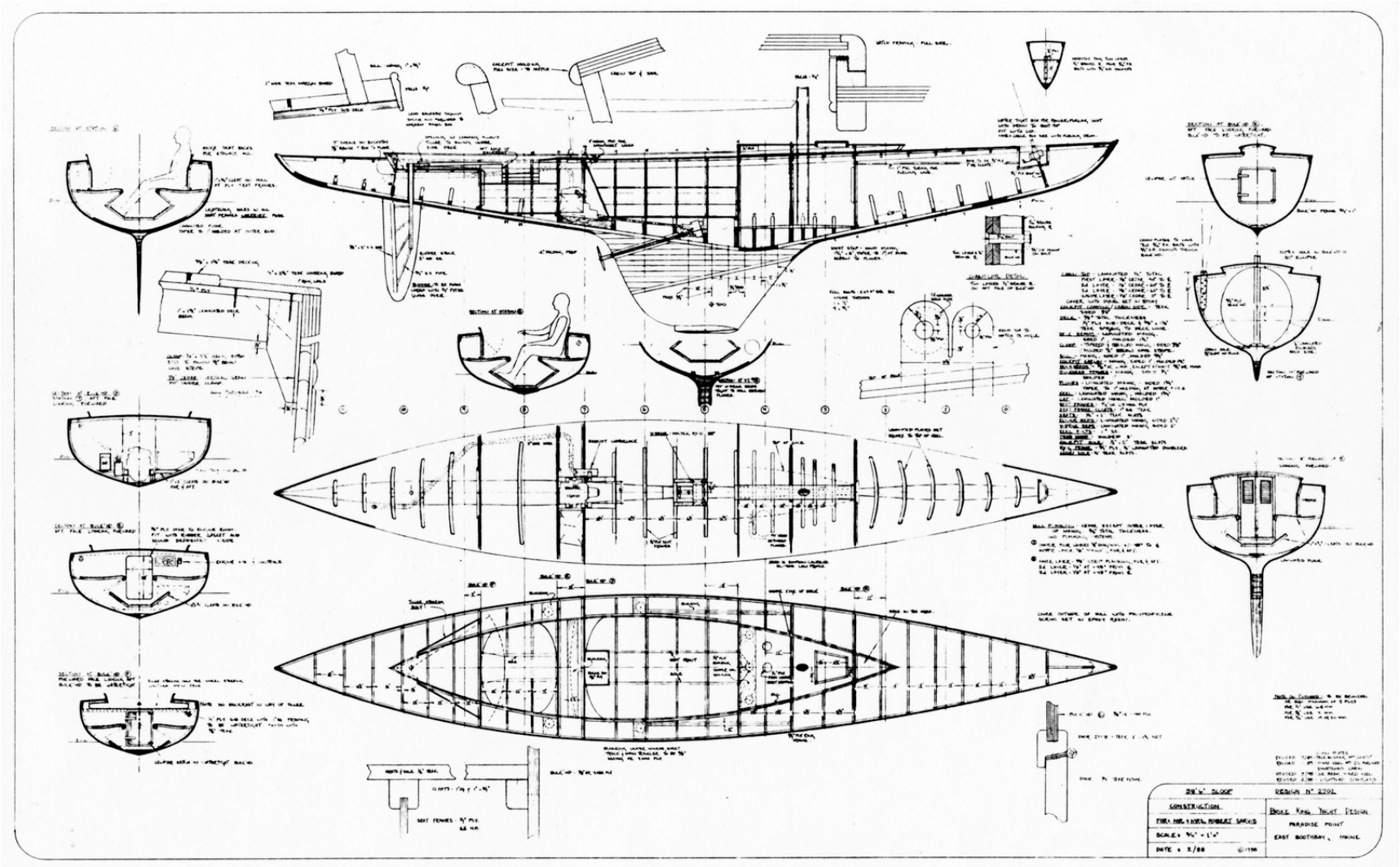
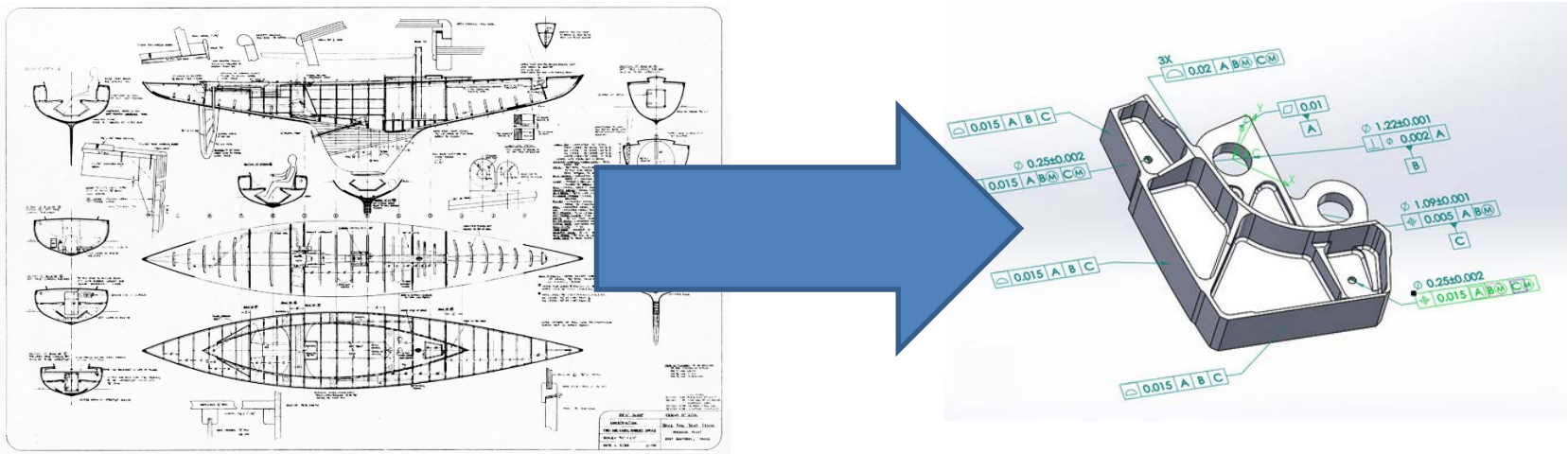
The old communications medium

- The paper thread – much of the information is implicit and based on context



What should go into a model-based definition?

- Implicit and explicit information must be included



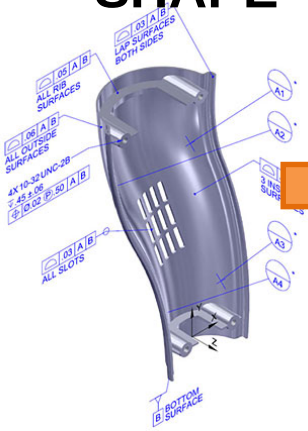
Historically, drawings contained both implicit and explicit information. Context was important for understanding.

However, CAD tools require explicit definition of information.

The communications spectrum…

- A complete MBD supports lifecycle communication for both **authors** and **consumers**.

SHAPE

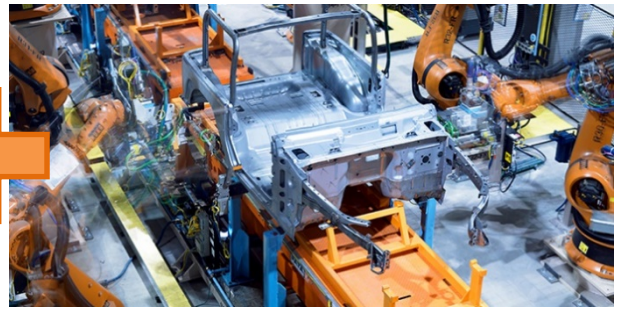


BEHAVIOR

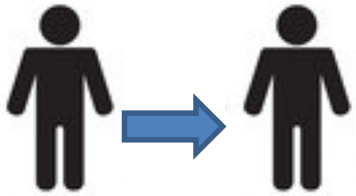
3.

Property	Test Standard DIN/ON EN ISO	corr.to ASTM	Unit	Value				Testing Frequency
Nominal Thickness			mil	78	100	98	196	
			mm	2.0	2.5	3.0	5.0	
	DIN EN ISO 14632	D 5994	%	+10/-5	+10/-5	+10/-5	+10/-5	every hour
Density (Black)	ISO 1183	D792	g/cm3	≥ 0.94				per production run 1)
Density (base/coloured)			g/cm3	≥ 0.931/935				
Melt Flow Rate (190°/5kg)	ISO 1183 Cond T	D 1238 Cond P	g/10	≤ 3	≤ 3	≤ 3	≤ 3	per production run 1)
(190/2 ,16kg)		D 1238 Cond E	min	≤ 1	≤ 1	≤ 1	≤ 1	
Heat Reversion (110°C/1, 5h)	DIN EN ISO 14632	D 1204 modified	%	≤ 3	≤ 3	≤ 3	≤ 2	per productio
Tensile Stress at Yield	DIN EN ISO 527	D 6693	MPa (PSI)	≥ 15 2,200	≥ 15 2,200	≥ 15 2,200	≥ 15 2,200	per production run 1)
Elongated at Yield	DIN EN ISO 527	D 6693	%	≥ 9	≥ 9	≥ 9	≥ 9	per production run 1)
Elongated at Break	DIN EN ISO 527	D 6693	%	≥ 300	≥ 300	≥ 300	≥ 300	per production run 1)
Instrumented Puncture Test (Penetration Test)	ON EN ISO 6603-2	D 4833	N N (lbs)	≥ 1500 ≥ 337	≥ 1800 ≥ 625	≥ 2000 ≥ 750	≥ 2500 ≥ 1250	Approval Testing

