

DFMA DESIGN DECISION

Understanding total product cost

Nicholas P Dewhurst

Boothroyd Dewhurst, Inc. 2016

June 8th, 2016

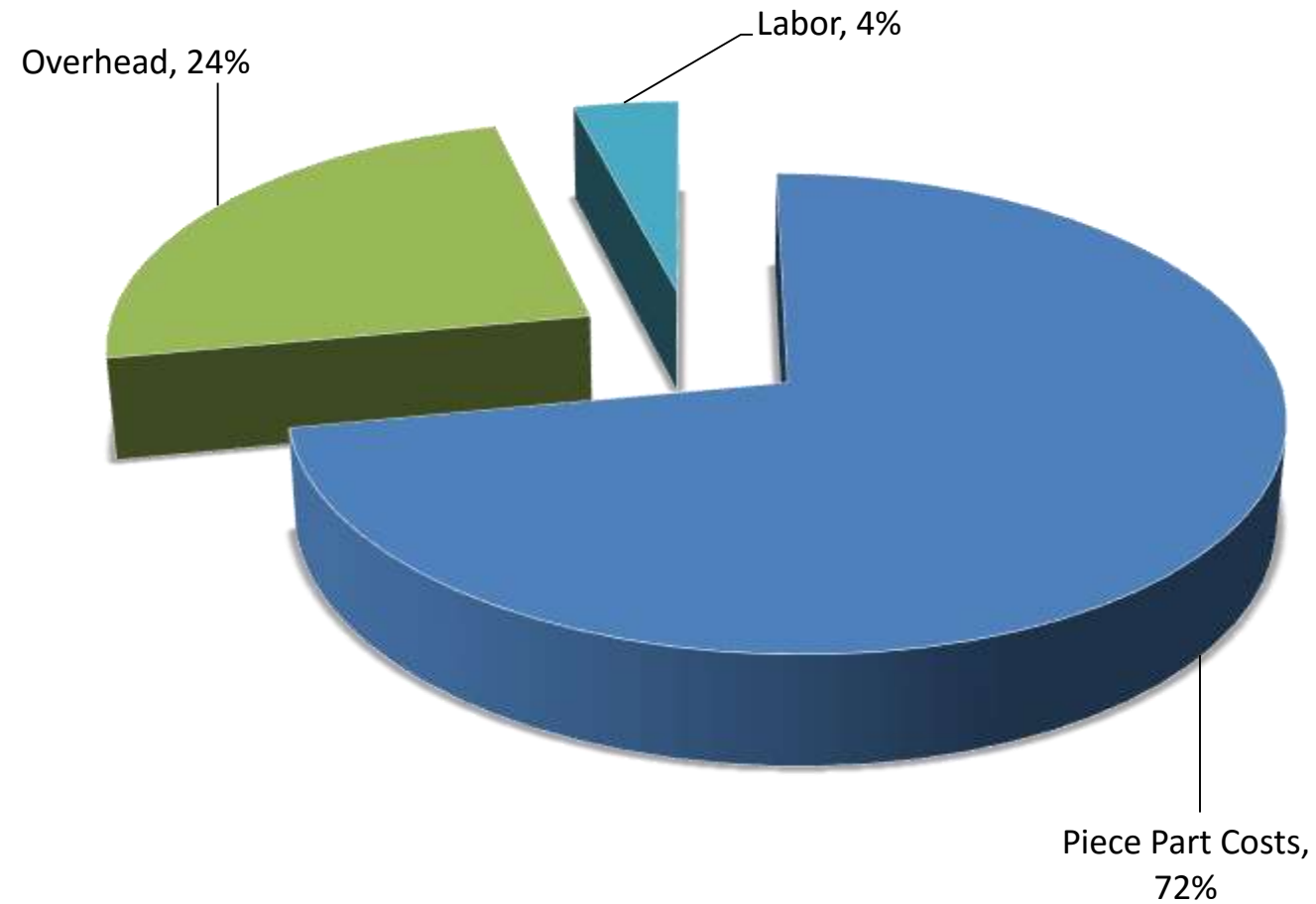
Nicholas P Dewhurst

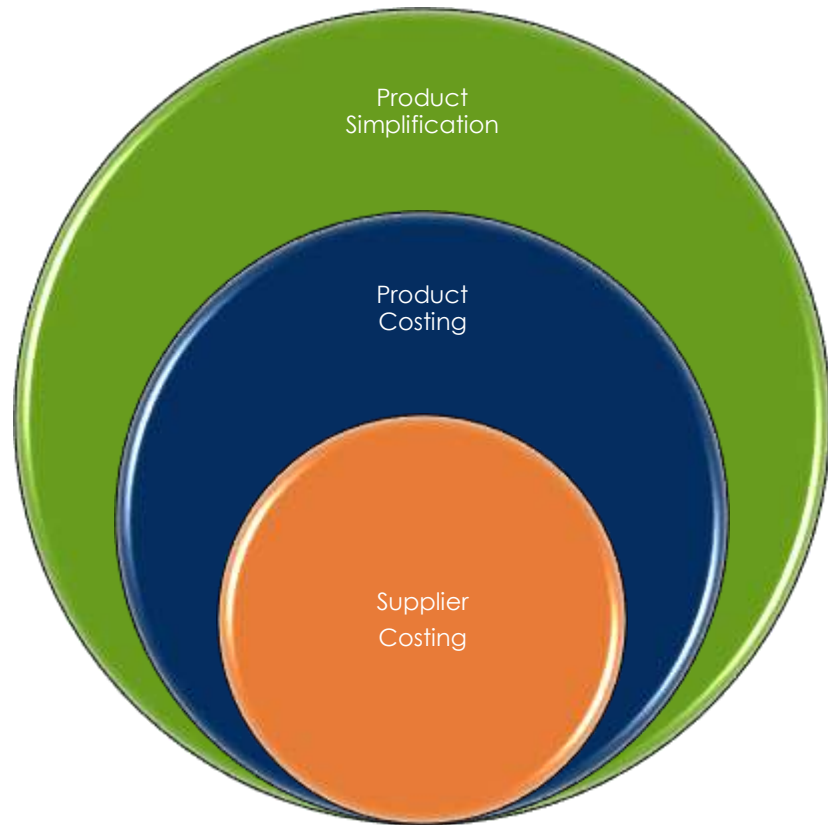
Executive Vice President
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- Background in Mechanical Engineering
- Help clients understand the benefits of DFMA
- Apply DFMA to products on a consulting basis
- Helped companies around the world make DFMA part of their product development process



Typical Product Cost Breakdown





PRODUCT SIMPLIFICATION

Our real time approach to product simplification unlocks the potential for part count reduction within your assemblies

PRODUCT COSTING

Looking at the alternative process and/ or material combinations that may lead to potential piece part cost savings

SUPPLIER COSTING

Using the outputs from our DFMA software to better negotiate price in a real time fashion

The Three main uses of DFMA

Its design decision not purchasing decision

- Purchasing can obviously use information generated by DFMA to generate savings.
- Conference title is DFMA Design Decision so that's where focus will be
- One quick case study example



Sample Case study

Supplier Negotiations

“According to our Product Management team we will sell 190,000 of these clips a year. So, it seems that the software helped us to negotiate a savings of \$361,000 on this one item.”

