Nathan W. Hartman

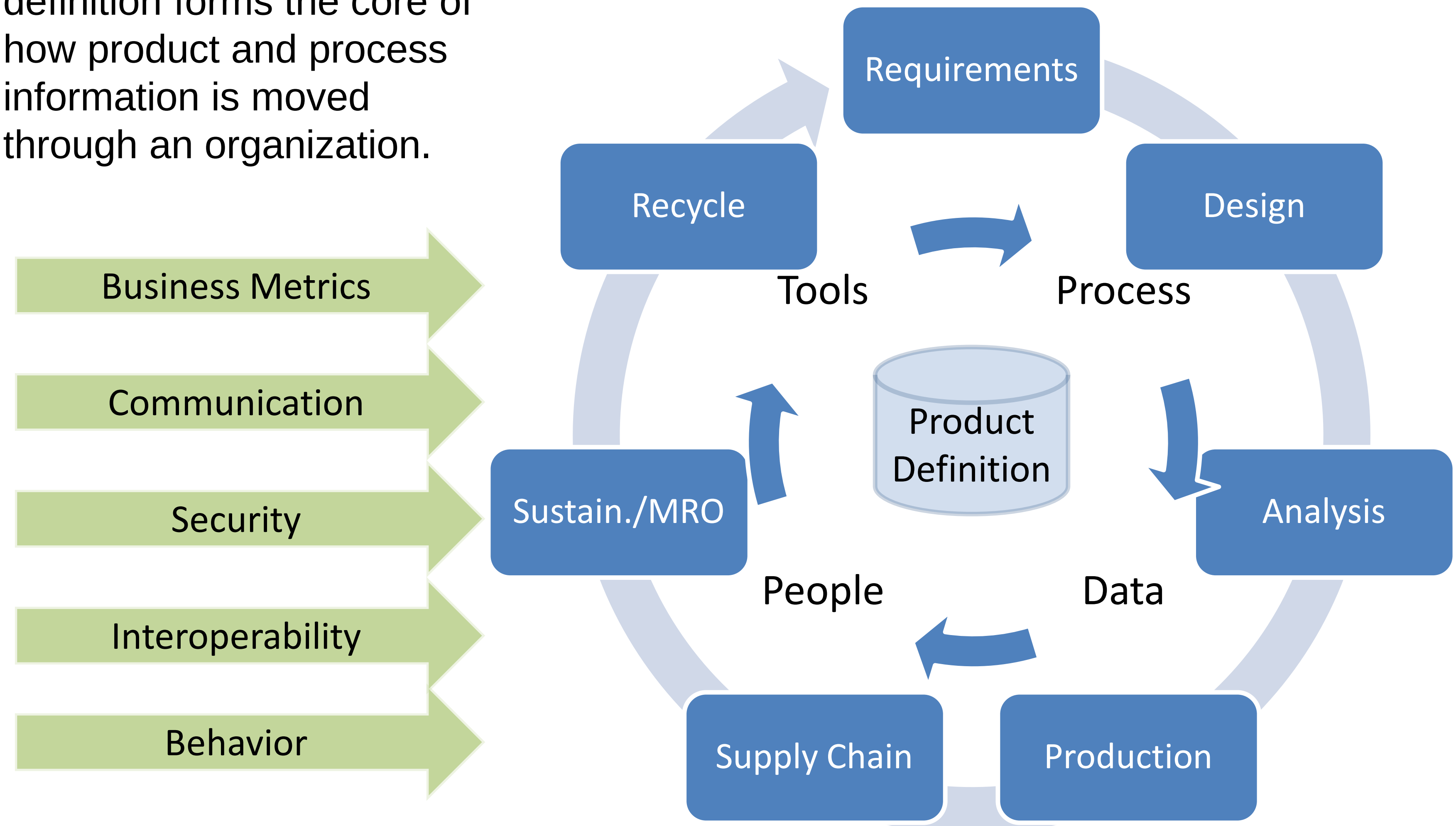
MBD, SYSTEMS ENGINEERING AND THE MINIMUM INFORMATION MODEL

PURDUE POLYTECHNIC

PLM PURDUE CENTER

What is PLM?

The digital product definition forms the core of how product and process information is moved through an organization.