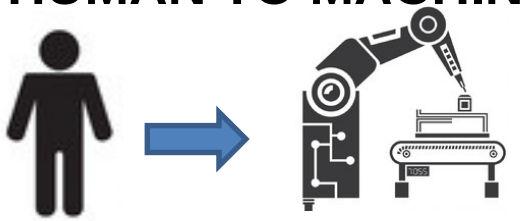
CONTEXT



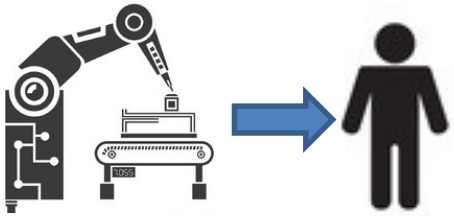
HUMAN TO HUMAN



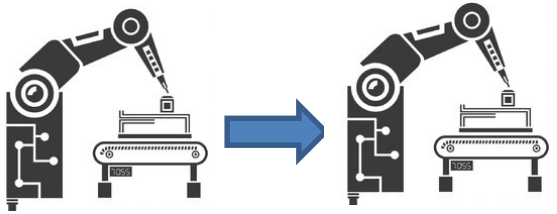
HUMAN TO MACHINE



MACHINE TO HUMAN



MACHINE TO MACHINE



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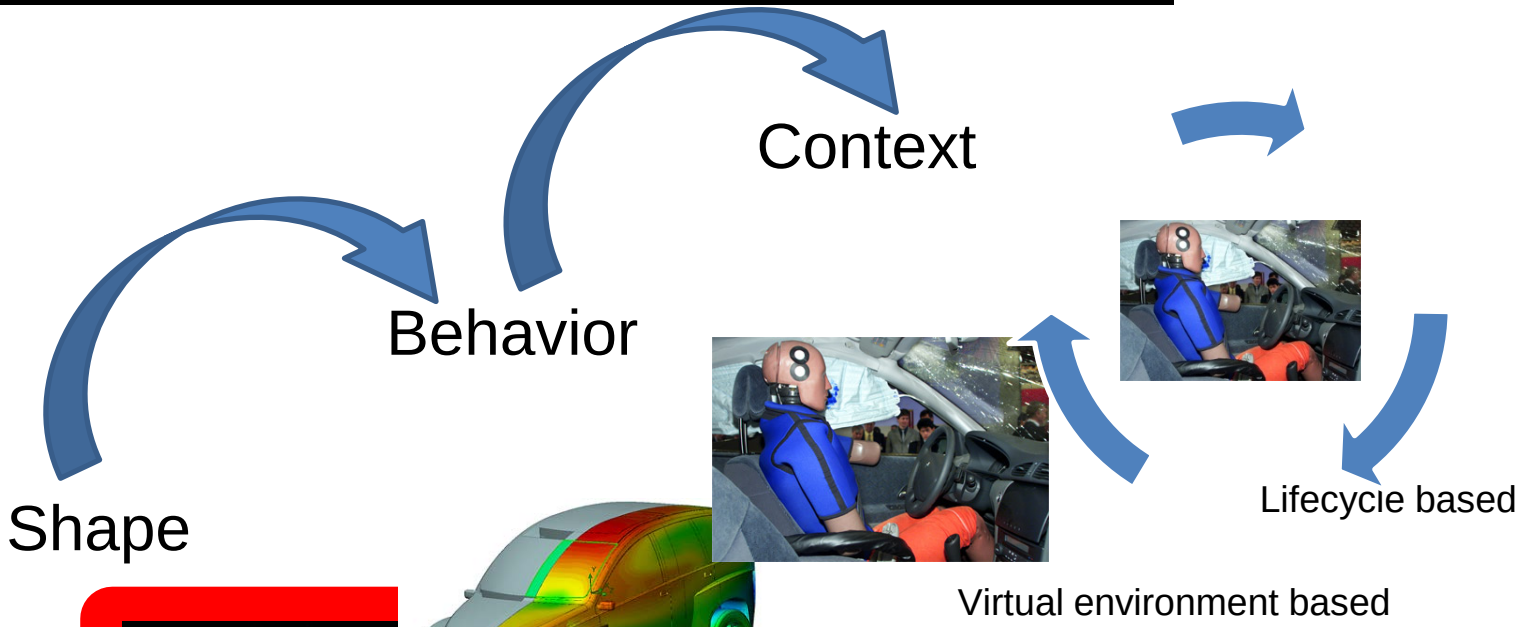
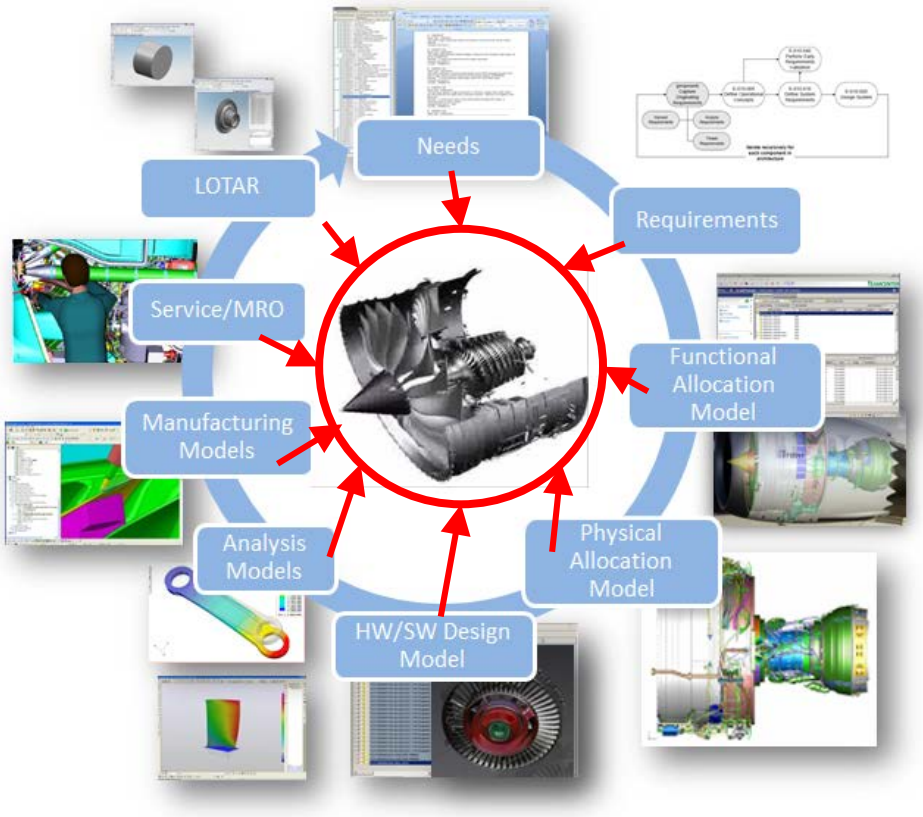
Evolution of Product Definition



Increased sophistication in the digital product and process representations and their fidelity to the physical world.

Model-Based Definition

- is a digital artifact (representation) of an object or system. It is representative of the physical object or system and all of its attributes, and is used to communicate information within various MBx activities in a model-based enterprise
- Workflows use resulting models to carry information.
- Models are both used for workflow specific tasks and transfer of information.

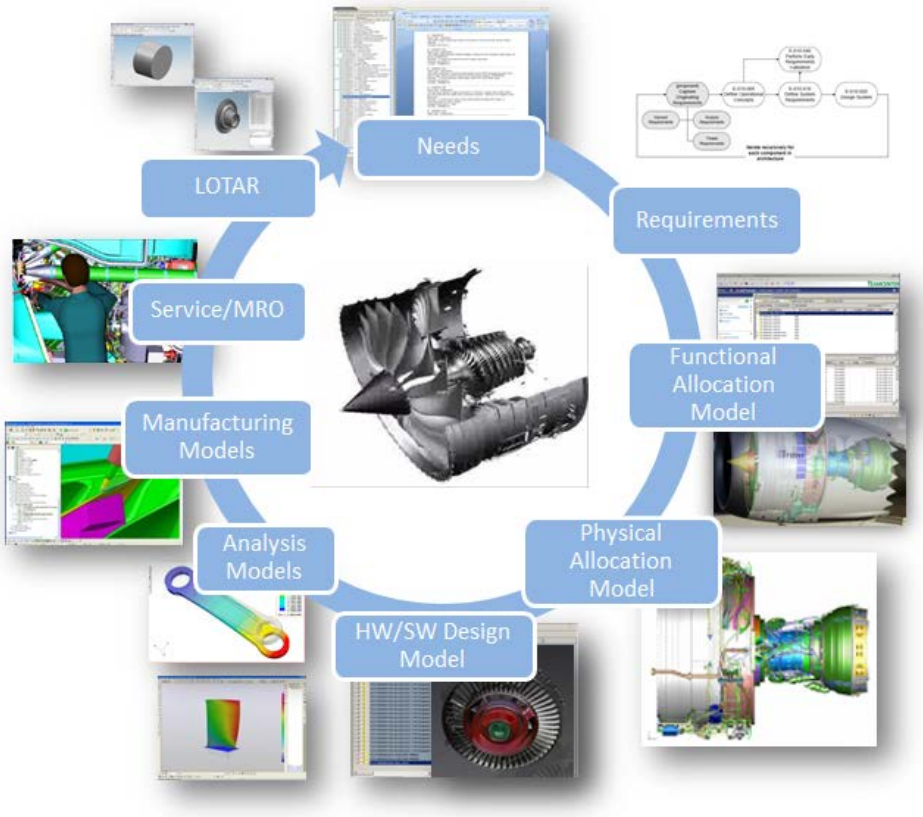


Model-Based Activity

- Model-based engineering, model-based manufacturing (MBm), model-based sustainment (MBs), and any other model-based [activity] (MBx) are categories of activities within the model-based enterprise.

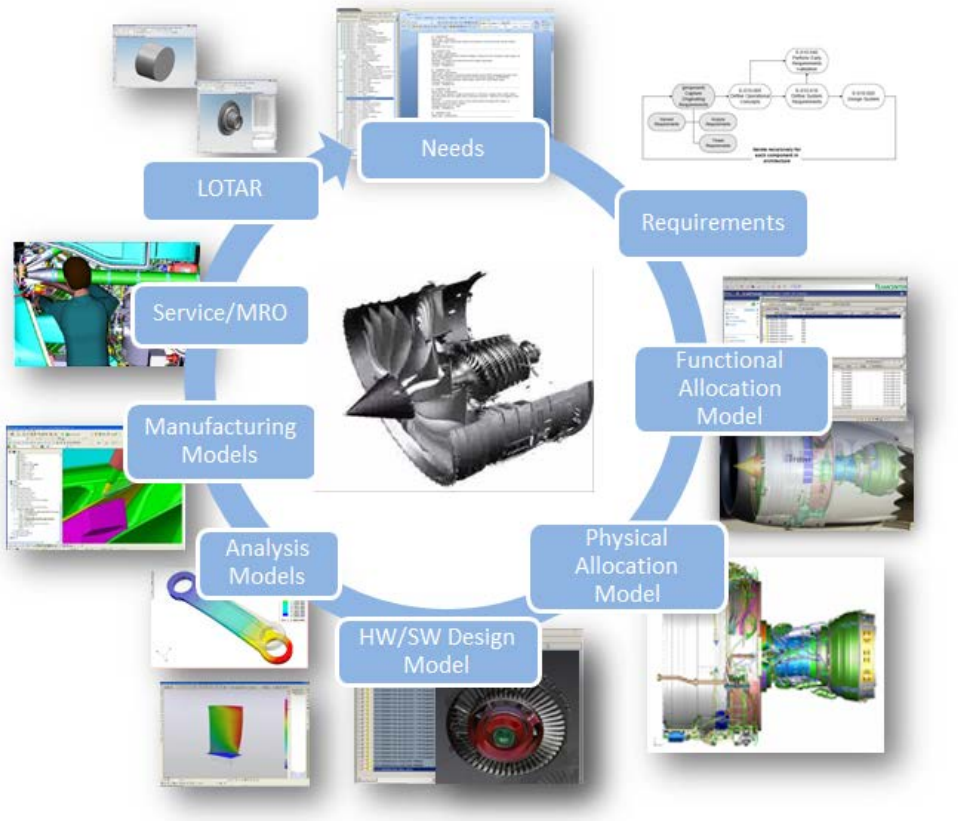
- use digital product data to represent shape, behavioral, and contextual information carried by the model-based definition to execute their functional role.

- rely on the predictive and archival capabilities of the model, by replying on its high levels of fidelity to physical object or system.



Model-Based Enterprise

- An environment which leverages digital model based representations.
- This environment is always changing and adapting.
- Ability to meet the requirements of the environment is a challenge.



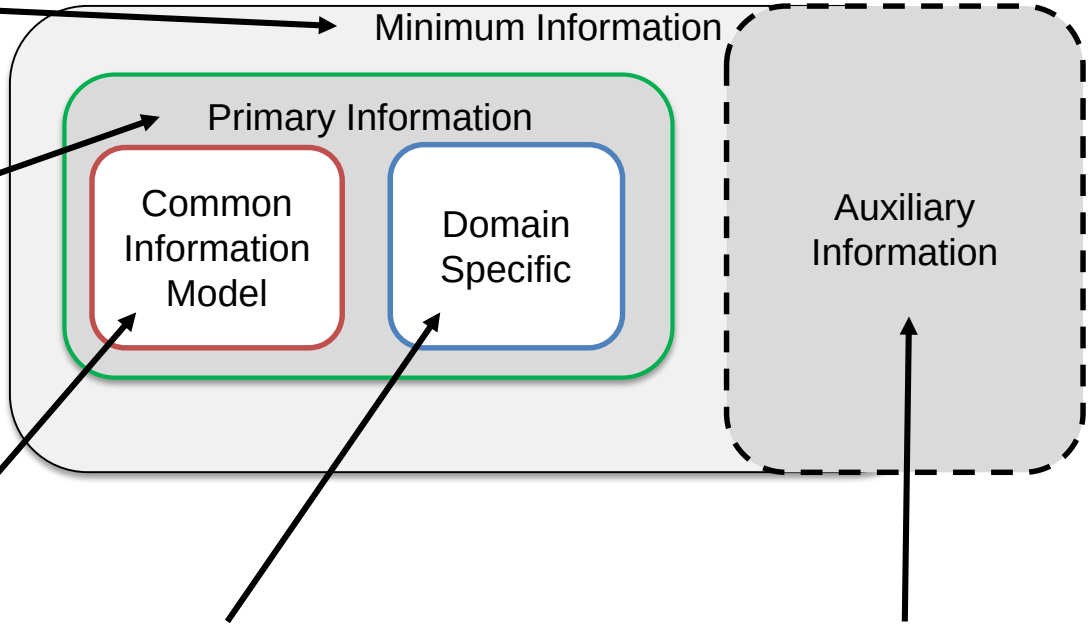
Minimum Information Model

Set of information which is required for a workflow to complete their work.

Primary information which is used in all iterations of the workflow.

Common Information is used across the entire organization, these are present in all MIM.

Generic workflow information model



Information which is only consumed within the specific workflow or domain.

Auxiliary information is in a state of flux. The elements of this information set come and go as needed.

