Designing Differently

There and Back Again

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Where do great designs come from ?

- Throughout recorded history there have been individuals that where great engineers, designers, project leaders, true visionaries.

Designing Differently

Widely credited with the invention of the telephone

Hydrofoil HD-4 in 1919 speed record of 114Km/hr. Record stood for several decades

Tetrahedral kites

Photo Phone

Quotes:

The devil is in the details

-Ludwig Mies van der Rohe

- **The details are not the details. They**
- **make the design.**

- Ray & Charles Eames

Designing Differently

Kelly Johnson famed aeronautical & system engineer. Credited with designing over 38 major aircraft in his lifetime including the P-38 , Kingfisher, most famously SR-71 Blackbird and U2 spy plane

His colleagues claimed he could see “air”

LOCKHEED MARTIN
SKUNK WORKS

Designing Differently

Engineering History trivia

Designing Differently

Engineering History trivia ?

The first recorded patent for an industrial invention was granted
When

OR

to Whom

Designing Differently

Fillippo Brunelleschi 1377-1446

- Patent granted 1421
- Credit with rediscovery of linear perspective
- One of the founders of the renaissance

The Santa Maria del Fiore cathedral in Florence possesses the largest brick dome in the world,[2][3] and is considered a masterpiece of European architecture.

Designing Differently

So if you are not one of the great designers of time how do you get a great design ?

Designing Differently

First a history lesson

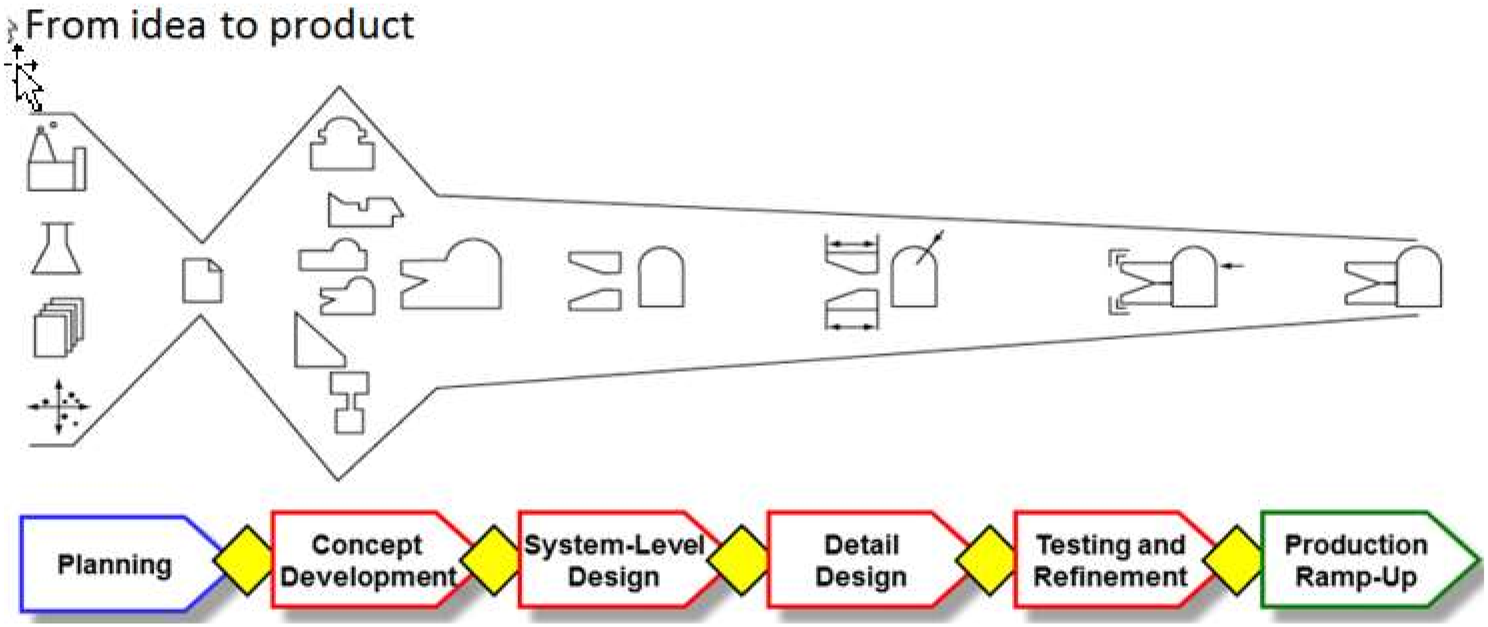
- 1988 Committee for the Advancement of Competitive Manufacturing formed, Members included GM, Ford, Loctite, DEC, Navistar, Allied Signal

- 1989- 1991 DFA 5.0 released with PCB analysis, Sheet metal
  DFM released, DFA 5.1 released supporting Macintosh and VMS, Die casting and Powder metal DFM software released.