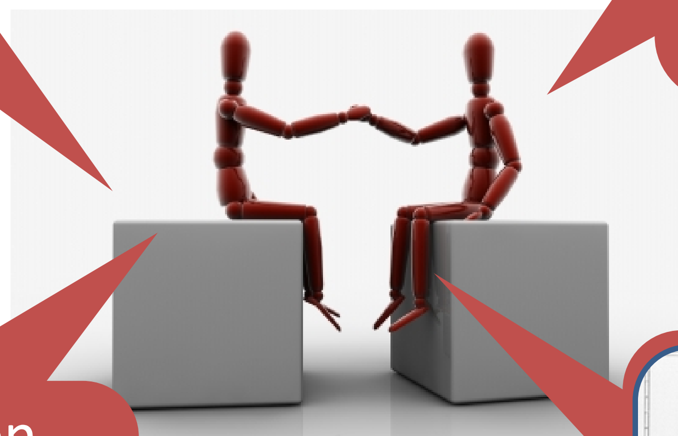


The collaboration journey…

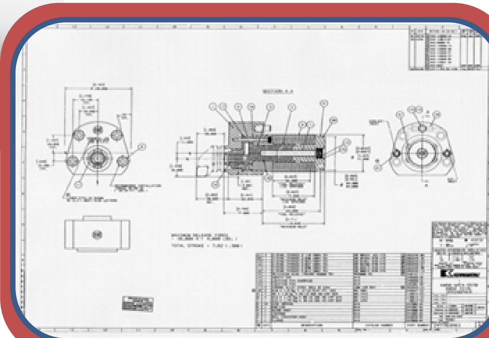
Yesterday

Communications often in serial fashion

You trusted the data because you trusted the person that generated the data



Collaboration meant face-to-face communication

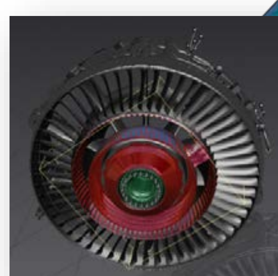


The collaboration journey…

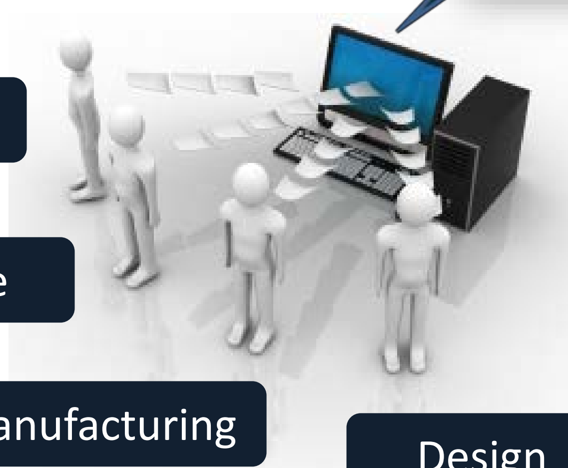
Tomorrow

The **digital product definition** becomes the *conduit* in a standards-based communication process.

The product *model* is the basis for a **secure**, **authoritative** source of product definition.



You come to *trust the process* that generates product data (because the person may be unknown).



Recycle

Service

Manufacturing

Design

Evolution of model-based representations

An exercise in information flow: right place, right form, right time

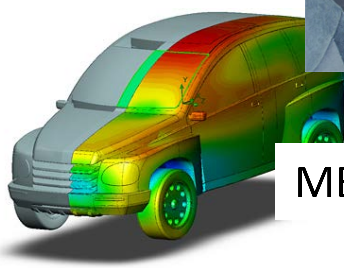
Context

Behavior

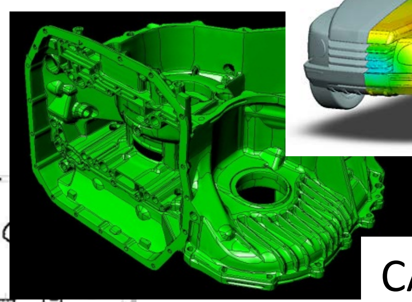
Shape

Lifecycle based

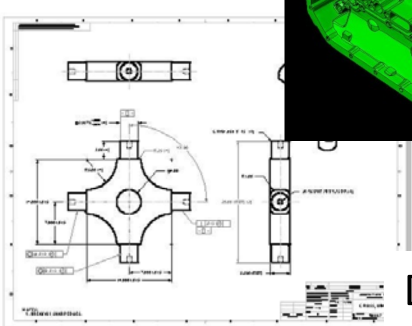
Virtual environment based



MBx based



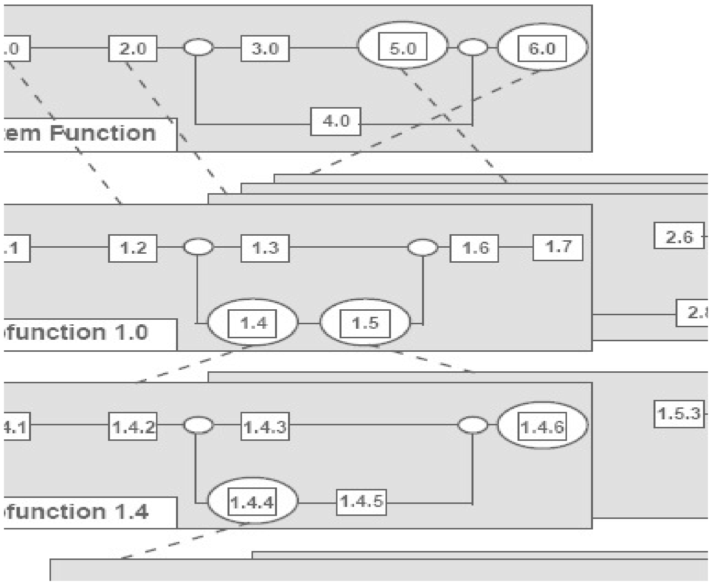
CAD based



Drawing based

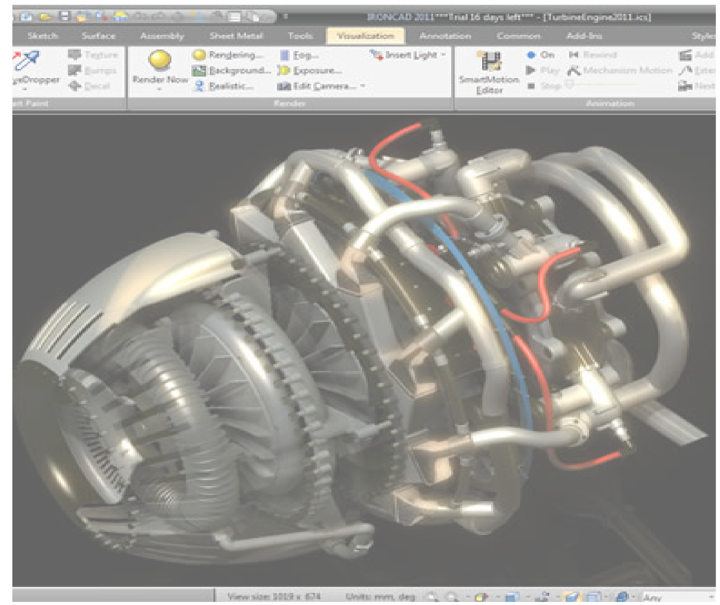
Increased sophistication in the digital product and process representations and their fidelity to the physical world.