Methodology

Survey Mechanism

- Study targeting industry professionals
  - Various sectors: aerospace, automotive, medical, consumer goods, etc.
  - Various positions: engineer, management, sales, etc.
  - Various locations around the world

- Goal to identify items and elements in various workflows to help establish the Minimum Information Model
  - Concept to prototype workflow
  - Prototype to detailed product definition workflow
  - Detailed product definition to manufacturing workflow
  - Manufacturing to inspection workflow

- The research methodology employed a survey, a Delphi technique, and interviews of industry participants.

Research Study Stages

Survey Mechanism

- **Stage 1:** Initial survey to gather demographics information and identify key factors in the information transition and the accompanying workflows
- **Stage 2:** A three-round Delphi study to validate the information elements in the drawing-to-model transition and their role in the identified workflows
- **Stage 3:** Creation of IDEF0 diagrams to illustrate the differences between textbook definitions of the workflows and the actual information flow characteristics derived from the surveys and Delphi interviews.

Workflows Targeted

Survey Mechanism

- Concept to prototype workflow
- Prototype to detailed product definition workflow
- Detailed product definition to manufacturing workflow
- Manufacturing to inspection workflow

Information Focus

Minimum Information Model

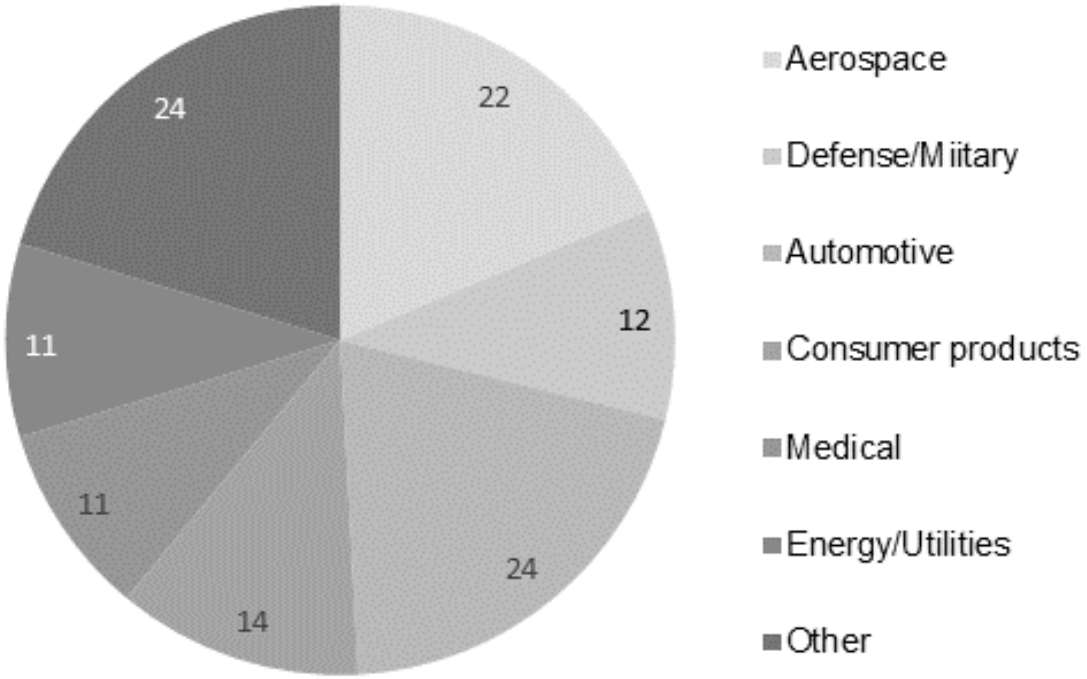
These items are common across the phases of the lifecycles

These items are specific to a given workflow and its actors

The resulting model is what is necessary to replace a drawing in a given workflow

Stage 1 Results

Conclusion and Discussion (Continued)

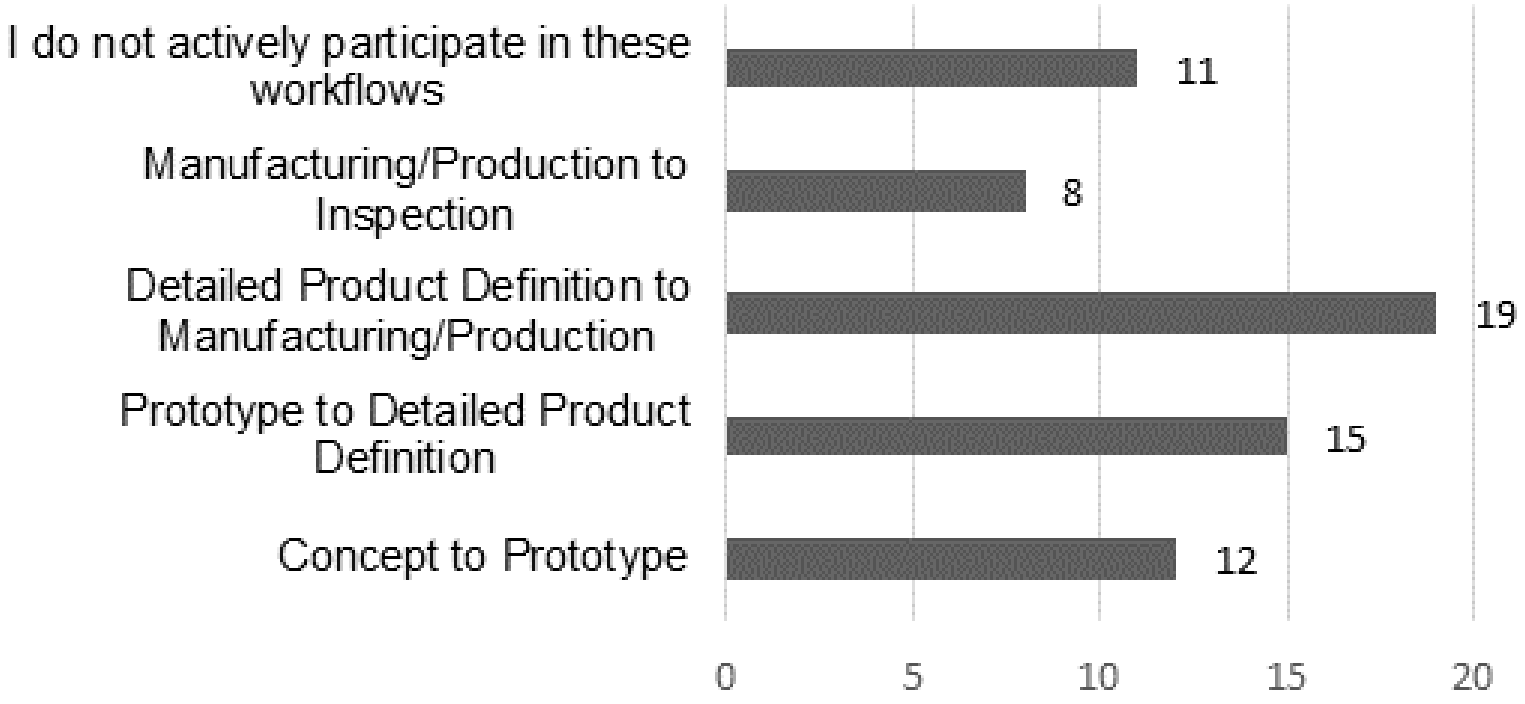


Distribution of Industry Participation

- 89 responses, 76 of which completed the Demographics
- 85% of respondents located inside of US, 15% outside

Stage 1 Results

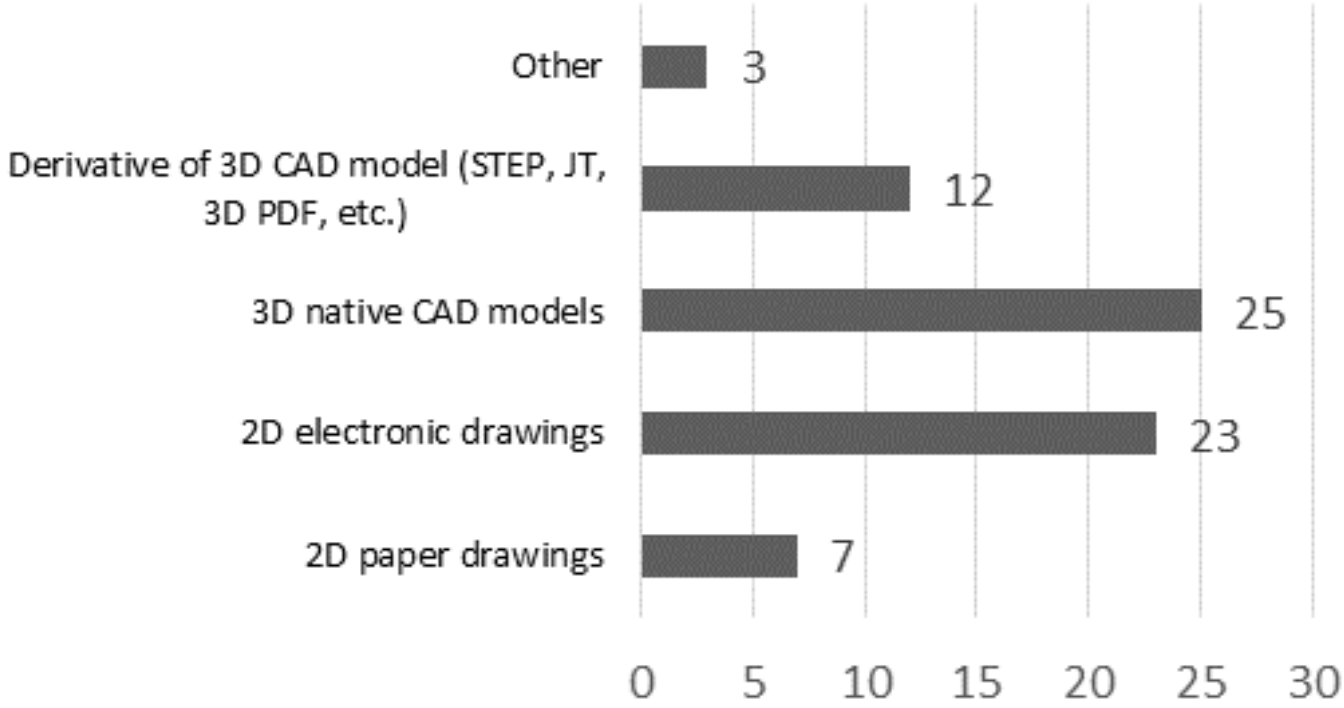
Conclusion and Discussion (Continued)



Participant workflow distribution

Stage 1 Results

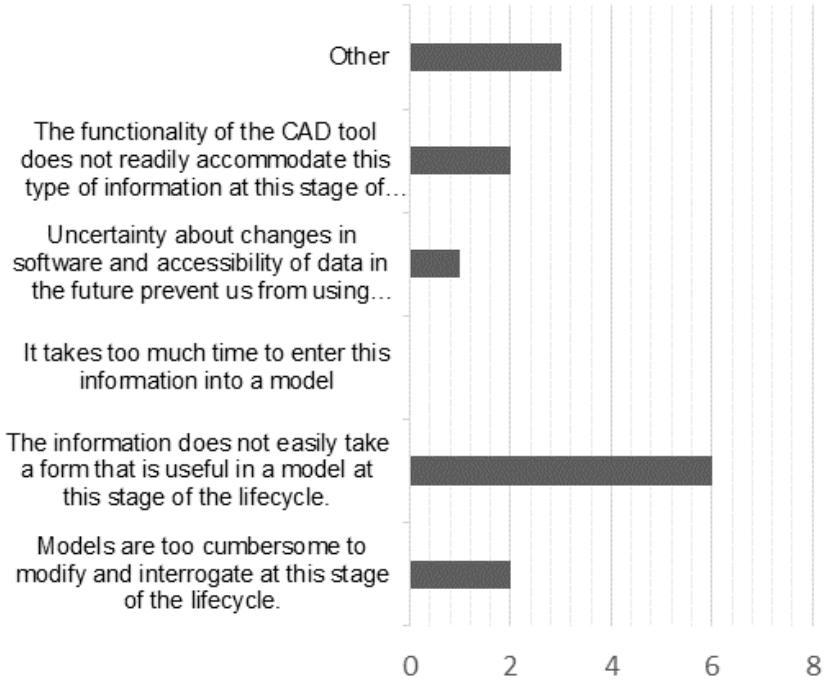
Conclusion and Discussion (Continued)