-VP of Engineering at a leading electronics company, May 2014

Challenge

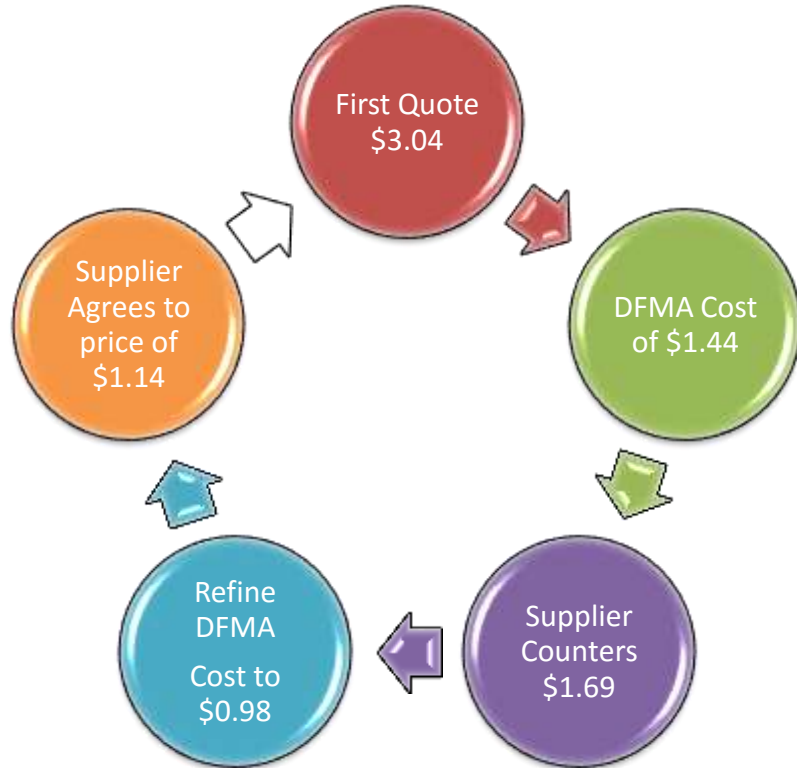
Needed young project engineers to more actively support negotiations on high production volume products to ensure best possible price.



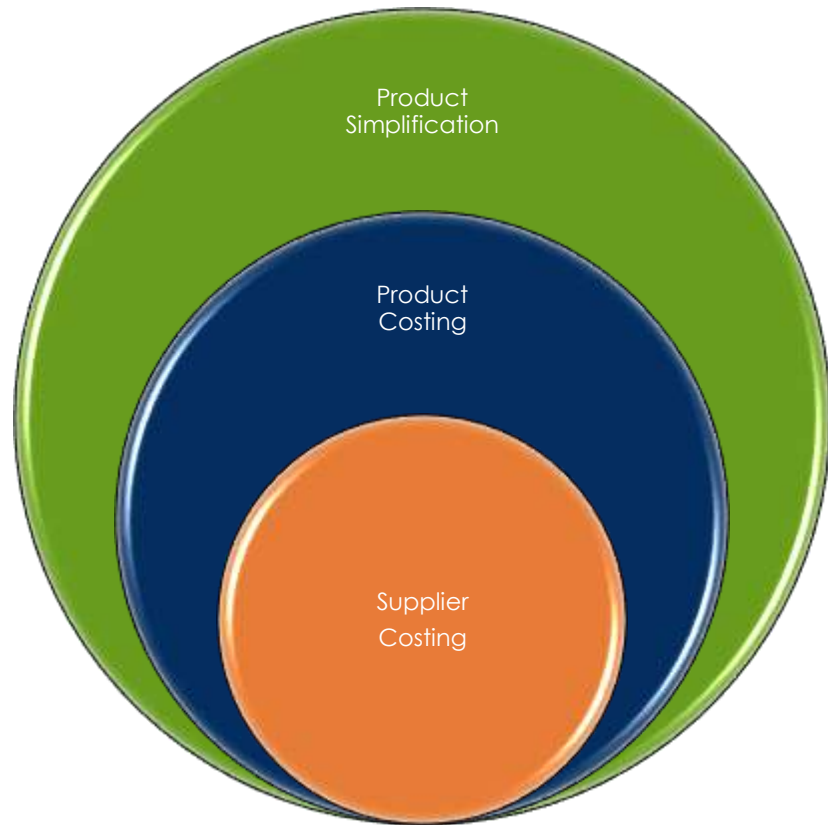
Solution

Use DFMA analysis to aide in the negotiation and apply information gathered from initial discussion to improve cost estimate accuracy in real time

Results – plastic clip assembly



- Annual Production Volume of 190,000
- ROI on software investment achieved on this single example
- Cost avoidance of \$361,000 annually



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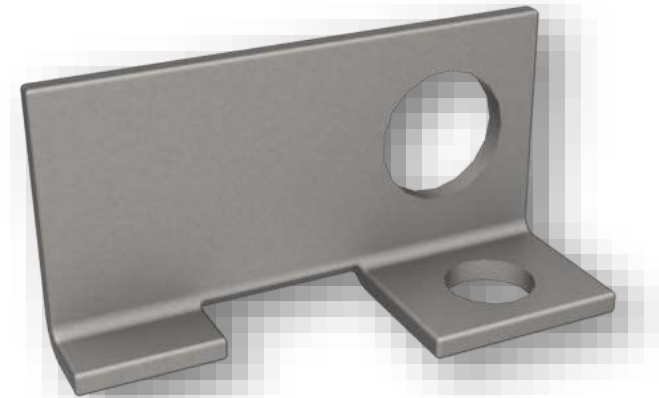
Using the outputs from our DFMA software to better negotiate price in a real time fashion

The Three main uses of DFMA

Decisions decisions decisions, what's a designer to do?

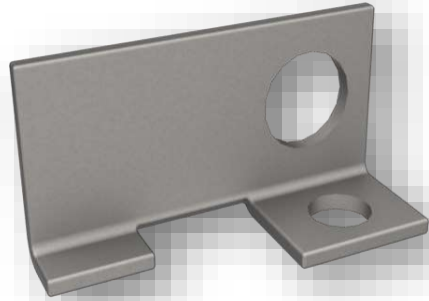
Part and manufacturing level decisions; “Product Costing”

- Cost is too high
- Corrosion is a problem
- Bending stiffness is critical and must be maintained
- Paint it, but what is the added cost?
- Might the paint crack around the mounting hole and allow for corrosion to begin?
- Make it from stainless, but what would that add in terms of cost?
- Make it from plastic but what would the tooling investment be and would we be able to maintain the stiffness requirement?



24 gage (0.61 mm) thick steel:

Alternative Designs



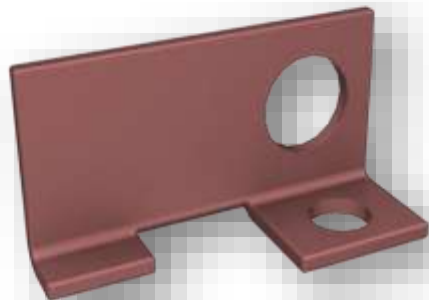
\$A

24 gage (0.61 mm) thick steel



\$C

stainless steel



\$B

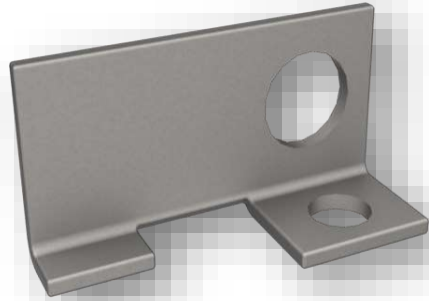
24 gage (0.61 mm) thick steel
painted



\$D

Injection molded

Cost of alternatives



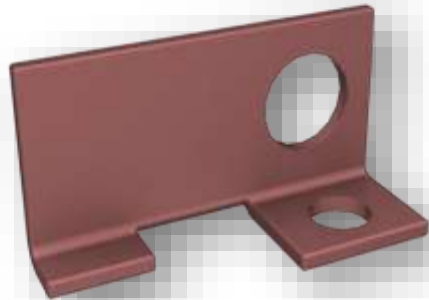
\$0.75

24 gage (0.61 mm) thick steel



\$2.42

stainless steel



\$1.31

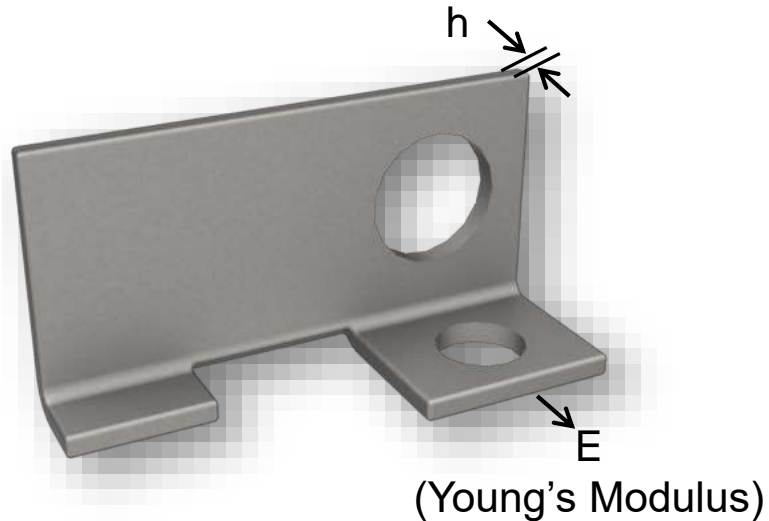
24 gage (0.61 mm) thick steel
painted



\$0.61

Injection molded

Injection Molding example



Bending stiffness depends upon $E h^3$

For equivalent stiffness of materials 1 and 2

$$E_2 h_2^3 = E_1 h_1^3$$
$$\text{or } h_2 = h_1 (E_1/E_2)^{1/3}$$

Thickness with equivalent stiffness to 24 gage (0.61 mm) thick steel:

$$\text{Polyethylene; } h = 0.61 (207,000/925)^{1/3}$$
$$= 3.7 \text{ mm}$$

$$\text{ABS; } h = 0.61 (207,000/2,100)^{1/3}$$
$$= 2.8 \text{ mm}$$

$$\text{Polycarbonate (30\% glass); } h = 0.61 (207,000/5,500)^{1/3}$$
$$= 2.0 \text{ mm}$$

Injection Molding example

Polymer Processing Data

Thermoplastic	Thermal diffusivity, α (mm ² /s)	Injection temp., T_i (°C)	Mold temp., T_m (°C)	Ejection temp., T_x (°C)
H.D. polyethylene	0.11	232	27	52
Polypropylene (40% talc)	0.08	218	38	88
ABS	0.13	260	54	82
6/6 Nylon	0.10	291	91	129
Polycarbonate	0.13	302	91	127
Polycarbonate (30% glass)	0.13	329	102	141

Injection Molding example

$$t_c = 4 + 15 (w_t - 0.1) + kh^2$$

where w_t = shot weight, kg

$$k = \frac{1}{\Pi^2 \infty} \log_e \frac{4 (T_i - T_m)}{\Pi (T_x - T_m)} \text{ sec.}$$

h = maximum wall thickness, mm

Examples

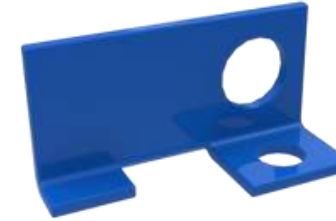
Polyethylene; $k = 2.16 \text{ sec/mm}^2$

ABS; $k = 1.74 \text{ sec/mm}^2$

PC (30% glass); $k = 1.56 \text{ sec/mm}^2$

PP (40% talc); $k = 1.93 \text{ sec/mm}^2$

Injection Molding example

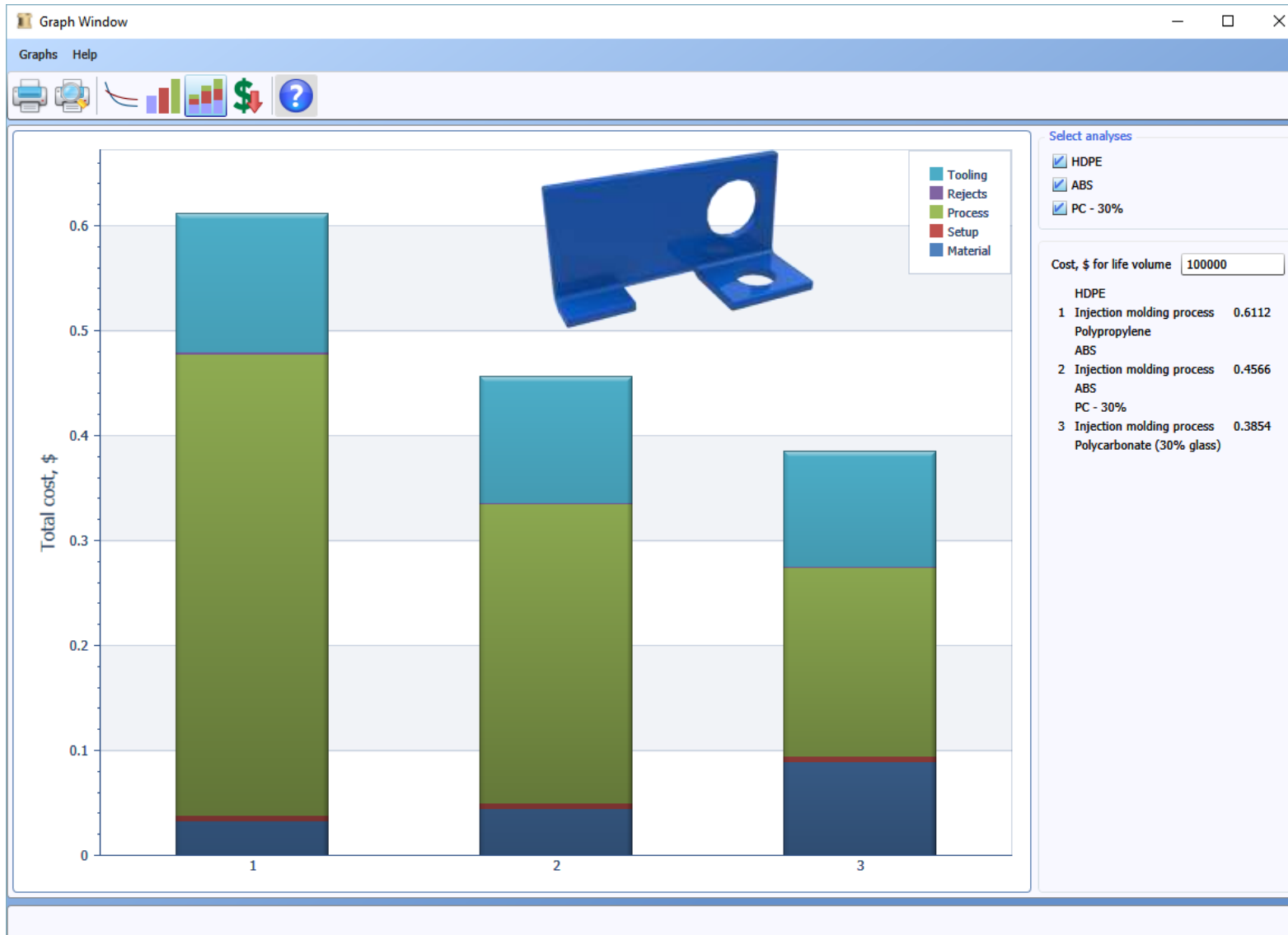


Criterion: Equivalent bending stiffness to 24 gage steel (0.61 mm)