Two engineering tribes



Systems Engineers

Masters of the abstract



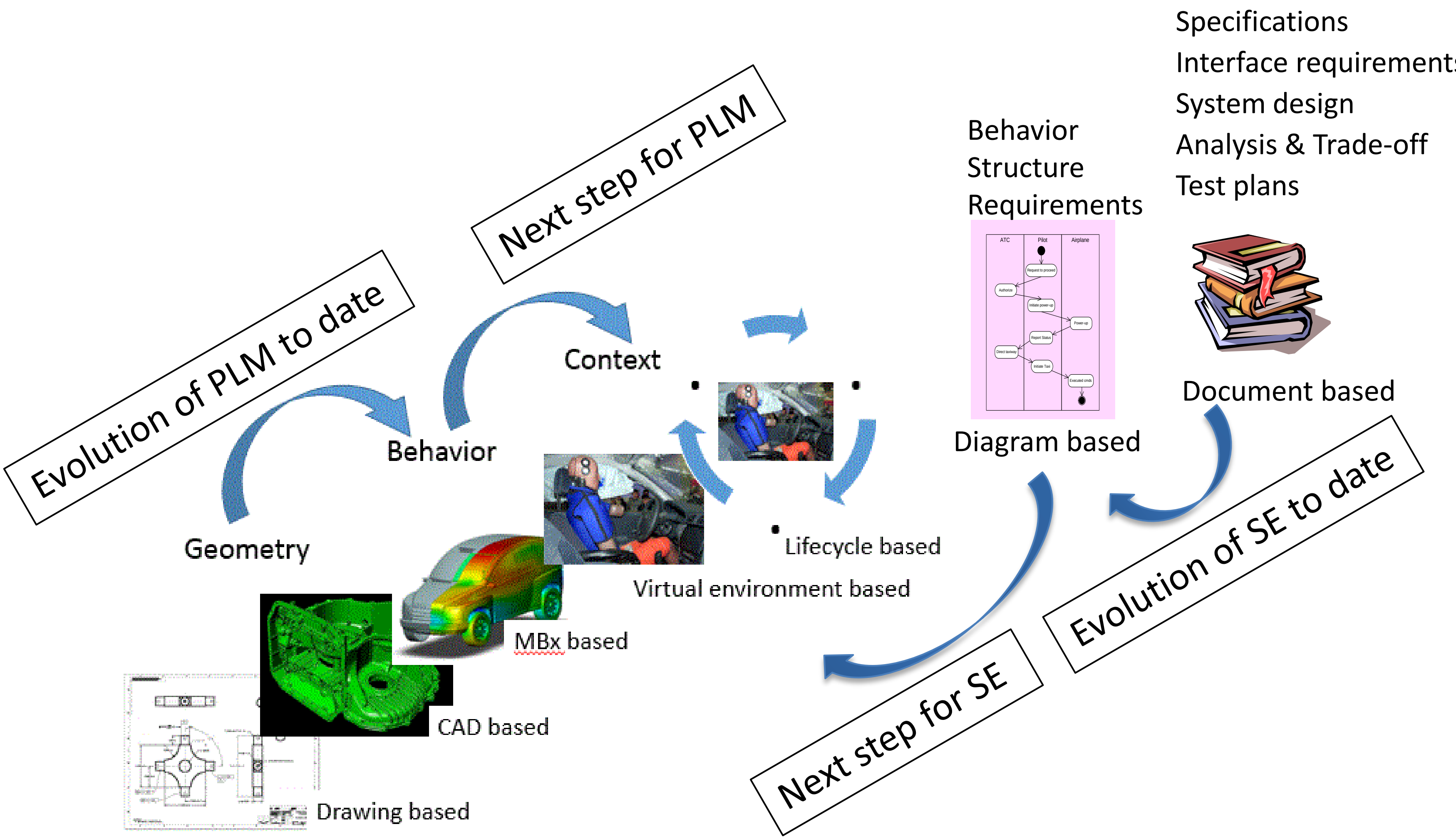
Product Designers

Masters of the tangible

Implications for systems eningeers

- Changes are response to availability of technologies
  - Ever-increasing computational power
  - Immersive technologies for data visualization
  - 3D printing (additive manufacturing)
  - Advances in materials science
  - Emergence of the internet of things
  - Globally connected IT environment
- Systems engineers neither the perceived nor actual agents driving changes in business processes
- Technology advances appear to be outpacing advances in methods and tools used by systems engineers