Responses for how participants receive information

Stage 1 Results

Conclusion and Discussion (Continued)

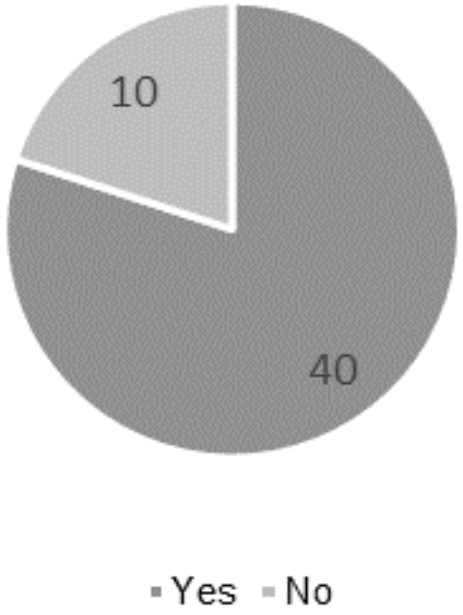


Issues adoption of MBD faces

- The main inhibitor of the use of 3D CAD models was that the information did not easily take a form that is useful in a model at this stage of the lifecycle

Stage 1 Results

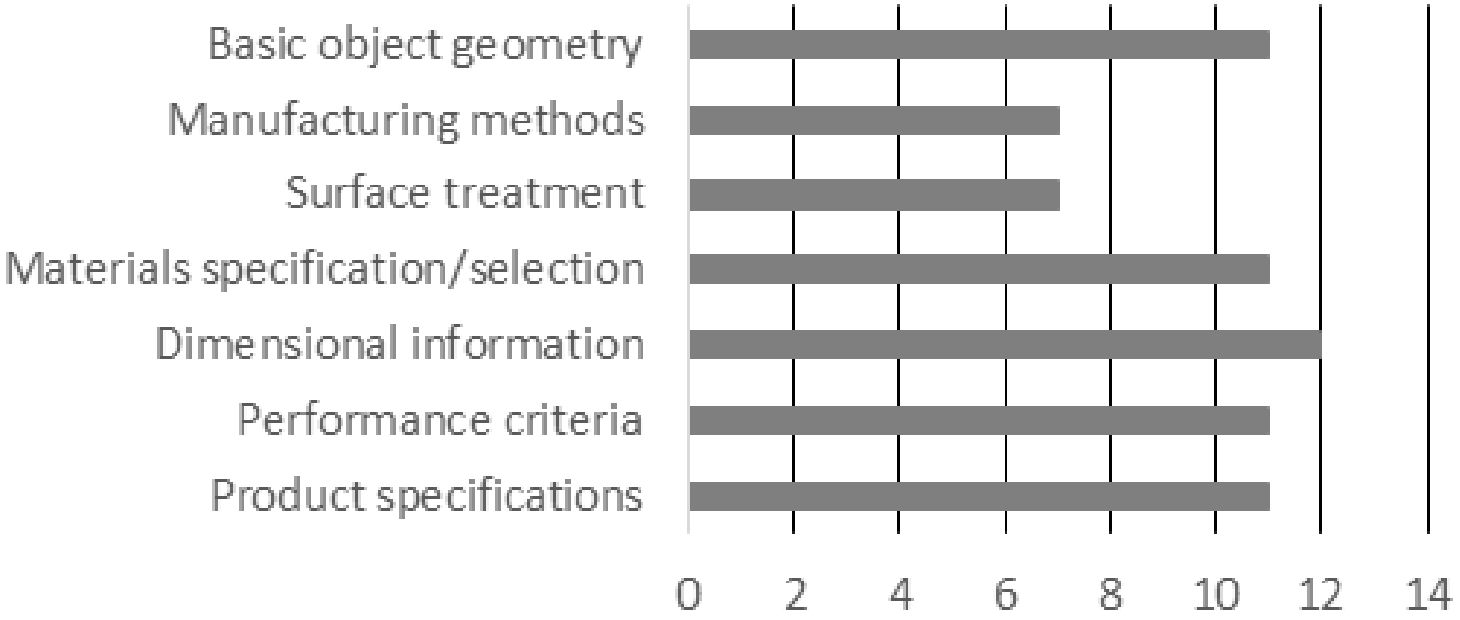
Conclusion and Discussion (Continued)



Could models be used in place of drawings in your workflow?

Stage 1 Results

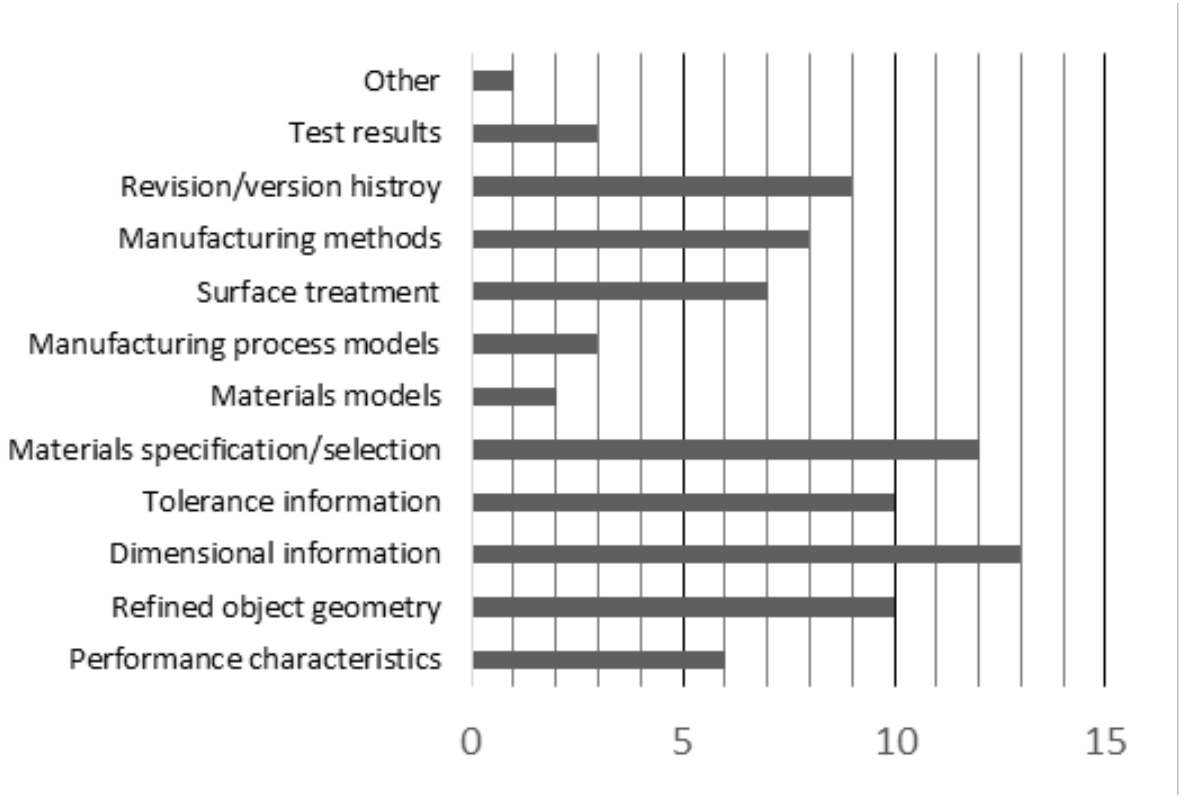
Conclusion and Discussion (Continued)



Participant responses for what information was created or used in the product information for concept to prototype

Stage 1 Results

Conclusion and Discussion (Continued)



Participant responses for what information was created or used in the prototype to detailed product definition workflow

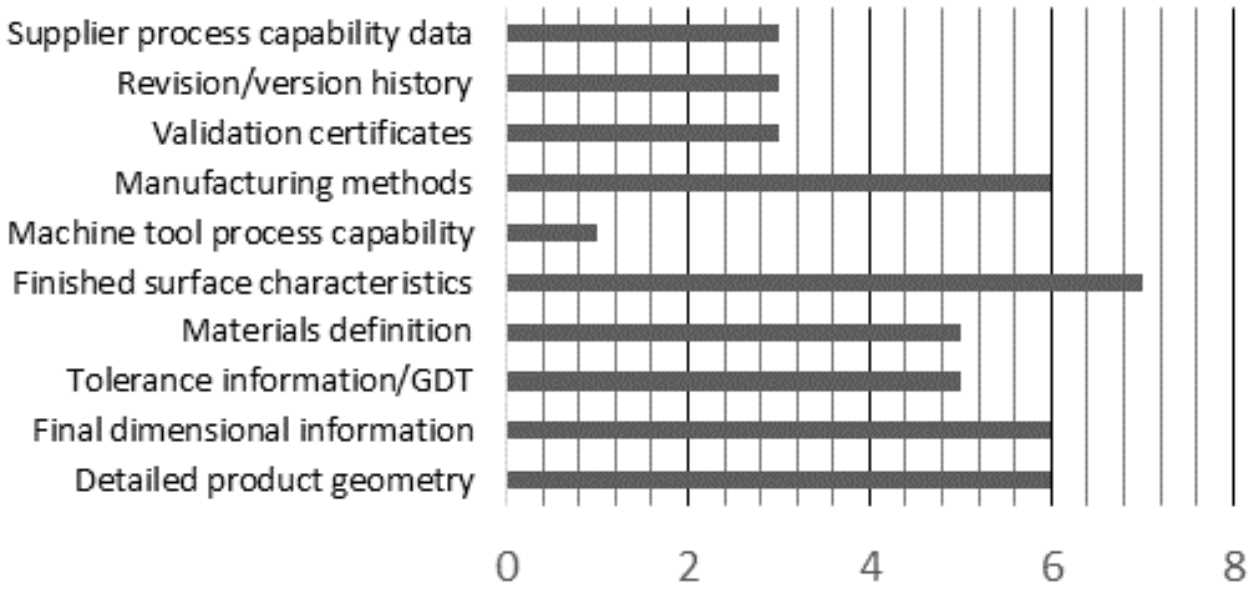
Stage 1 Results

Conclusion and Discussion (Continued)

Participant responses for what information was created or used in the detailed product definition to manufacturing workflow

Stage 1 Results

Conclusion and Discussion (Continued)



Participant responses for what information was created or used in the manufacturing to inspection workflow

Stage 1 Conclusions

- Model is ready to replace drawings in majority of participant processes.
- Theme in responses which indicate that the model itself is not necessarily the inhibitor.
- There is a need for research which targets the data flow.

Stage 1 and 2 Breakdown

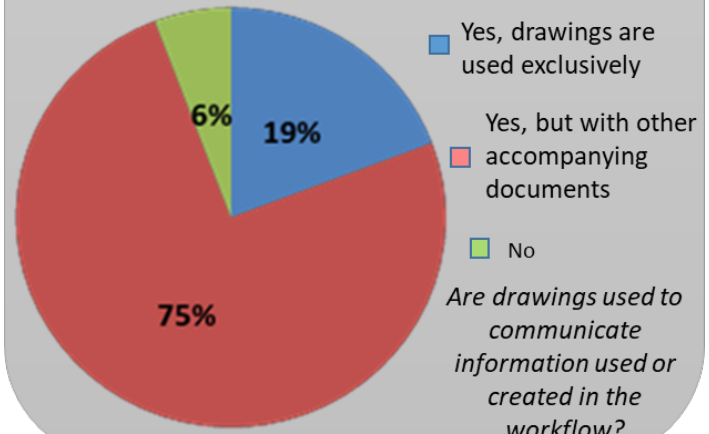
Stage One Results and Stage Two Results

Research Study Stage One

Objective: Identify items and elements in various workflows to establish the common information model and minimum information model

Conclusions

- 2D drawings most common
- Inhibitors to MBD adoption:
  - Information doesn't take a form that is useful in a model at given stage of lifecycle
  - No method for model manipulation



Are drawings used to communicate information used or created in the workflow?