- 1991 – 1994 Newer versions of DFA, Large parts DFA, and
  Design for the Environment, and additional DFM modules released

Designing Differently

The resulted was a methodology and modular software tool that is customizable, easy to use, and capable of being used during the entire Product Development process



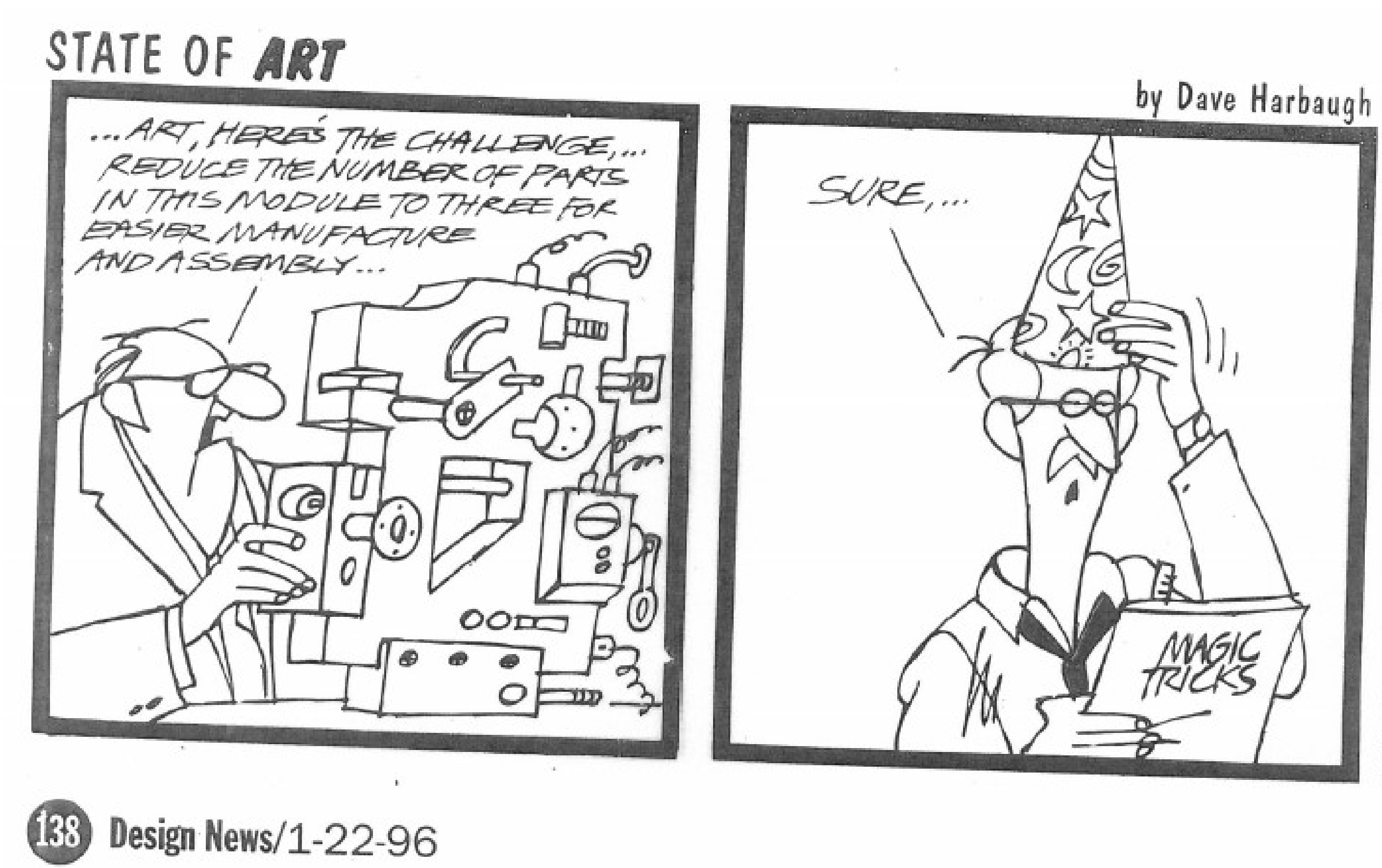
Product Design and Development Eppinger & Ulrich 5th edition

Designing Differently

The application of the methodology and software tool can be applied:

- Bottoms up
- Top down
- Subassemblies
- Single Parts
- Labor
- Quality Prediction
- Cost Estimates
- Almost anything you can think of ……..