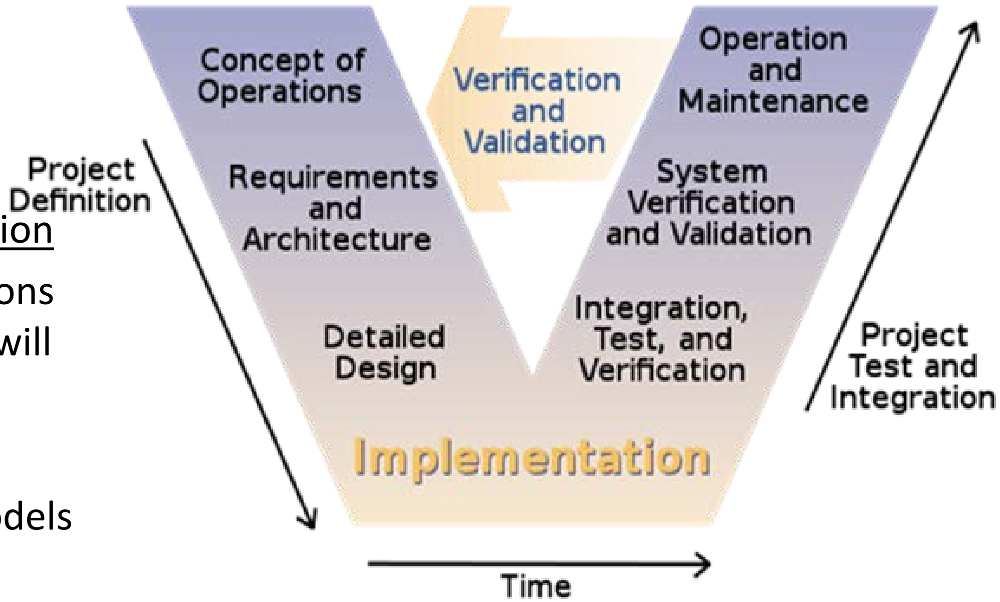
Evolution of PLM and SE



The Vee-Model and the Information Disconnect

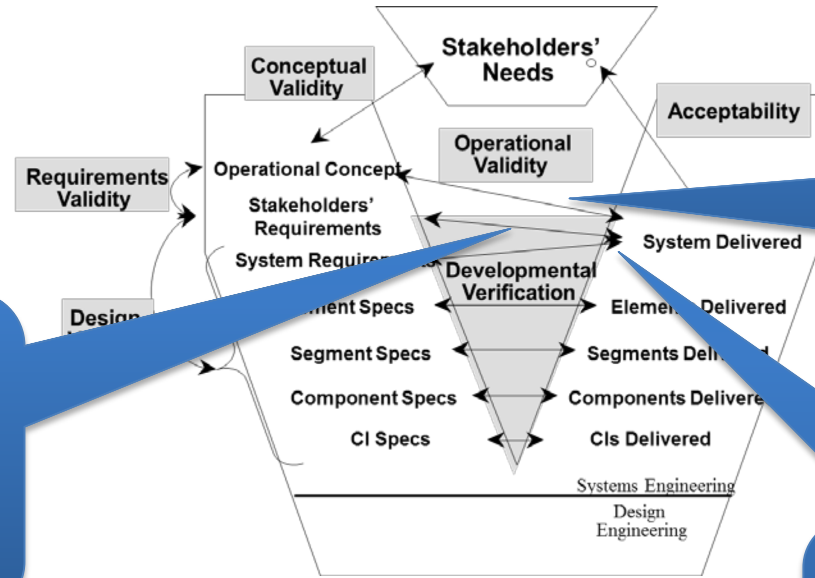
- Authors and consumers of product definition unable to move information fluidly between the levels of abstraction going down ***and coming up*** the Vee
  - No common authoring environment
  - No common language or ontology
- Consequences for design & implementation
  - Static "actionable" information regarding SE's desired solution requires considerable interpretation
  - Difficulty in validating how solutions composed from existing designs will perform SE's desires
- Consequences for V&V
  - Test cases unaccompanied by models and rationale
  - Testers check the box by performing test cases and turning in reports so can move on to solve the real problems

Vee-Model for the Product Lifecycle (from Hartman, Rosche, and Fischer (2012))



Using PLM to connect SE With V&V

Vee Model for Verification, Validation, and Acceptance [from (Buede 2009)]

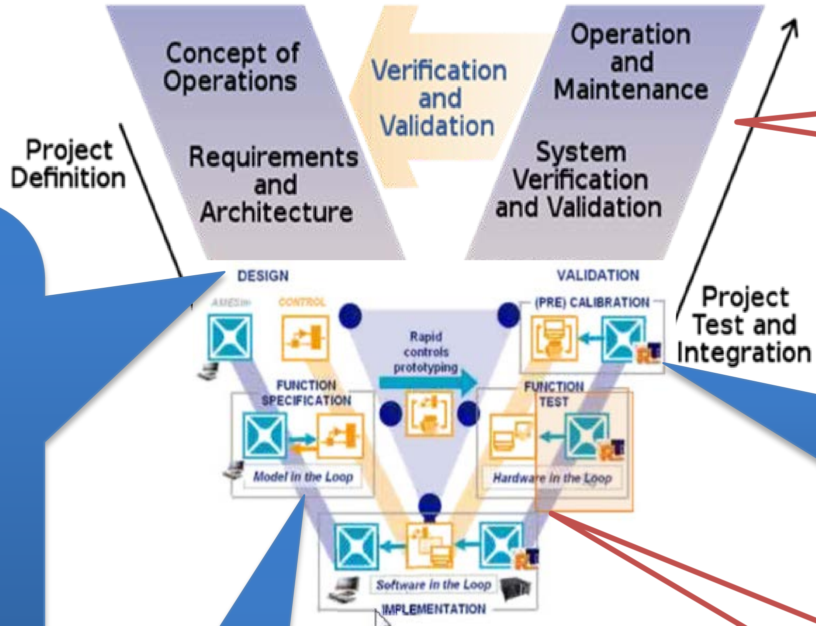


Allows updating SE models and sims with test results to predict performance and resource utilization more accurately

Models and simulations in PLM coming down left-hand side of the Vee available to testers when coming up the right-hand side

Ultimately, SE models and sims can replace instrumented tests and demonstrations

Using PLM to connect SE With Design



- Enables using existing design solutions to compose new system design solutions
- Big-data analytics can be used on information captured in PLM to generate suggestions for existing design existing design solutions to meet current requirements

Top of Vee-Model (from Hartman, Rosche, and Fischer (2012))

- Enables SEs to contribute to discovery and validation of proposed design changes during integration & test

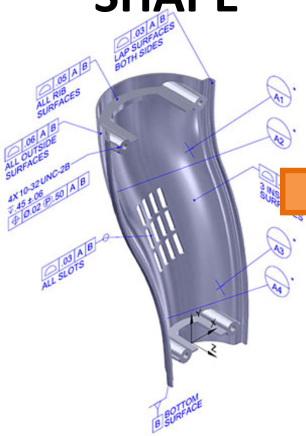
- Linking MSBE to executable simulation permits evaluation of virtual designs for impacts of compositional choices on performance, interfaces, and value delivered