Research Study Stage Two

Objective: Identify elements that are necessary in MBDs to survive throughout the lifecycle

Conclusions

- MBD has a steep learning curve
- Training is a very important factor for MBD
- Elements in MBD can have different meanings based on context and culture

Q4 - 3D Geometry

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	3.00	7.00	6.65	0.82	0.68	40

Q5 - Dimensional Information

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	1.00	7.00	5.85	1.56	2.44	39

Q6 - Detailed Product Geometry

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	2.00	7.00	6.21	1.24	1.55	39

Q7 - Revision/Version History

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	2.00	7.00	5.58	1.44	2.09	38

Q8 - Geometric Dimensions and Tolerances (GD&T)

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	1.00	7.00	6.03	1.37	1.87	39

Q19 - Bill of Materials

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	1.00	7.00	5.27	1.75	3.06	37

Stage One and Two Breakdown

Stage One Results, Stage Two Results and Interview Data

Interview Round 2 Data:

- Lack of consensus about terms
- Infrastructure can be an inhibitor to the adoption of a MBE
- Company culture may be an inhibitor of MBE
- Education on MBE, PLM and associated terms may be an inhibitor of MBE
- Having a proper data architecture may be an inhibitor of MBE
- Certain elements (such as 3D Model) are of more importance early in the lifecycle

Stage 1 and 2 Breakdown

Stage Two Results and Interview Data

Key Elements Identified

3D Geometry

Dimensional Information

Detailed Product Geometry

Revision/Version History

Geometric Dimensions and Tolerances

Materials Specifications/Definitions

Surface Finish/Characteristics

Engineering Notes

Bill of Materials

Referenced/Related Appropriate Standards

Change Management Data

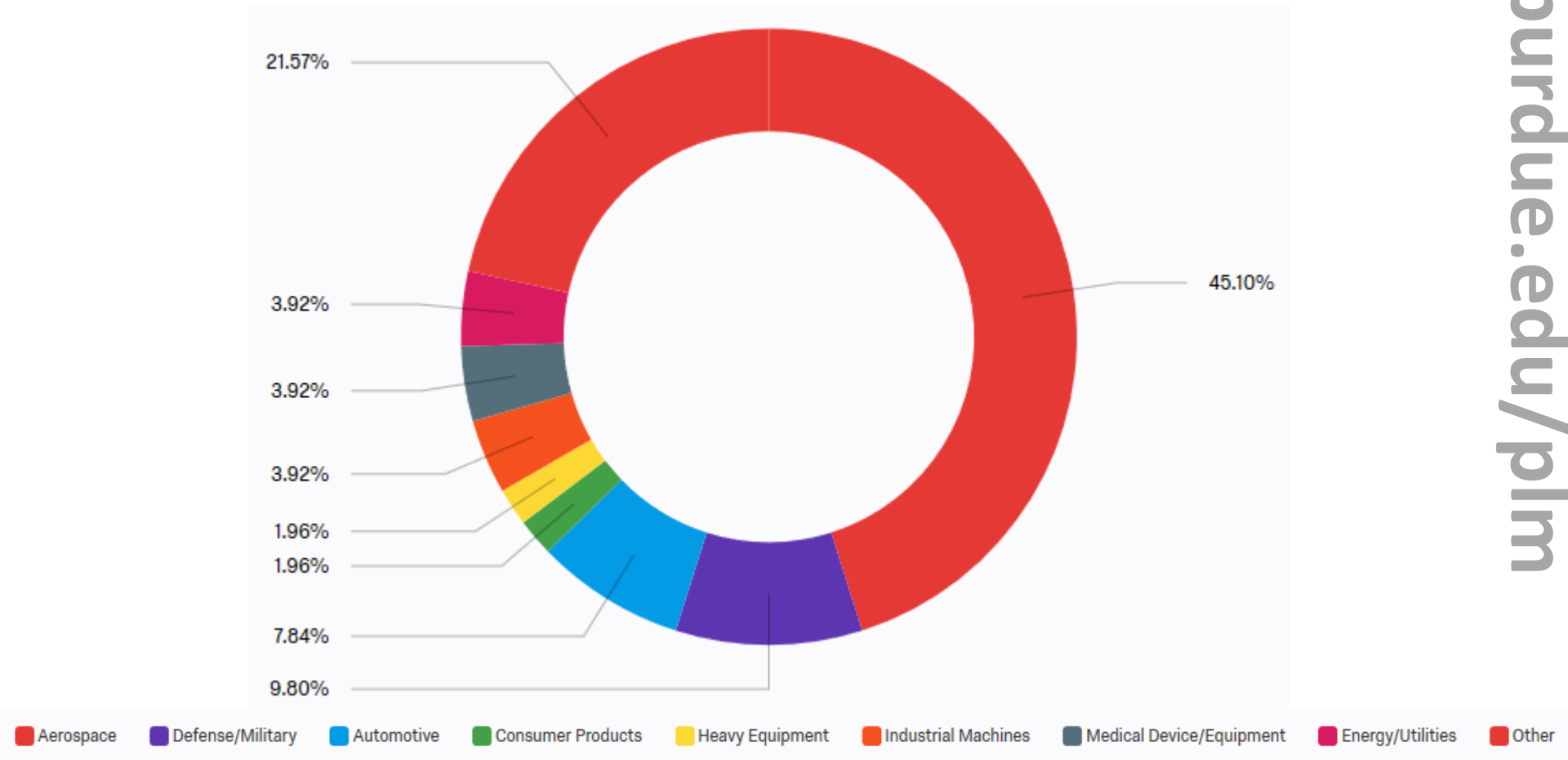
Product Specifications

- 12 key elements found from Stage One and Delphi rounds one and two
- There is a lack of consensus about the meanings of elements
- Difference between minimum and common information often confused

Stage 2 Delphi Study Round 3 Data

Round Three Results So Far

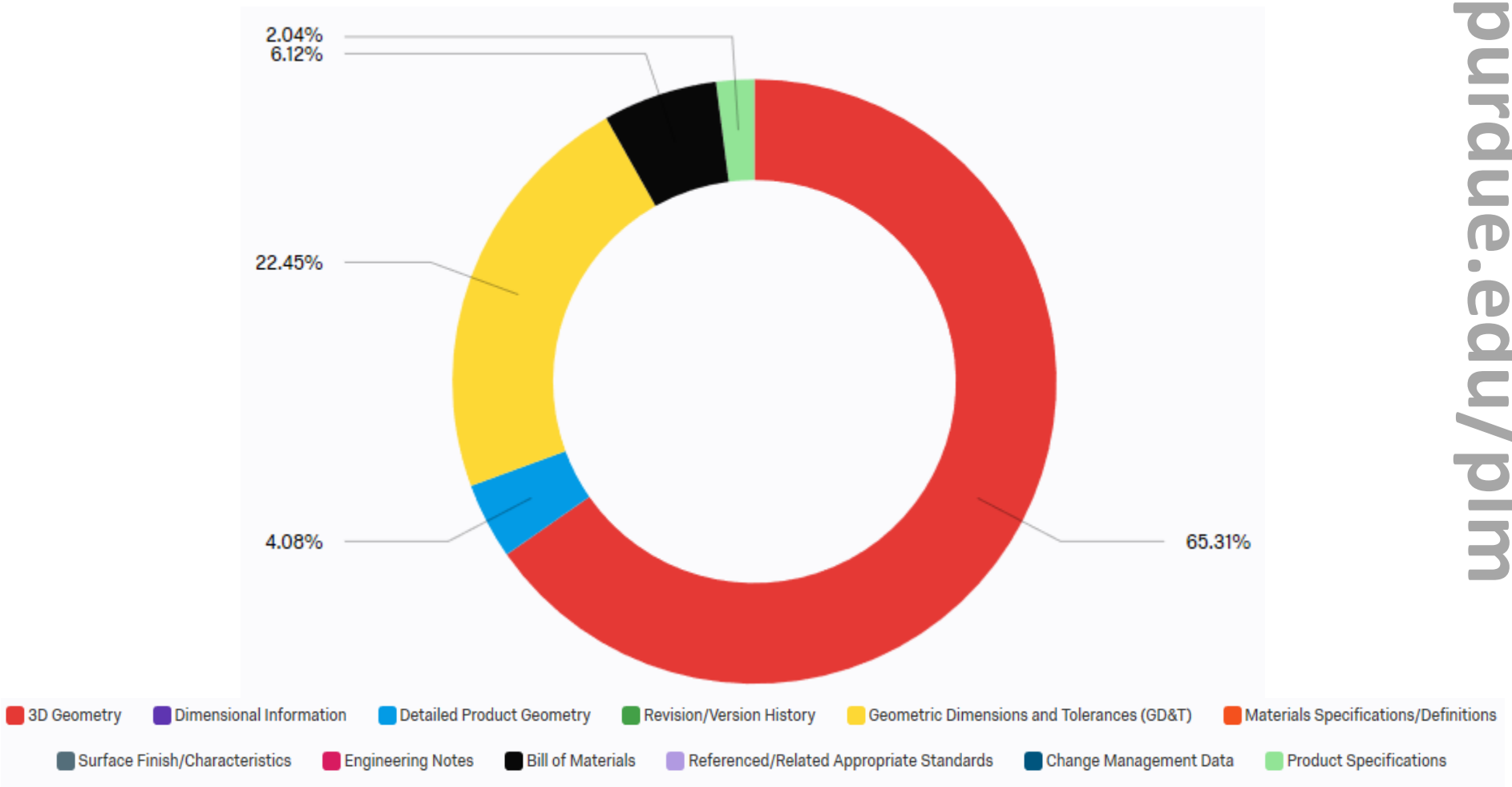
Q2 - Which industry sector best represents your company or the division of the company where you work?



Stage 2 Delphi Study Round 3 Data

Round Three Results So Far

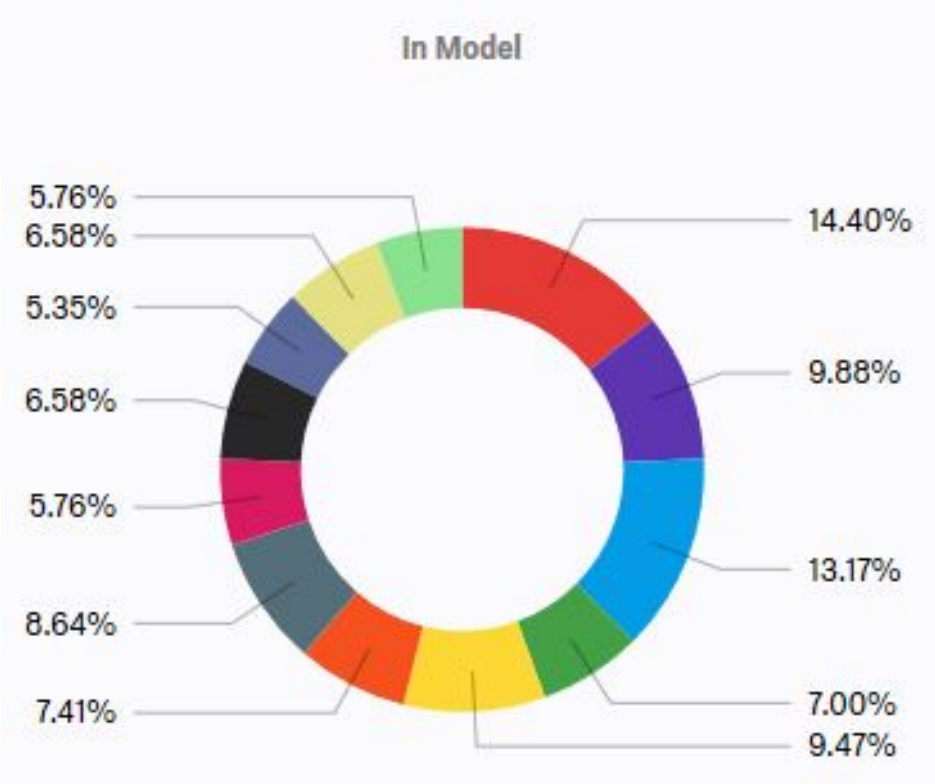
Q20 - If you could only select one item, which do you believe is the most important? (select only one)