A couple of prerequires:



Product Development Design Process

- A high Quality new product development process
- A clear well communicated new product development strategy
- Adequate resources
- Senior management commitment to new products
- An entrepreneurial climate
- Senior management accountability
- Strategic focus and synergy
- High quality development teams
- Cross functional teams

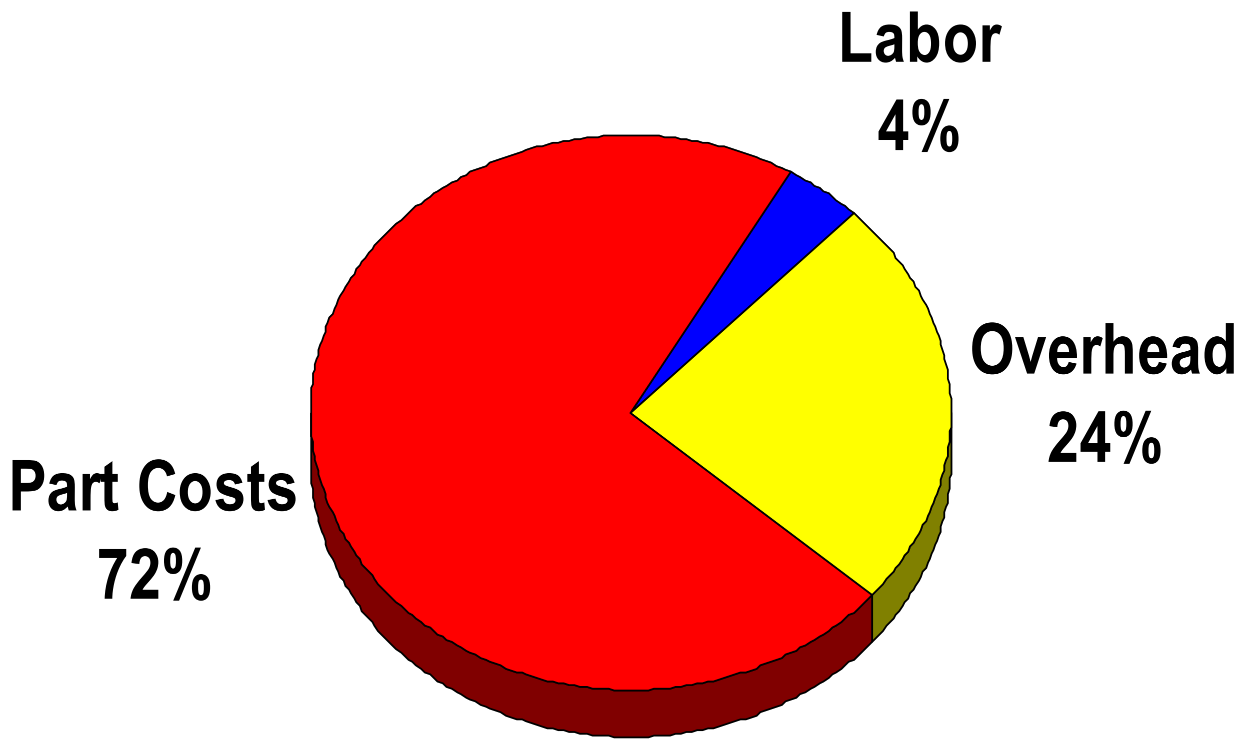
Source: Benchmarking the firm's Critical Success Factors in New Product Development Robert G. Cooper and Elko Kleinschmidt, Journal of Innovation Management, 1995 12: 374-391

Product development

DFMA can be used throughout the entire Product Development Process

- **Early Product Costing**
- Competitive product benchmarking
- Concept selection
- Creation of time standards
- Assembly Instructions
- Deign Simplification
- Cost reduction
- Quality
- Vendor quote verification
- Estimate hard tooling