Bottom of Vee-Model (from Siemens Webinar "Optimizing electric powertrain design with model-based systems engineering" (April 2015))

The communications spectrum…

A complete MBD supports lifecycle communication

SHAPE

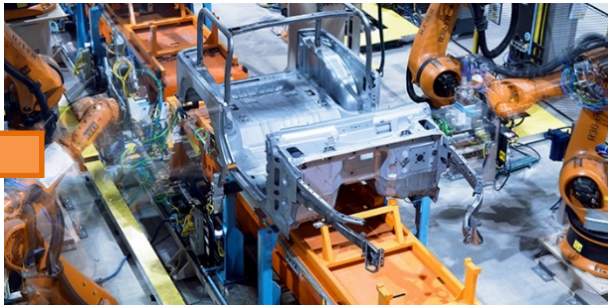


BEHAVIOR

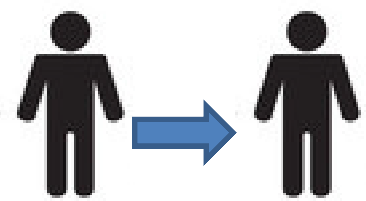
3.

Property	Test Standard DIN/ON EN ISO	corr.to ASTM	Unit	Value				Testing Frequency
Nominal Thickness	DIN EN ISO 14632	D 5994	mil mm %	78 2.0 +10/-5	100 2.5 +10/-5	98 3.0 +10/-5	196 5.0 +10/-5	every hour
Density (Black) Density (base/coloured)	ISO 1183	D792	g/cm3 g/cm3	≥ 0.94 ≥ 0.931/935				per production run 1)
Melt Flow Rate (190°/5kg) (190/2 ,16kg)	ISO 1183 Cond T	D 1238 Cond P D 1238 Cond E	g/10 min	≤ 3 ≤ 1	≤ 3 ≤ 1	≤ 3 ≤ 1	≤ 3 ≤ 1	per production run 1)
Heat Reversion (110°C/1, 5h)	DIN EN ISO 14632	D 1204 modified	%	≤ 3	≤ 3	≤ 3	≤ 2	per production run 1)
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 ≥ 537	≥ 1800 ≥ 625	≥ 2000 ≥ 750	≥ 2500 ≥ 1250	Approval Testing

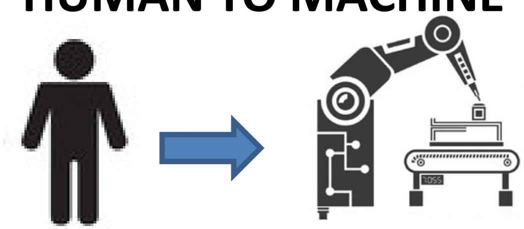
CONTEXT



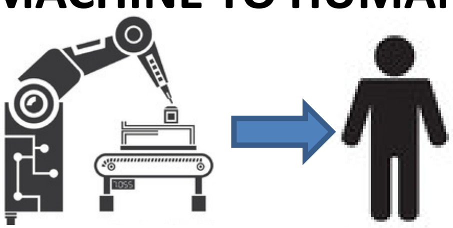
HUMAN TO HUMAN



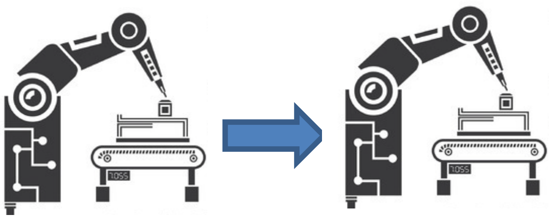
HUMAN TO MACHINE



MACHINE TO HUMAN



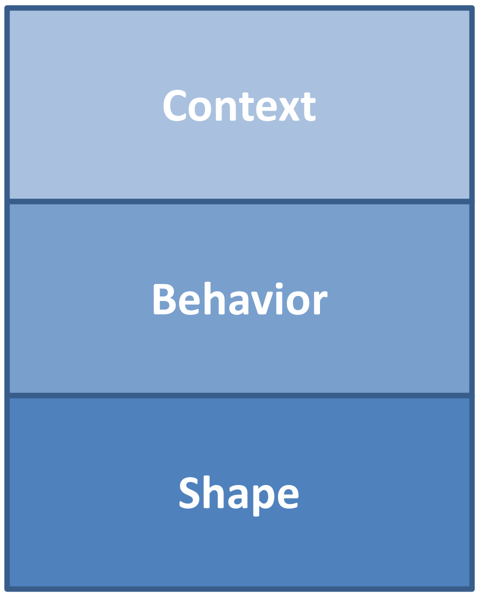
MACHINE TO MACHINE



How is the model structured?