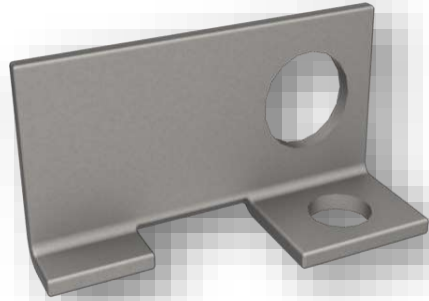
Material	Thickness (mm)	Cooling time (sec)	Process cost*
Polyethylene	3.7	29.6	\$0.68
ABS	2.8	13.6	\$0.31
PC (30% glass)	2.0	6.2	\$0.14

** based on same machine; cooling time only*

Injection Molding example



Final Design Decision Result



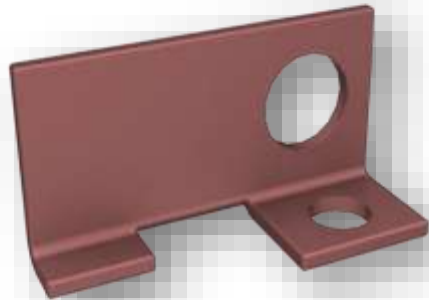
\$0.75

24 gage (0.61 mm) thick steel



\$2.42

stainless steel



\$1.31

24 gage (0.61 mm) thick steel
painted

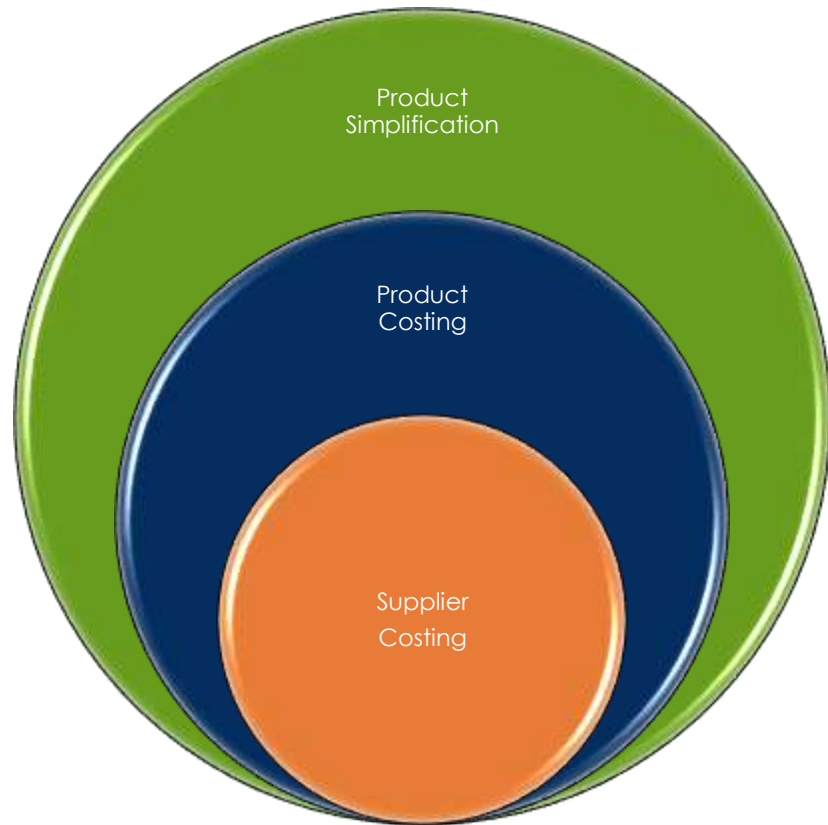


\$0.61

\$0.39

Includes amortized tooling cost

Injection molded



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SUPPLIER COSTING

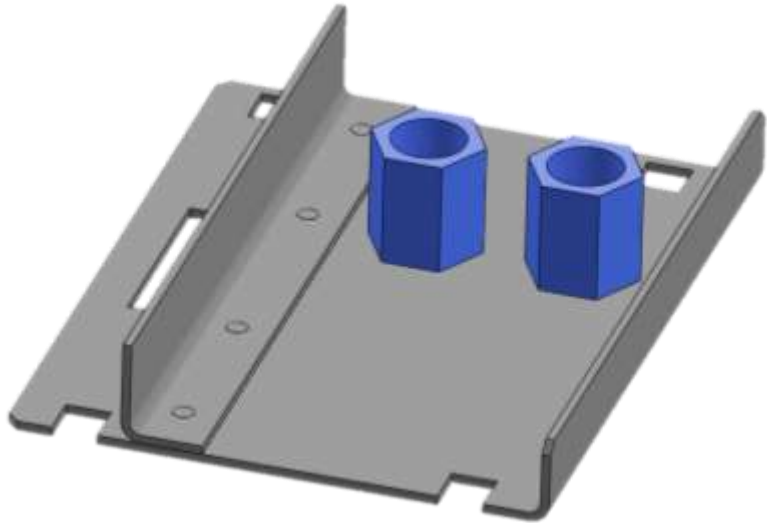
Using the outputs from our DFMA software to better negotiate price in a real time fashion

The Three main uses of DFMA

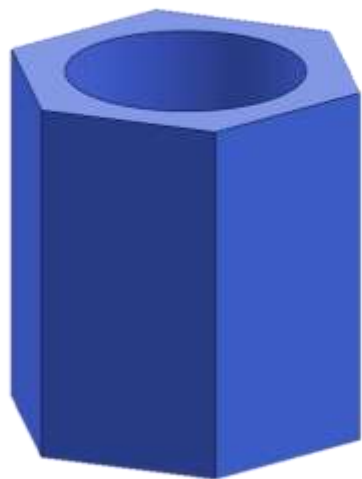
DFA as a design decision tool

- Guides a team through a series of steps to ensure part count efficiency
- Simply changes rarely have dramatic impacts on cost
- People are generally risk averse and making significant changes is difficult
- Better to implement early in the design process so there isn't as much to change
- Payoff in upfront design time is tremendous, you just have to believe

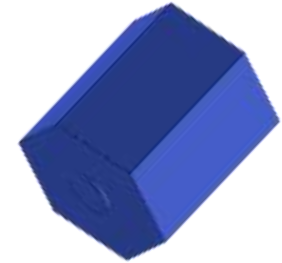
Sample Product Design



- Simple to design
- Use of off the shelf components
- No tooling investment required
- Fixtures required for welding and alignment
- Prototype or production



Sample Assembly – Part 1



DFM Concurrent Costing 3.0 [C:\Users\ndewhurst\OneDrive - Boothroyd Dewhurst, Inc\Cost Justified Design\Standoff - CAD analysis.dfm]

File Edit Insert Analysis External Libraries Results Help

Assembly A - Part1 Standoff-2

Generic low carbon steel machined/cut from st

- Stock process
 - Workpiece
- Hass SL-10 CNC lathe
 - Setup/load/unload
 - Finish face
 - Finish cylindrical turn

Part

Part name: 3/8" hex pipe cap

Part number: []

Life volume: 2,000

Manufacturing profiles

Current profile: BDI North America

Select a different profile...

Envelope shape

Solid cylinder, Hollow cylinder, Solid block, Hollow block, Stepped block

CAD view

Thumbnail picture: [Load file]

Approximate envelope dimensions

CAD model is in millimeters

X axis, in: 1.010

Y axis, in: 1.025

Z axis, in: 0.875

Average thickness, in: 0.100

Select process and material...