Typical Product Cost Breakdown



Source : The True Cost of Oversea Manufacturing June 2004 N. Dewhurst & D. Meeker

Define Levels of Cost Analysis

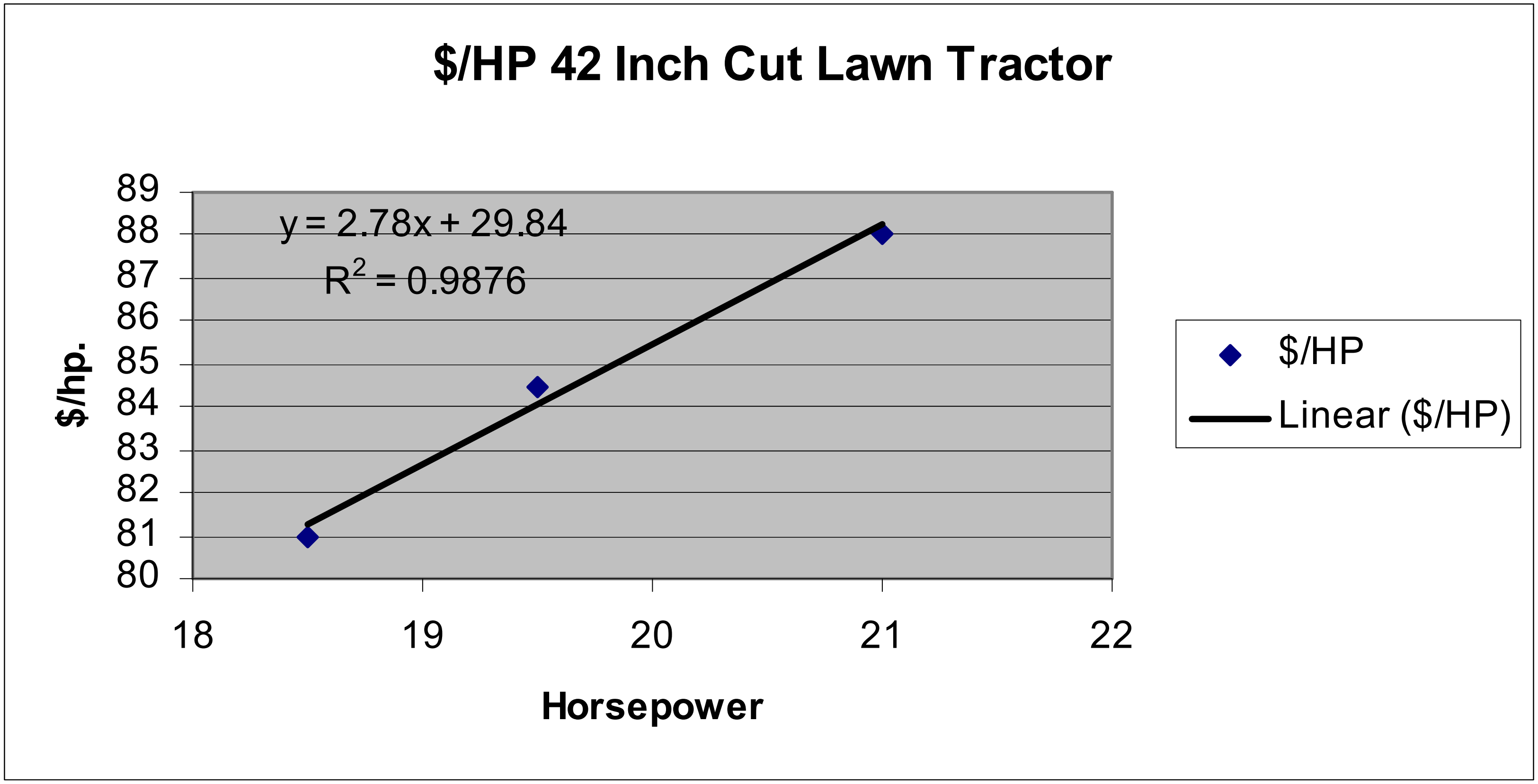
Level 1 **- A first impression by knowledgeable engineers of what a part , assembly or system would cost based on prior experience. (parametric)**

Level 2 **- An estimation based on prior experience with similar products, budgetary estimates, vendor quotes and expert opinion and experience. (analogy)**