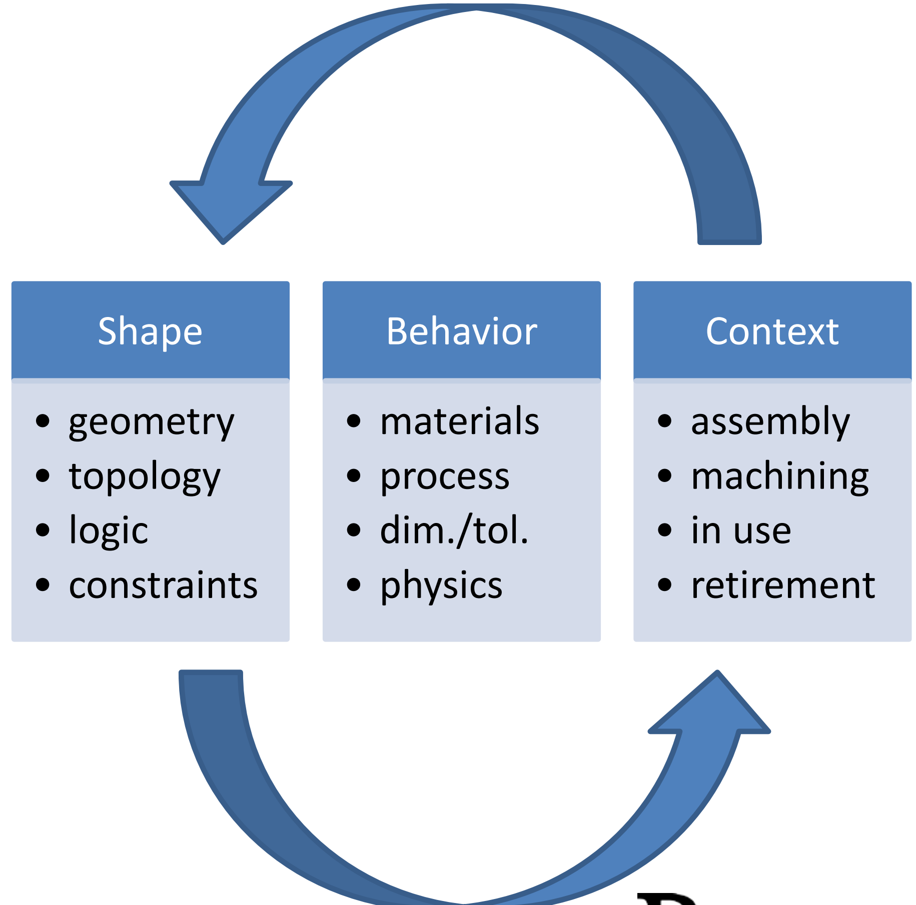
Singular representation vs. multiple, connected representations

Singular Representation



OR

Multiple Connected Representations



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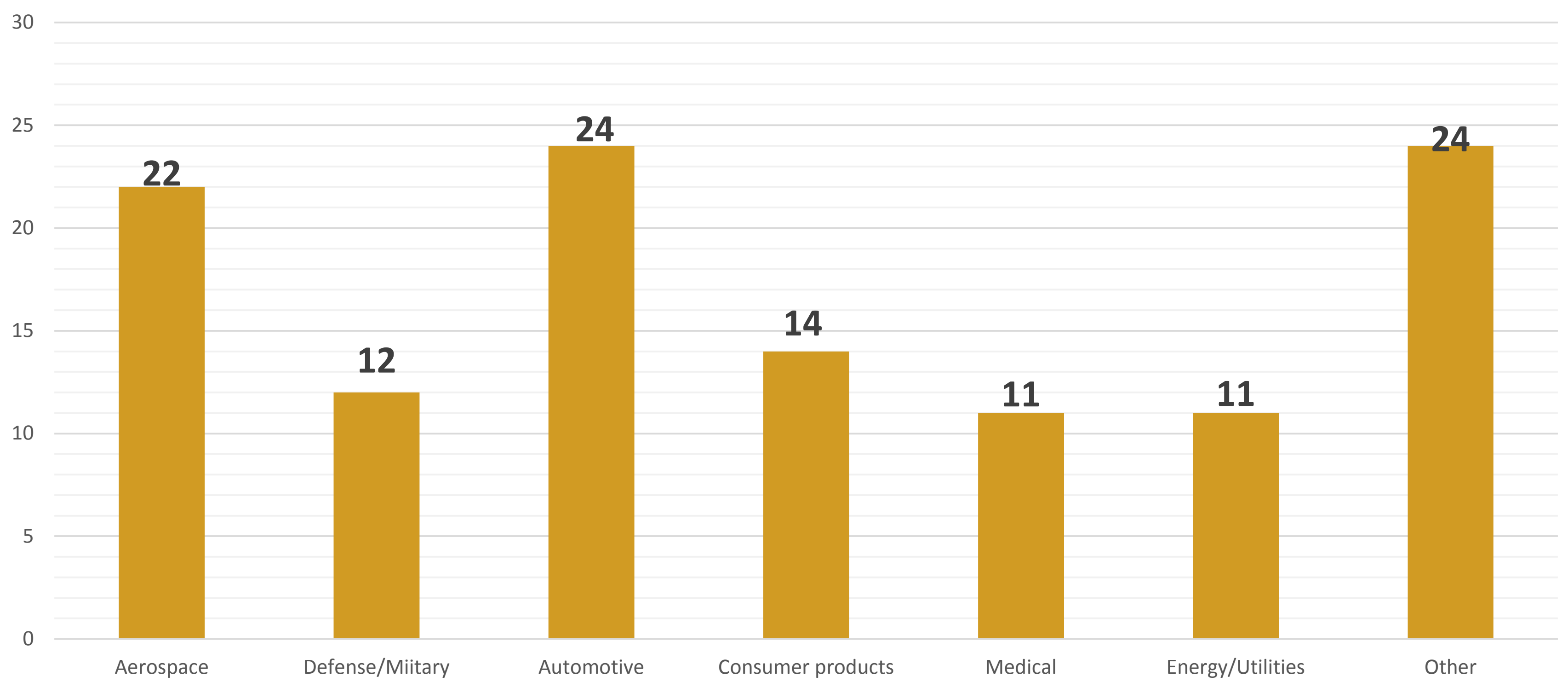
THE MINIMUM INFORMATION MODEL