Notes: []

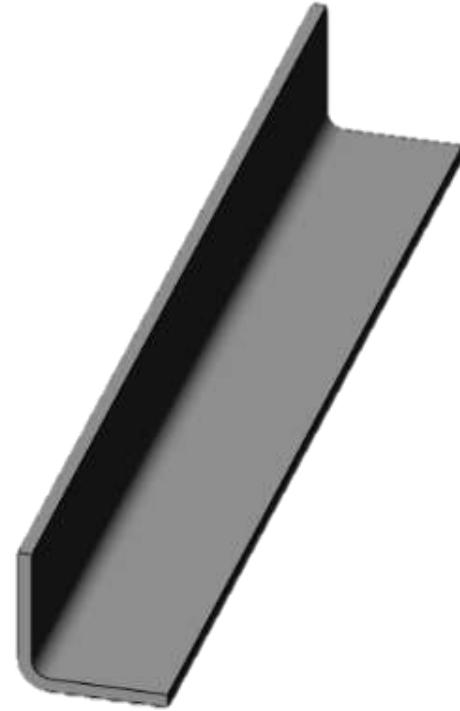
Cost results, \$

	Previous	Current
material	1.1400	1.1400
setup	0.1301	0.1031
process	0.3067	0.3067
rejects	0.0073	0.0073
piece part	1.5921	1.5572
tooling	0.0000	0.0000
total	1.5921	1.5572
Tooling investment	0	0

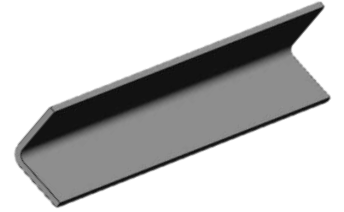
Manufacturing profile: BDI North America | Total piece part cost = \$1.5572 | Total initial tooling investment = \$0 | Total cost per part = \$1.5572

Cost Breakdown	Cost, \$
Material	\$1.1400
Setup	\$0.1031
Process	\$0.3067
Rejects	\$0.0073
Piece Part Cost	\$1.5572

Part 1 Analysis – Details



Sample Assembly – Part 2



DFM Concurrent Costing 3.0 [C:\Users\ndewhurst\OneDrive - Boothroyd Dewhurst, Inc\Cost Justified Design\Stiffener - CAD.dfm]

File Edit Insert Analysis External Libraries Results Help

Part2 Stiffener, short leg down

Generic low carbon steel sheet metal part

- Laser cutting process
 - Cincinnati CL-6 Laser System
 - Load and unload
 - Laser cut operation
 - Amada F801D-8025 Hydraulic Press Brake
 - Acquire and set-aside part
 - Form bends

Part

Part name: Part2 Stiffener, short leg down

Part number: []

Life volume: 1,000

Manufacturing profiles

Current profile: BDI North America

Select a different profile...

Envelope shape

Solid cylinder, Hollow cylinder, Solid block, Hollow block, Shaped block

CAD view

Thumbnail picture: Load file

Approximate envelope dimensions

CAD model is in millimeters

X axis, in: 0.717

Y axis, in: 0.917

Z axis, in: 6.000

Average thickness, in: 0.076

Forming direction

Select process and material...

Notes

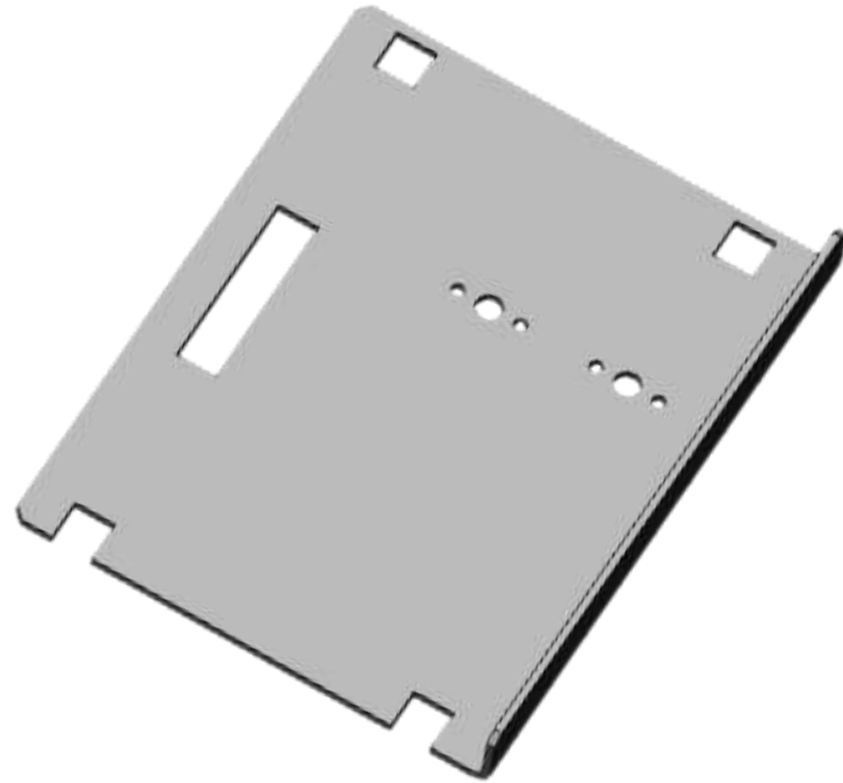
Cost results, \$

	Previous	Current
material	0.1188	0.1188
setup	0.0947	0.4720
process	0.2323	0.2323
rejects	0.0030	0.0030
piece part	0.3588	0.8261
tooling	0.0000	0.0000
total	0.3588	0.8261
Tooling investment	0	0

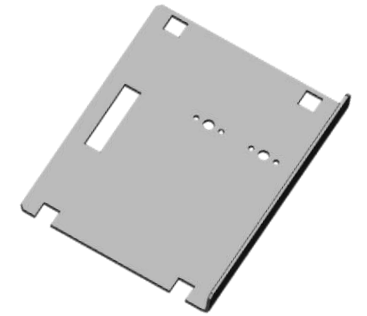
Manufacturing profile: BDI North America | Total piece part cost = \$0.8261 | Total initial tooling investment = \$0 | Total cost per part = \$0.8261

Cost Breakdown	Cost, \$
Material	\$0.1188
Setup	\$0.4720
Process	\$0.2323
Rejects	\$0.0030
Piece Part Cost	\$0.8261

Part 2 Analysis - Details



Sample Assembly – Part 3



DFM Concurrent Costing 3.0 [C:\Users\ndewhurst\OneDrive - Boothroyd Dewhurst, Inc\Cost Justified Design\Stiffener - CAD.dfm]

File Edit Insert Analysis External Libraries Results Help

Part2 Stiffener, short leg down

Generic low carbon steel sheet metal part

- Laser cutting process
 - Cincinnati CL-6 Laser System
 - Load and unload
 - Laser cut operation
 - Amada F80111-0025 Hydraulic Press Brake
 - Acquire and set-aside part
 - Form bends

Cost results, \$

	Previous	Current
material	0.1188	0.1188
setup	0.0947	0.4720
process	0.2323	0.2323
rejects	0.0630	0.0630
piece part	0.3588	0.8261
tooling	0.0000	0.0000
total	0.3588	0.8261
Tooling investment	0	0

Part name: Part2 Stiffener, short leg down
 Part number:
 Life volume: 1,000

Manufacturing profiles
 Current profile: BDI North America

Envelope shape

Approximate envelope dimensions
 CAD model is in millimeters
 Forming direction
 X axis, in. 0.717
 Y axis, in. 0.917
 Z axis, in. 6.000
 Average thickness, in. 0.076