Stage 2 Delphi Study Round 3 Data

Round Three Results So Far

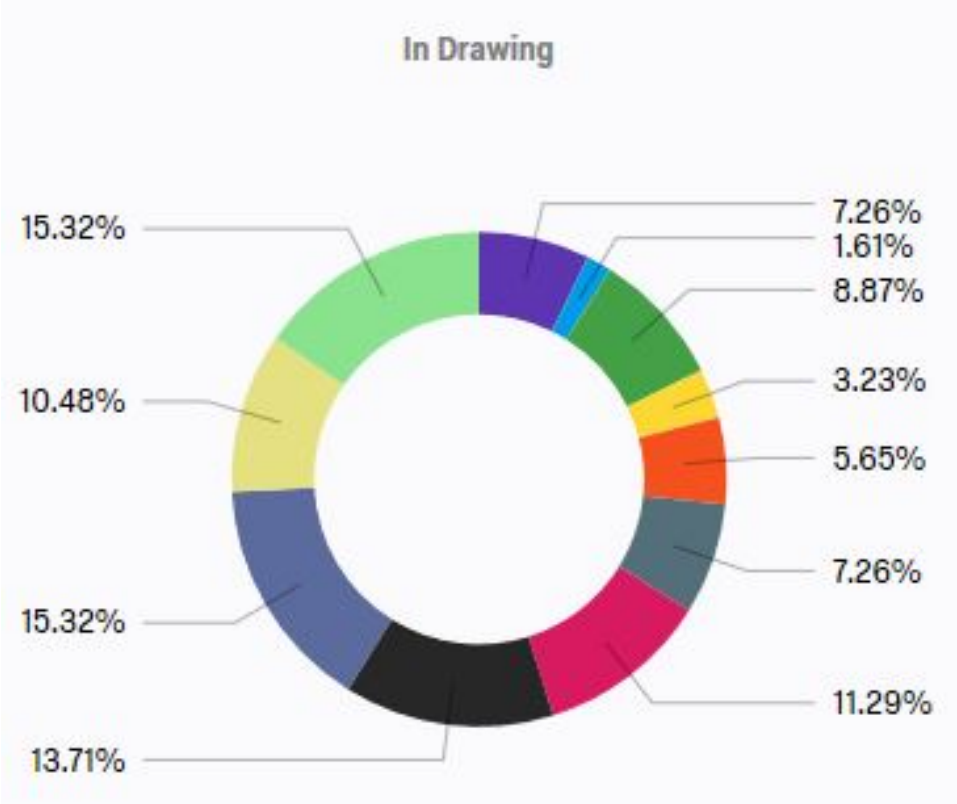
Q19 - For this section, please specify the form in which the element needs to be present.



Stage 2 Delphi Study Round 3 Data

Round Three Results So Far (n=50)

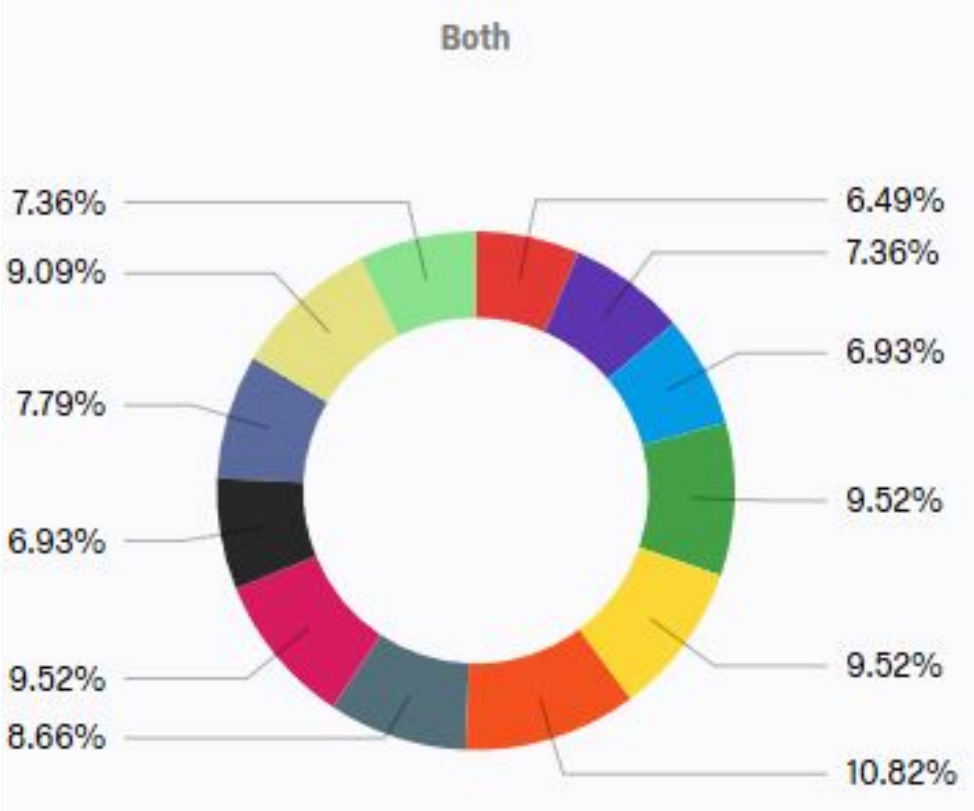
Q19 - For this section, please specify the form in which the element needs to be present.



Stage 2 Delphi Study Round 3 Data

Round Three Results So Far
(n=50)

Q19 - For this section, please specify the form in which the element needs to be present.



Stage 2 Delphi Study Round 3 Data

Round Three Results So Far

Q22 - To what extent is the lack of education a factor in the ability of a company to adopt MBD/MBE?

Minimum	Maximum	Mean	Std Deviation	Variance	Count
1.00	7.00	4.70	1.78	3.17	50

Q23 - To what extent does corporate culture factor into the ability of a company to adopt MBD/MBE?

Minimum	Maximum	Mean	Std Deviation	Variance	Count
2.00	7.00	5.96	1.30	1.68	50

Q24 - To what extent does the availability of proper technology infrastructure affect the adoption of MBD/MBE?

Minimum	Maximum	Mean	Std Deviation	Variance	Count
2.00	7.00	5.40	1.51	2.28	50

Q25 - To what extent does having a relevant data architecture affect the adoption of MBD/MBE?

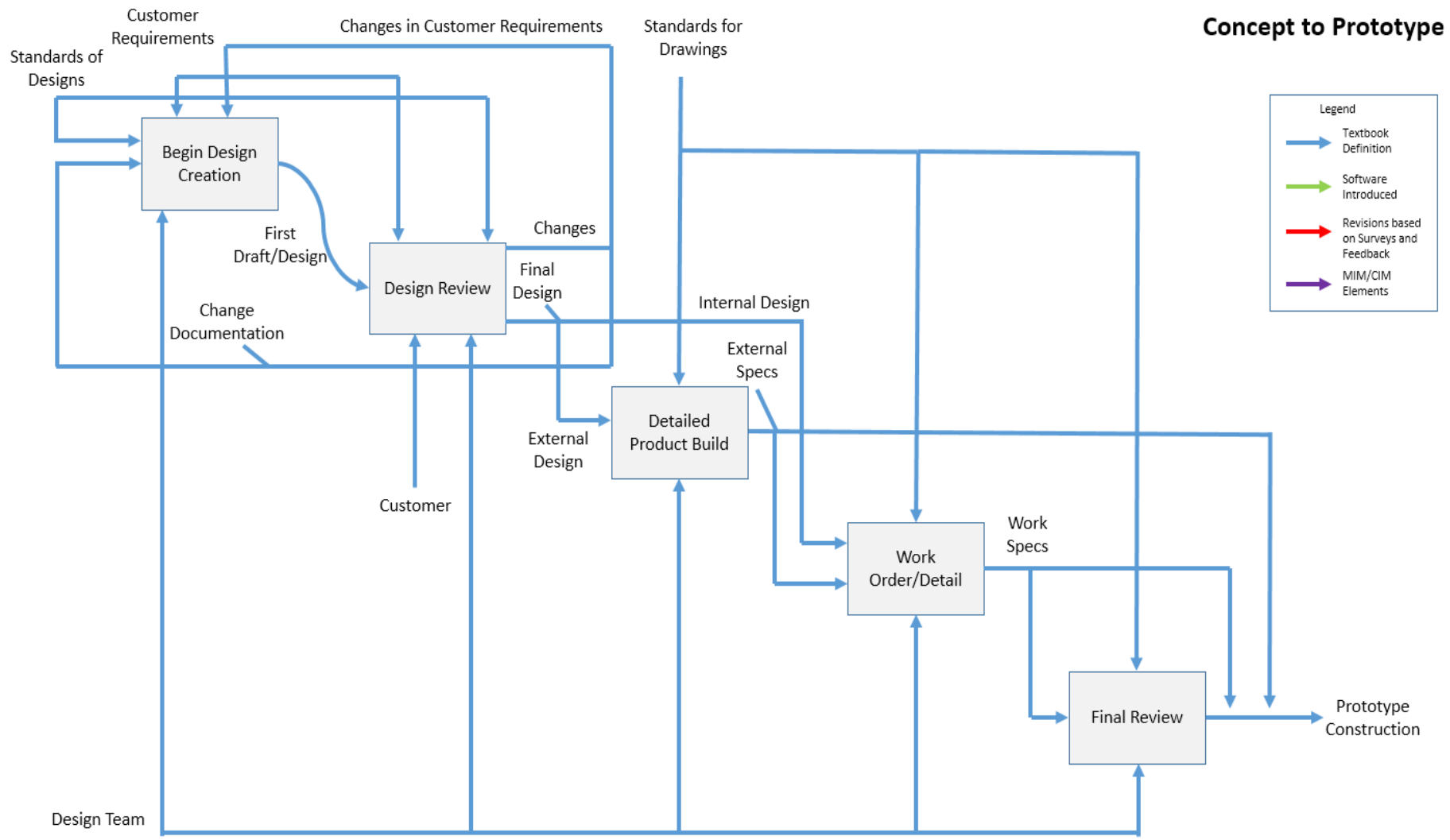
Minimum	Maximum	Mean	Std Deviation	Variance	Count
2.00	7.00	4.98	1.33	1.78	49

Stage 2 Delphi Study Round 3 Data

Round Three Results So Far

- 3D Geometry is the most important element to communicate information
- Of the twelve elements identified for round 3, only five of them were deemed “important” this round
- References/Related Standards and Product Specifications were the most important elements for drawings
  - –3D Geometry most important for models
- 3D Geometry and Detailed Product Geometry are most important to the MBD

Stage 3: IDEF0 Workflow Representations



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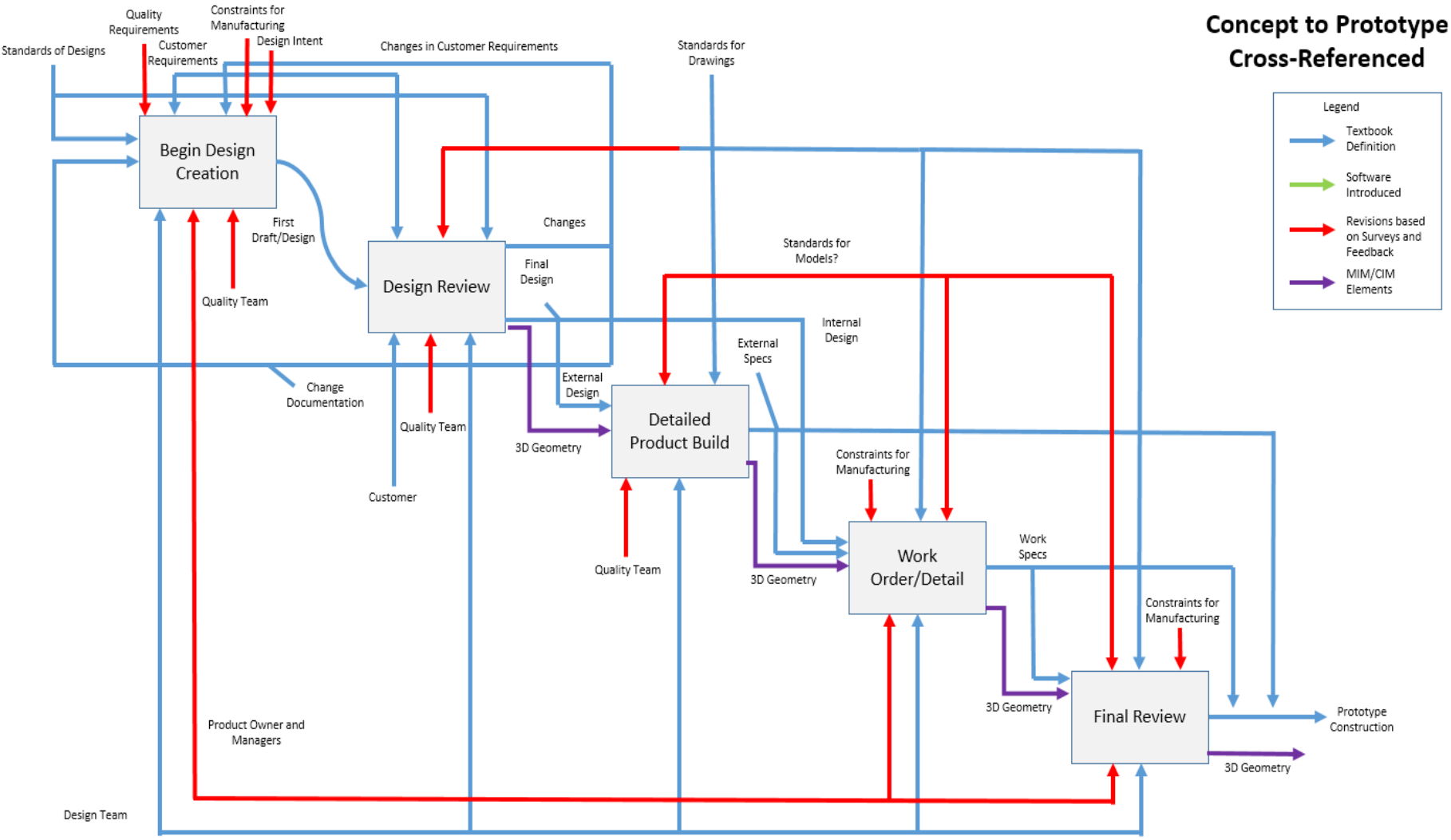
Stage 3: IDEF0 Workflow Representations