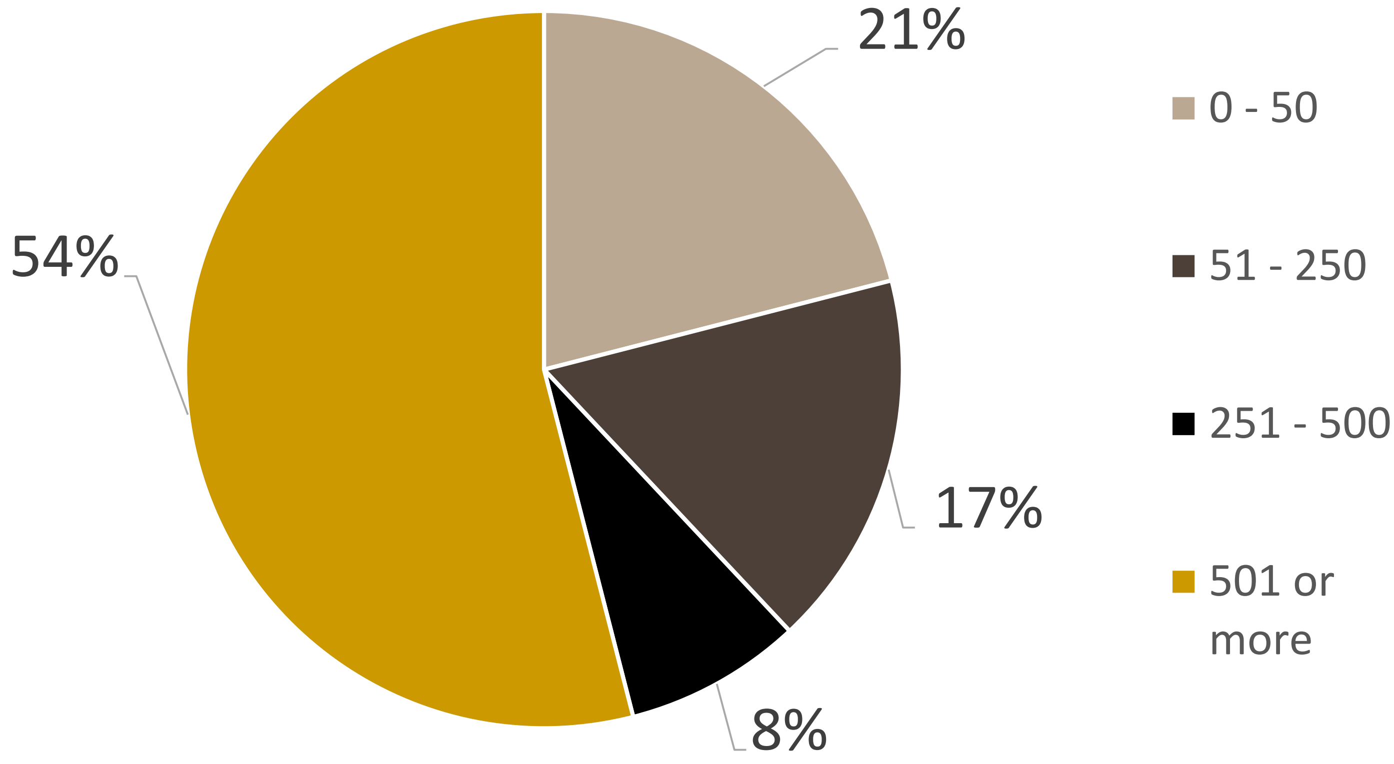
Demographics

MINIMUM INFORMATION MODEL INDUSTRY DISTRIBUTION



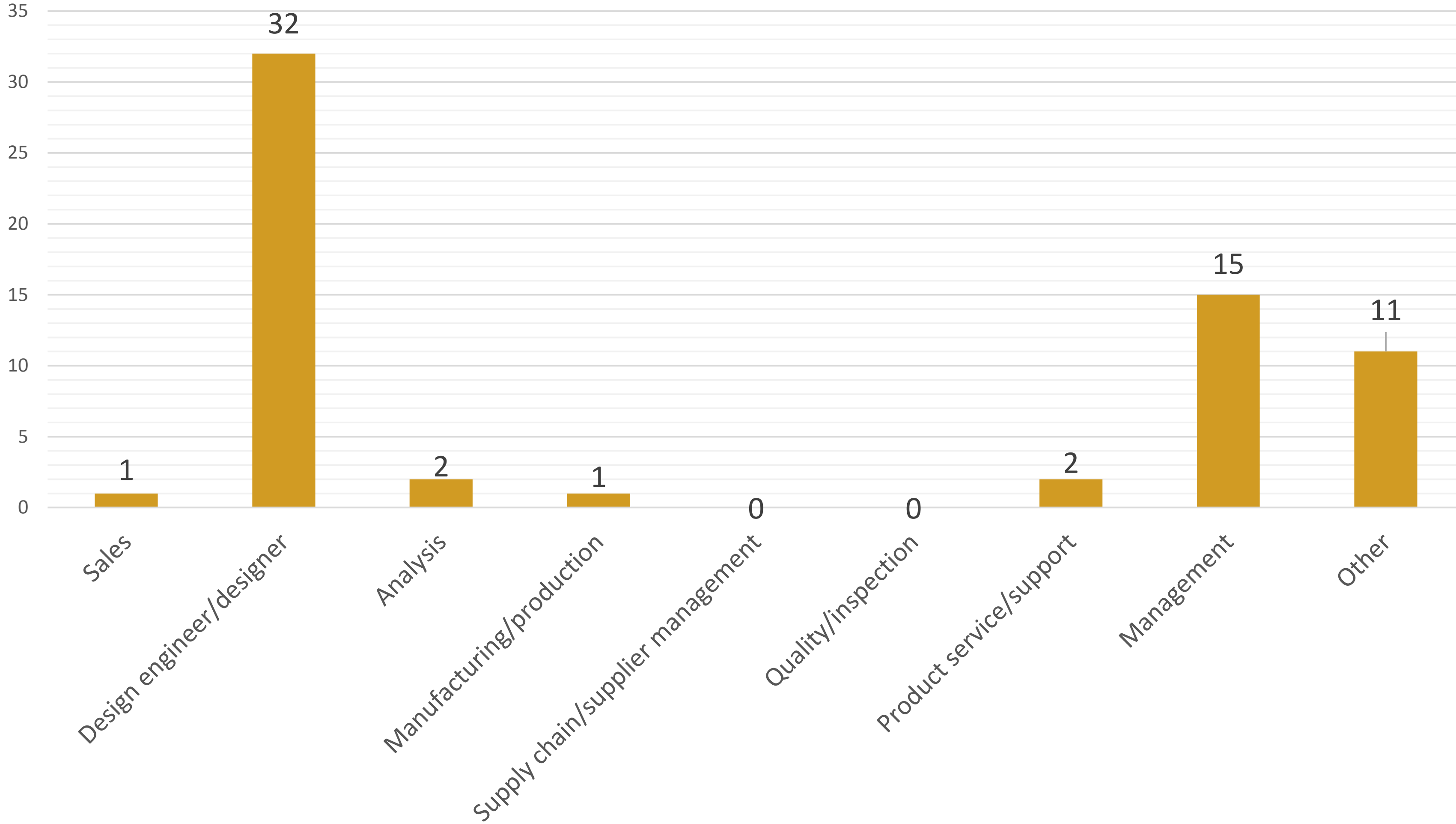
Company Size

SIZE OF COMPANIES THAT RESPONDENTS WERE WORKING IN



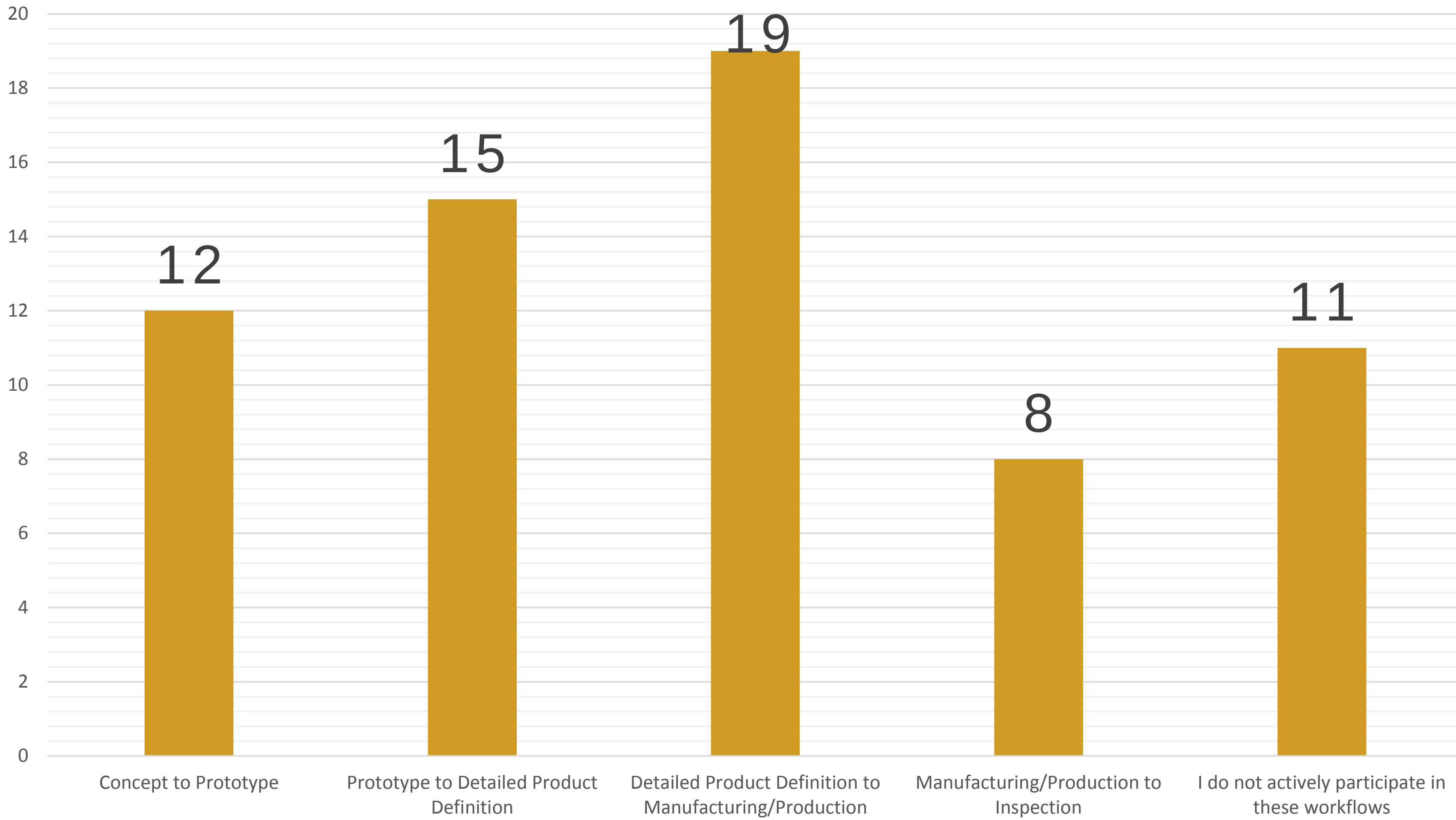
Job area

RESPONDENTS JOB AREA



Workflow Distributions

RESPONDENTS WORKFLOW PARTICIPATION



Inhibitors of MBD

SURVEY PARTICIPANTS WERE PROMPTED TO INDICATE WHAT PREVENTS USE OF MODELS IF THEY SELECTED THAT MODELS COULD NOT BE USED IN PLACE OF DRAWINGS