Notes

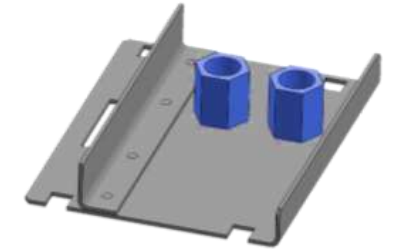
Thumbnail picture

Manufacturing profile: BDI North America | Total piece part cost = \$0.8261 | Total initial tooling investment = \$0 | Total cost per part = \$0.8261

Cost Breakdown	Cost, \$
Material	\$0.3197
Setup	\$0.4720
Process	\$0.5582
Rejects	\$0.0080
Piece Part Cost	\$1.3579

Part 3 Analysis - Details

Assembly Fabrication



DFM Concurrent Costing 2.4 [C:\Users\ndewhurst\OneDrive - Boothroyd Dewhurst, Inc\Cost Justified Design\Plate and standoffs.DFM]

File Edit Analysis View Reports Graphs Tools Help

Assembly fabrication\Generic low carbon steel\Steel

- Assembly fabrication process
 - Plate
 - Acquire plate and place on bench
 - Stiffener
 - Acquire stiffener piece on plate
 - Secure parts together with vice grips
 - Spot welding
 - Remove vice grips
 - Spot welding
 - 3/8" hex pipe cap
 - Acquire pipe caps and place in fixture
 - Acquire and insert plate/stiffener into fixture
 - Secure parts in jig
 - Manual MIG/TIG plug welds
 - Remove assembly

Part: Part name: Plate fabrication
Part number:
Life volume: 1,000

Envelope shape:

Approximate envelope dimensions, in.: 1 0.07 average thickness:
6 4
Forming direction: Y Z X

Select process and material...

Picture: Load Save Show to fit Transparent

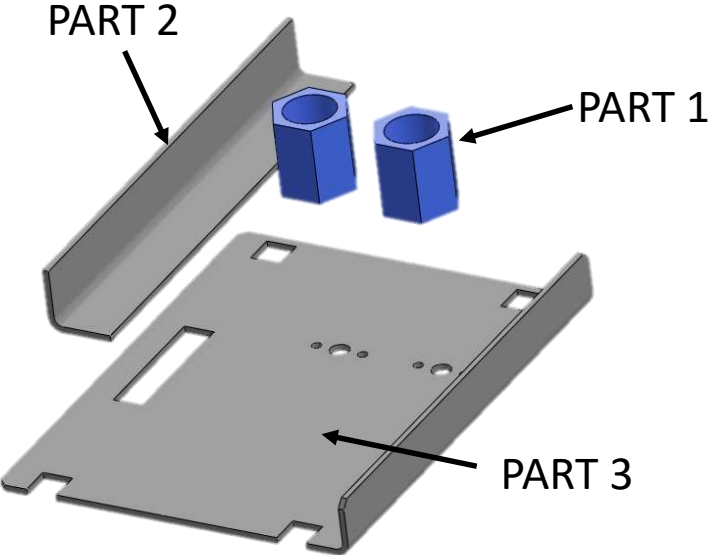
Notes:

Cost results, \$	Previous	Current
material	2.6724	2.6724
setup	1.0958	1.5130
process	6.3104	6.2049
rejects	0.0259	0.0253
piece part	10.0144	10.4156
tooling	0.0500	0.0000
total	10.0144	10.4156
Tooling investment	0	0

Cost Breakdown	Cost, \$
Material	\$2.6724
Setup	\$1.5130
Process	\$6.2049
Rejects	\$0.0253
Piece Part Cost	\$10.4156*

*Total cost including assembly and welding at a rate of \$65/hr.

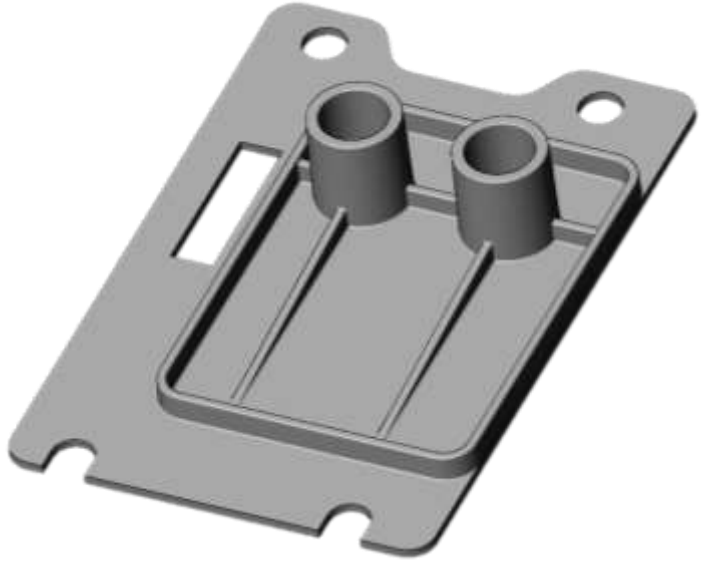
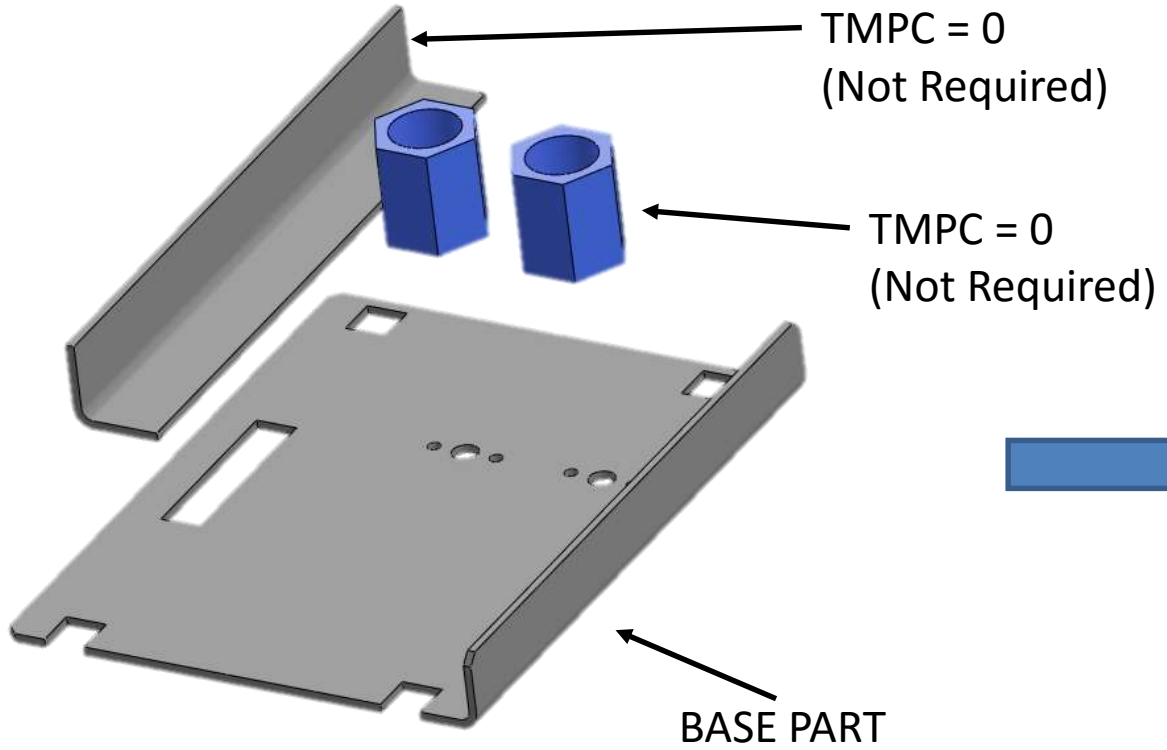
Cost Summary