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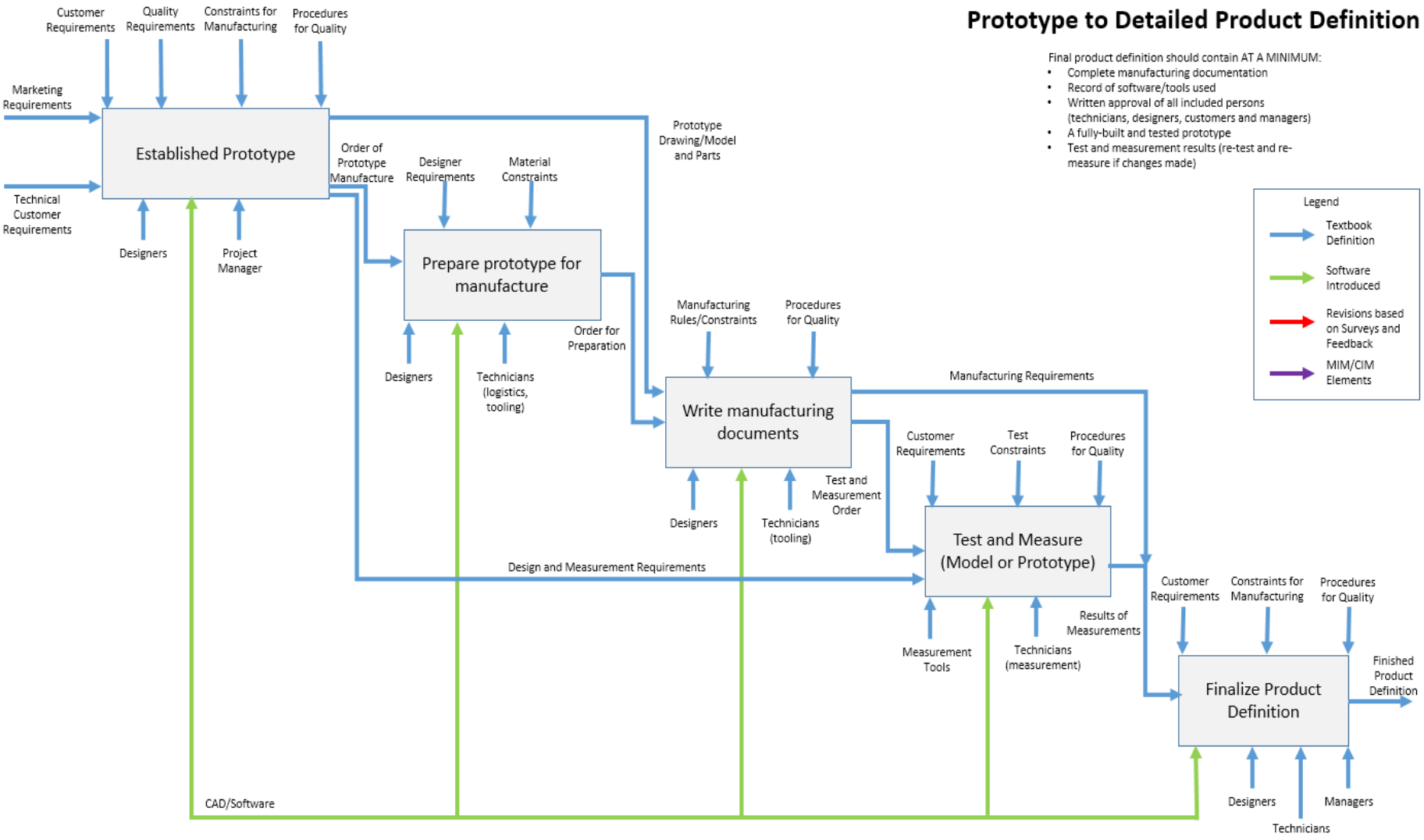
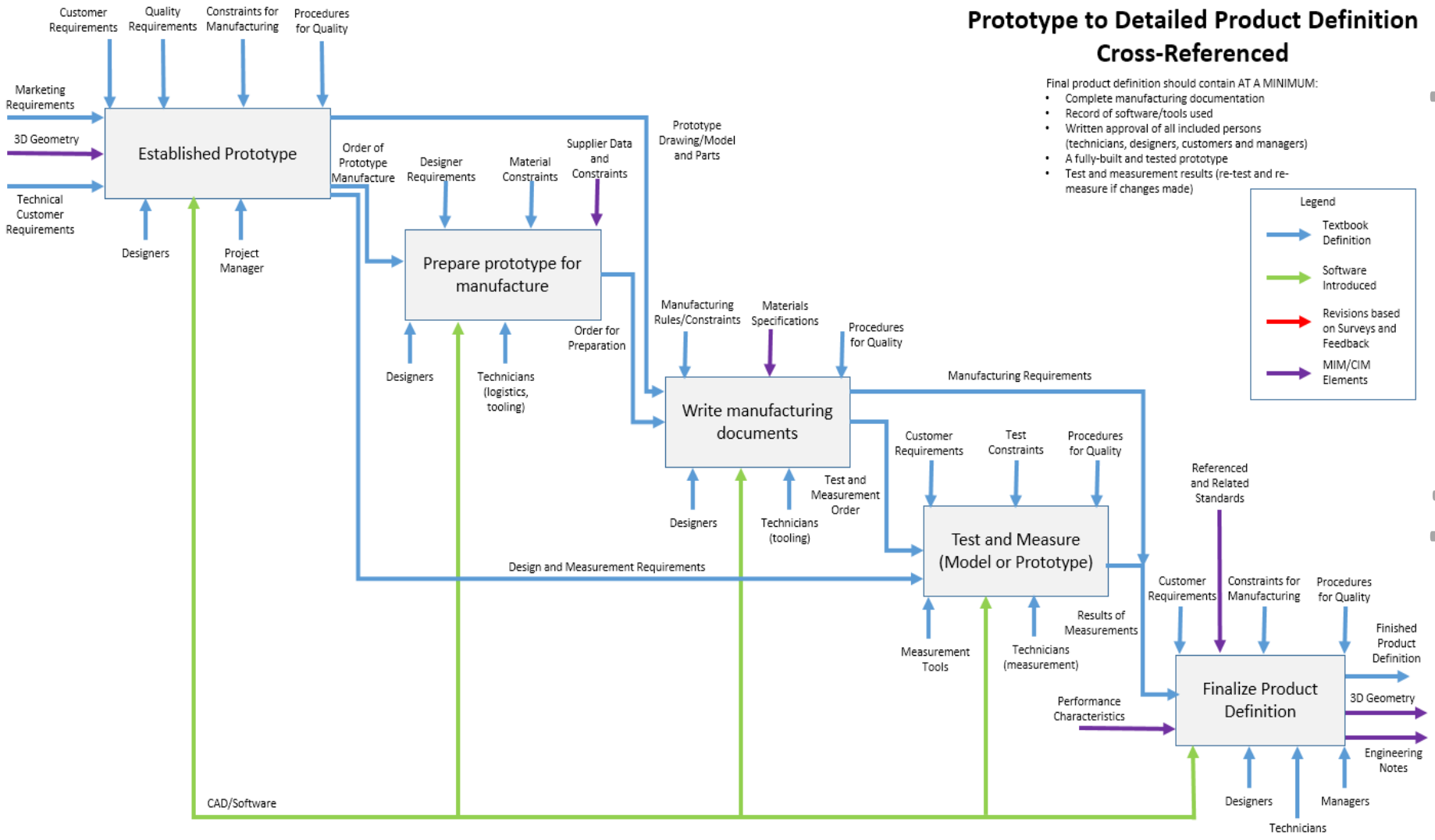
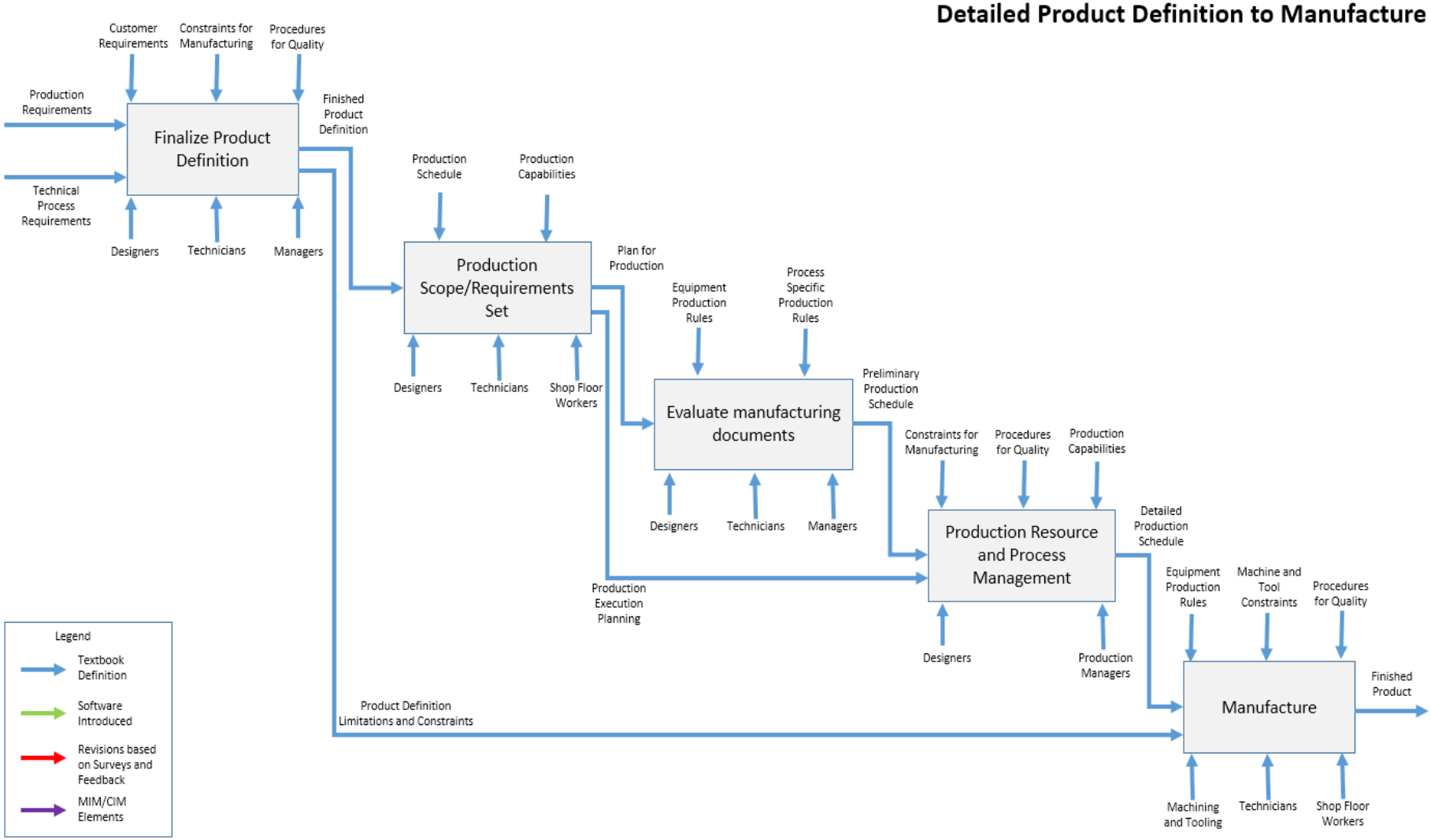
Stage 3: IDEF0 Workflow Representations