Cost Breakdown	Cost, \$
Part 1	\$1.5572
Part 2	\$0.8261
Part 3	\$1.3579
Assembly Time	3.715 min.
Assembly Fabrication	\$10.4156*

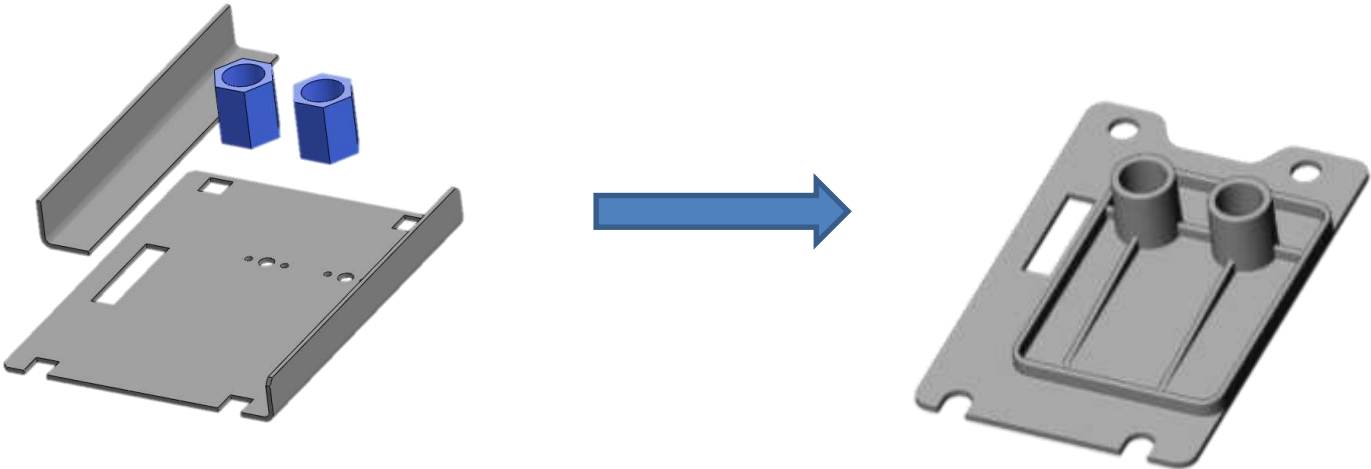
*Total cost including assembly and welding at a rate of \$65/hr.