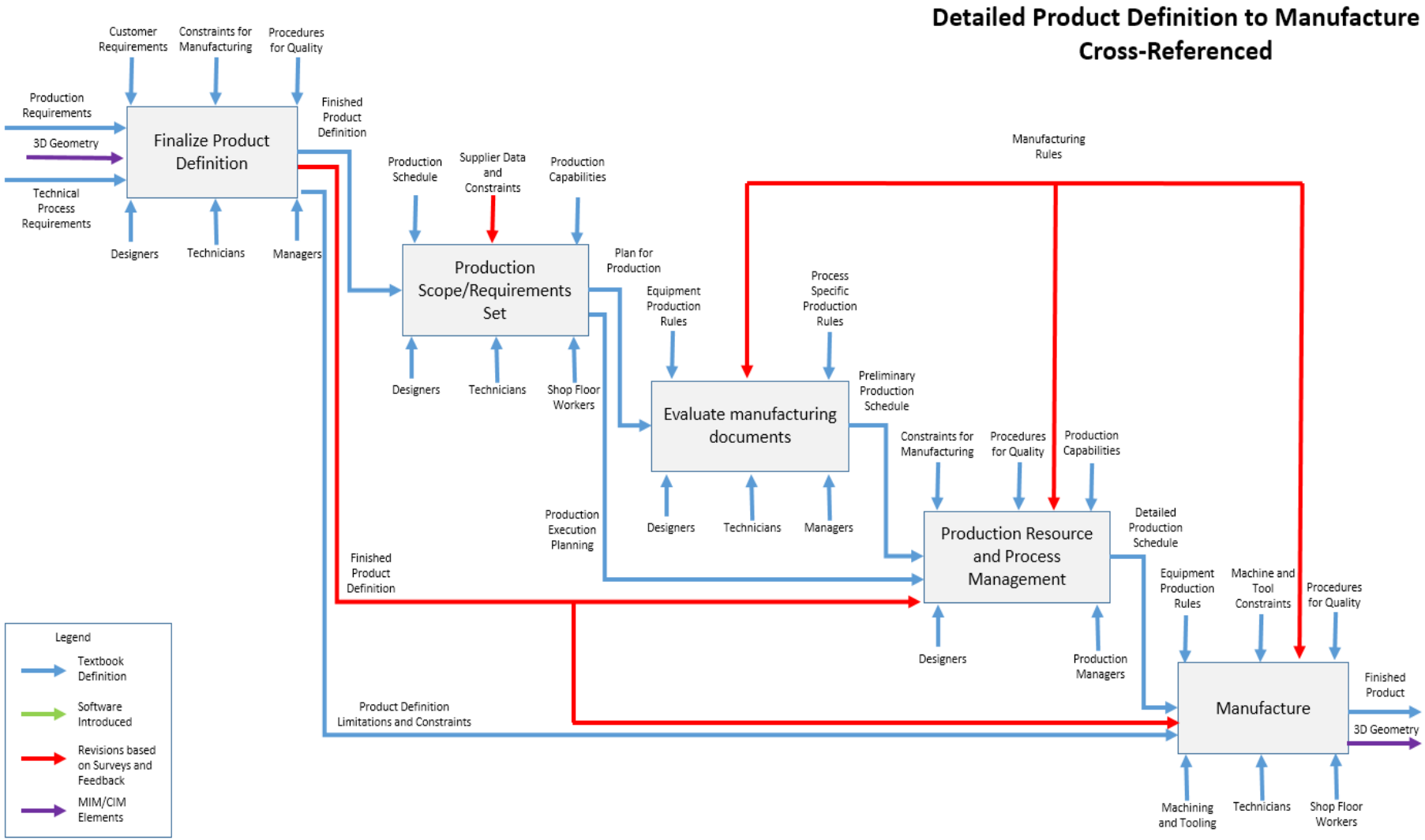
IDEF0 Workflow Representations



Stage 3: IDEF0 Workflow Representations



Stage 3: IDEF0 Workflow Representations



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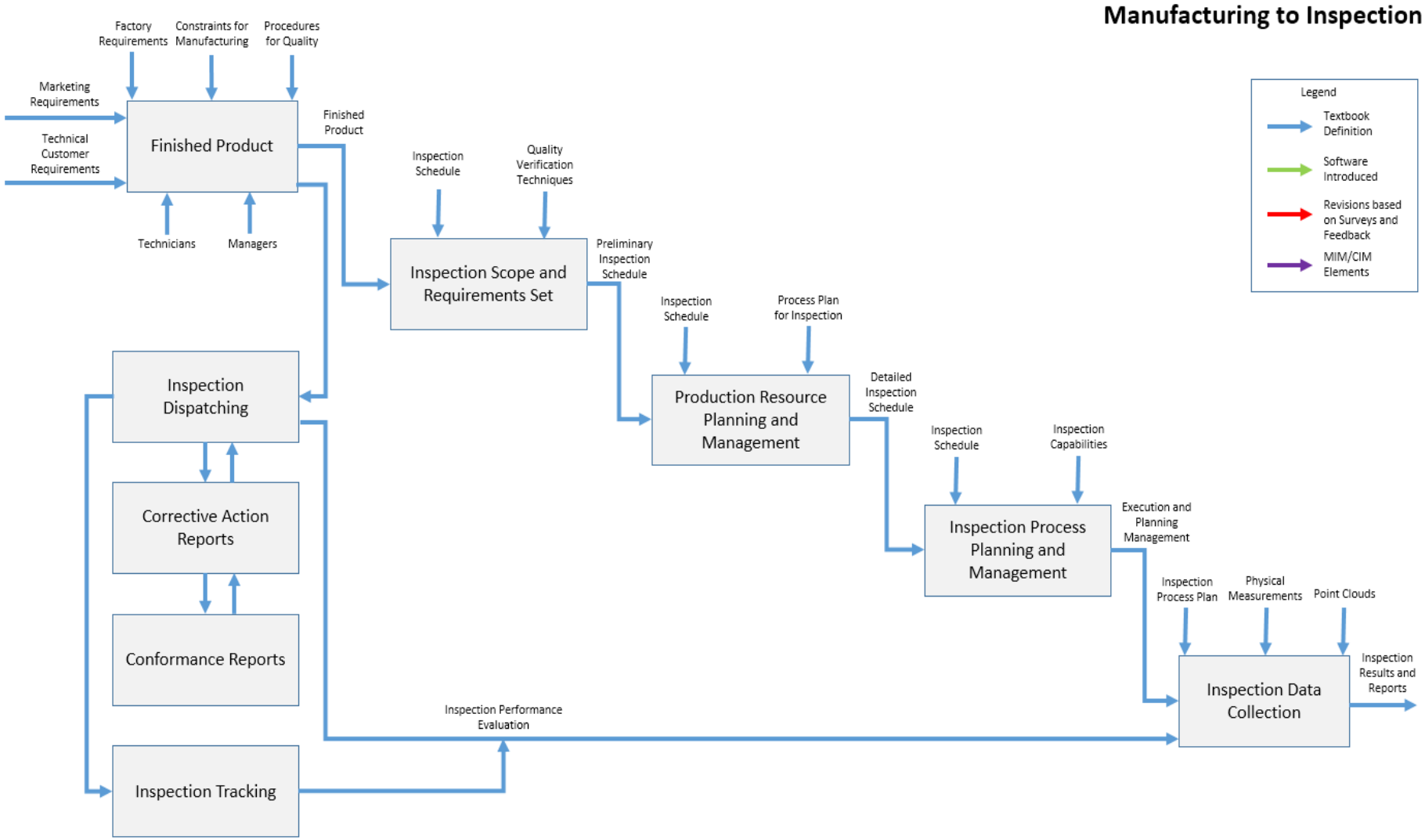
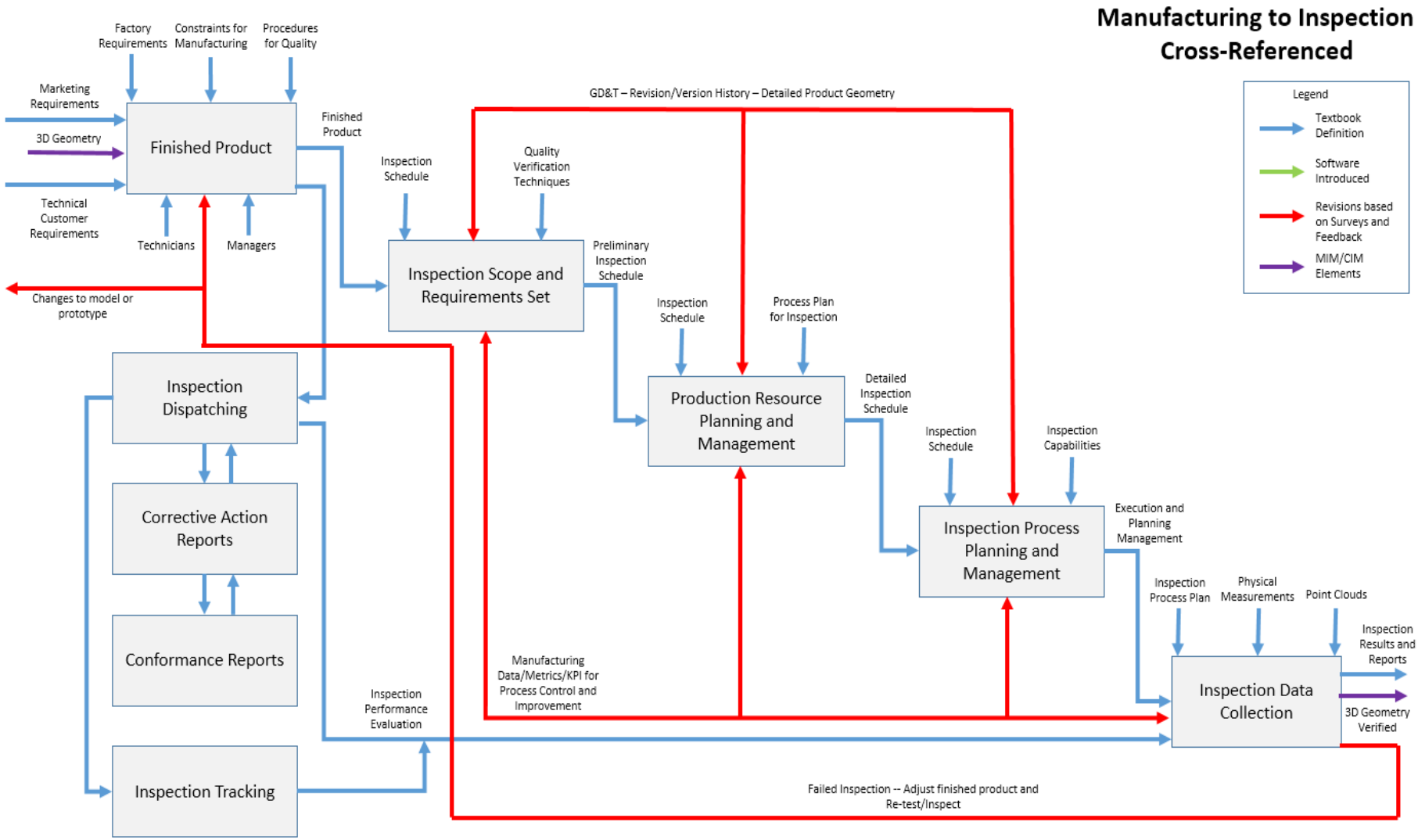
Stage 3: IDEF0 Workflow Representations



Stage 3: IDEF0 Workflow Representations



Conclusion

- CIM and MIM are views of a model-based definition. The CIM will be a portion of all MIM.
- Adopting a MBE/MBD is a challenge
  - Lack of infrastructure
  - Lack of experience
  - Lack of willingness to change
- Understanding the MIM and CIM will help alleviate the stress of adoption
  - Knowing what you need to know is the first step
- Emerging effects of implicit and explicit information
- The standards community needs to embrace an information emphasis, not a format emphasis

Nathan W. Hartman, Jesse Zahner, Tom Hedberg, Allison Feeney

Extending and Evaluating the Model-based Product Definition

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