Apply DFA

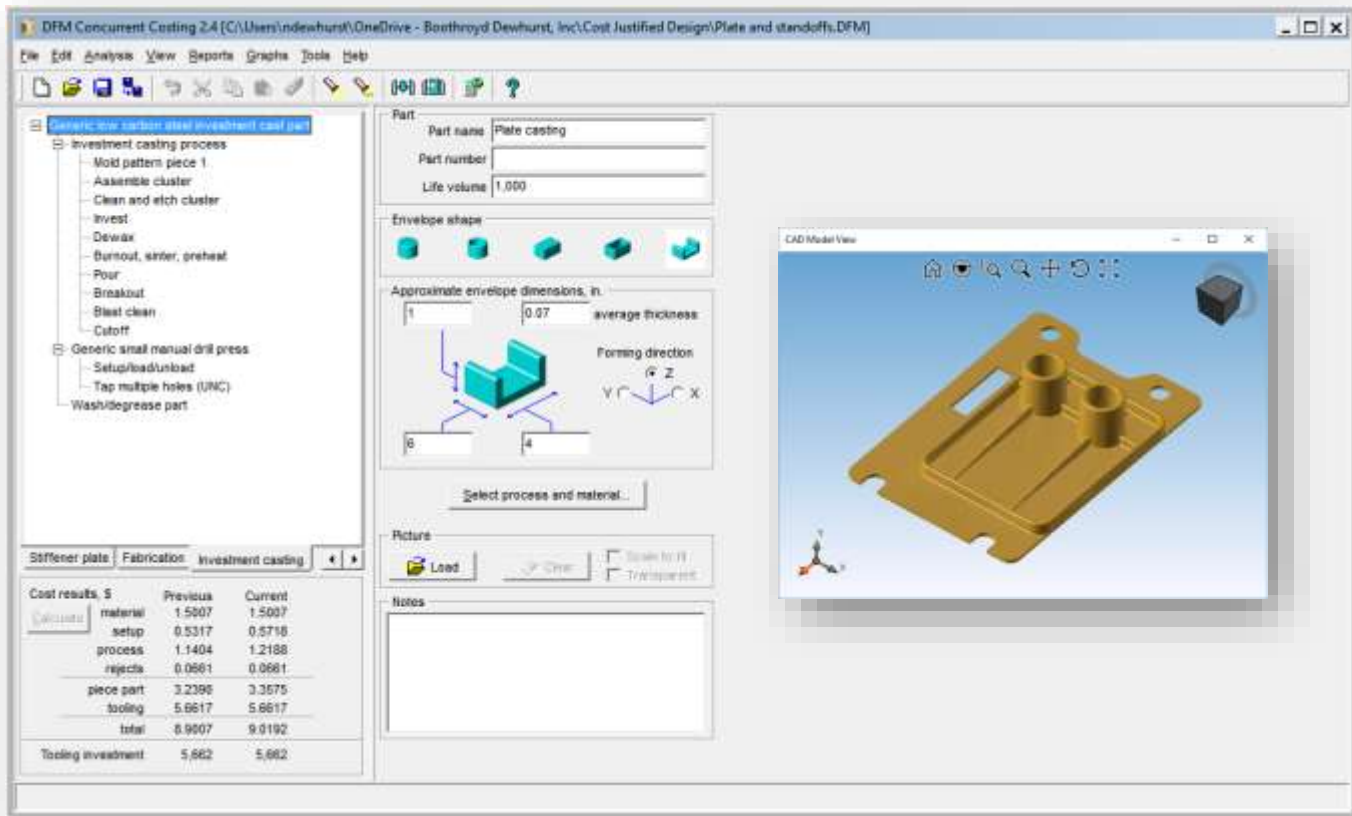


Single Piece Investment Casting

Apply DFMA



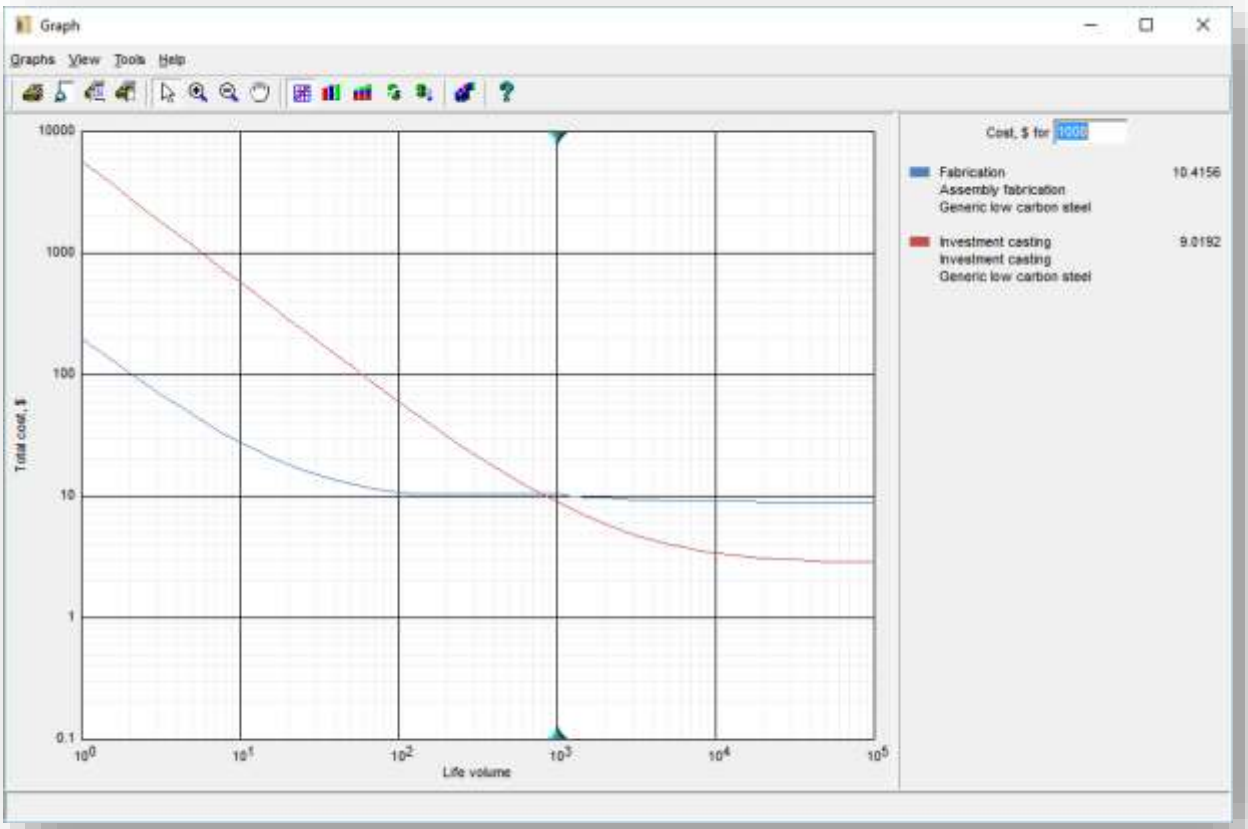
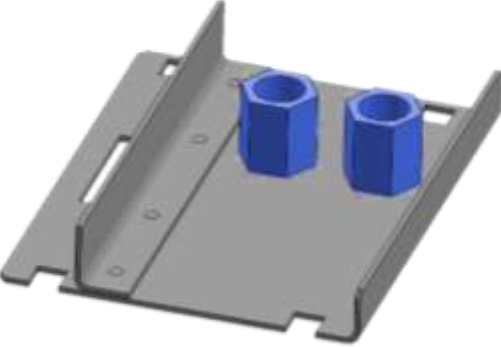
Great DFA idea and a great concept but what will it cost to manufacture?



Cost Breakdown	Cost, \$
Material	\$1.5007
Setup	\$0.5718
Process	\$1.2188
Rejects	\$0.0661
Piece Part Cost	\$3.3575
Tooling Investment	\$5,662
Total Cost	\$9.0192

Production part – Details

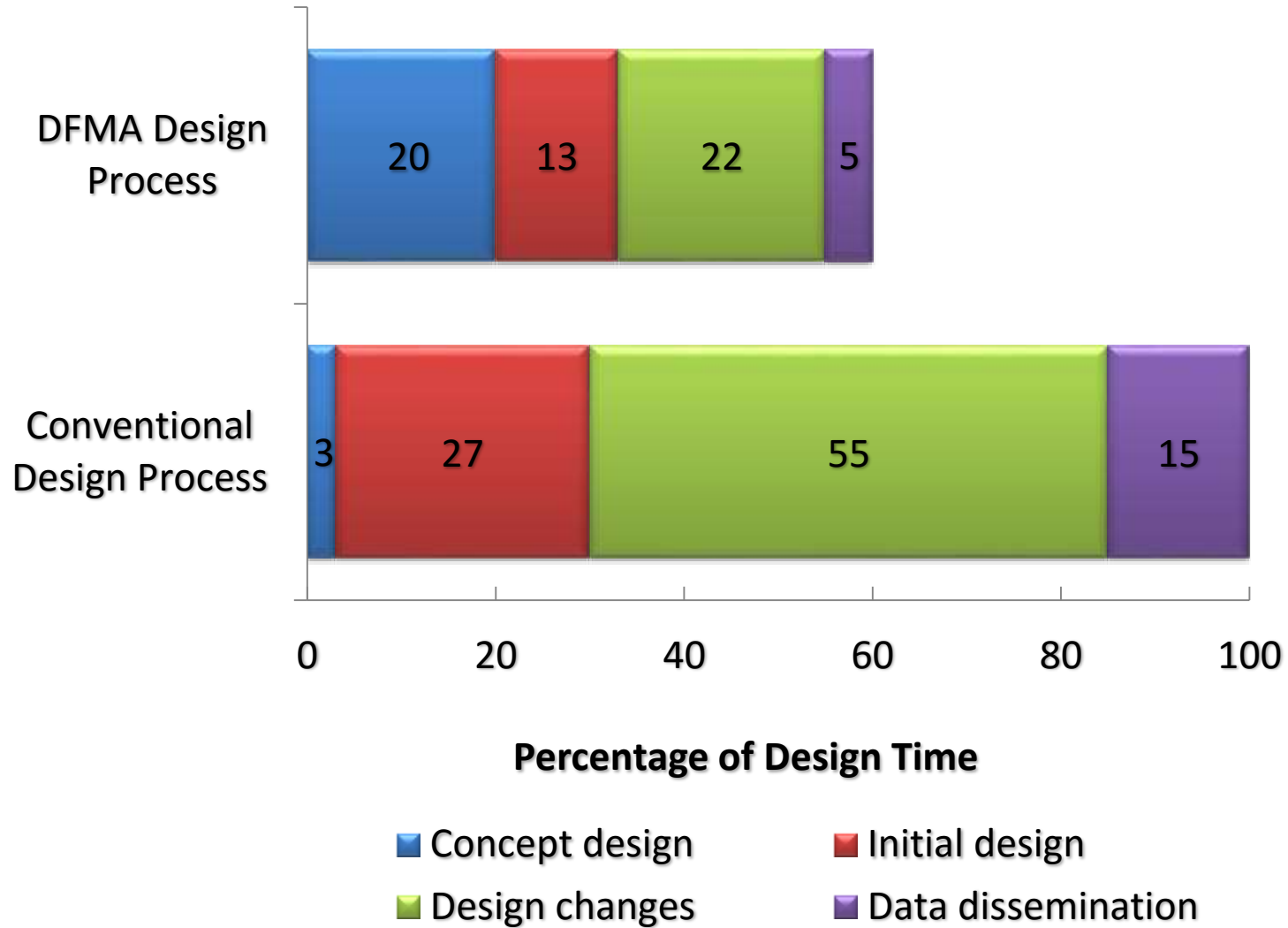
Summary Results Using DFA Design Decision



Design	Cost, \$
Assembly Fabrication	\$10.4156
Investment Casting	\$9.0192



DFMA's Impact on Design Cycle



Design Decision Summary & Conclusions

- Cost information in the hands of purchasing is invaluable
- Trade offs in part design, manufacture, and material must be considered early in the development process
- Time to design 'simple' parts individually is less than more complex ones
- Cost impact of products made from lots of 'simple' parts can be significant
- Tooling investments are often seen as a barrier to entry but true understanding of actual costs are rare
- Cost of production of products made from 'simple' parts are surprisingly high
- Labor impact on production is usually not the focus but can sway decision making
- Cost tools should really be a requirement in the design decision process
- If you aren't using cost to make design decisions you really should
- Have engineers justify the cost of their designs