Level 3 **- Detailed costing of every part accomplished by using material cost estimation data bases, and time/motion studies. A high degree of accuracy is achieved by comparisons to industry standards and vendor quotes. (analytical)**

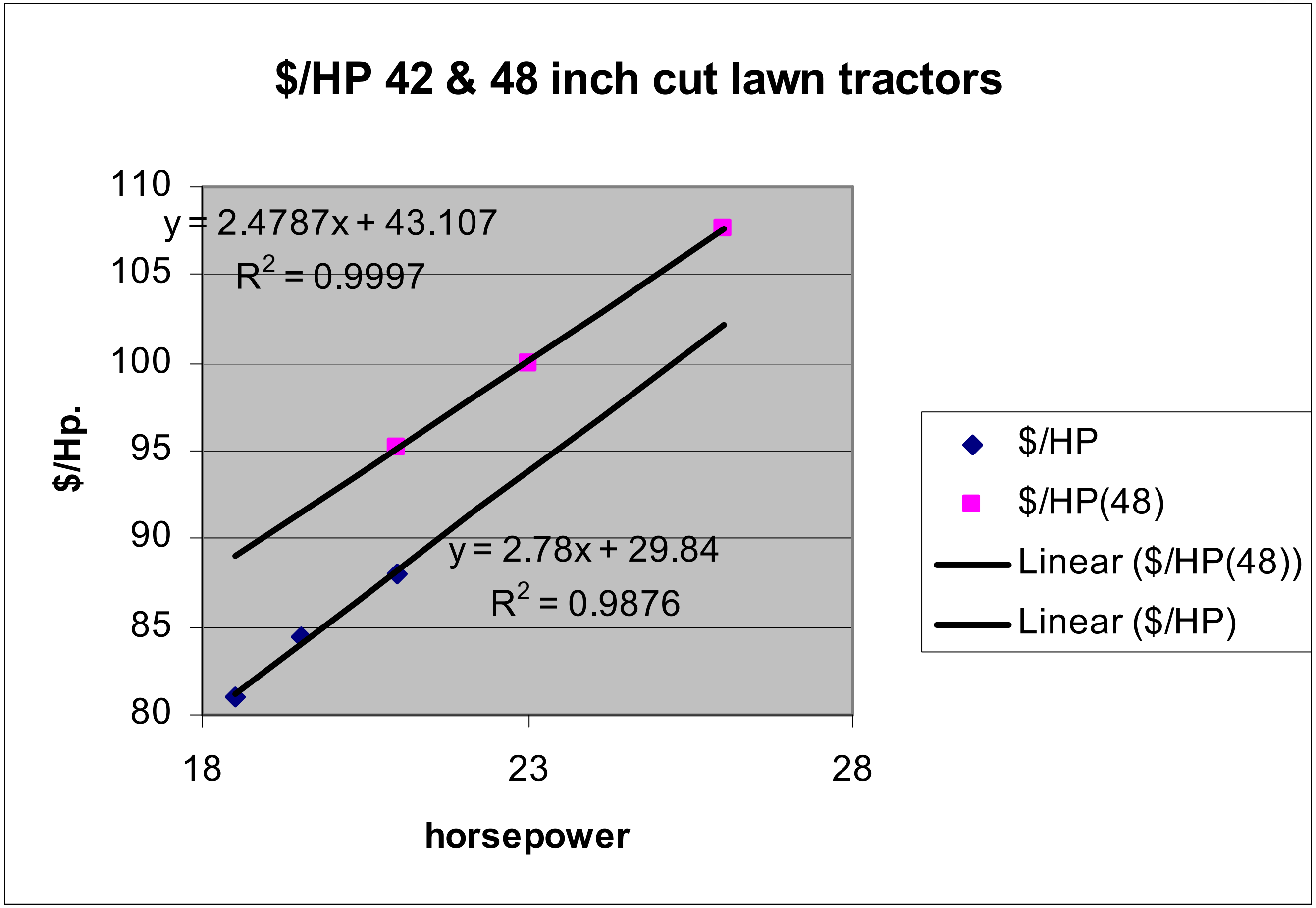
Trend Line Analysis

Tractor example



Trend Line Analysis

Tractor example



Trend Line Analysis

Next steps:

Break lawn tractor into major subassemblies

Project trend lines for each major subassembly

- Next level is to break down material content of
- each major subassembly, to incorporate material trends.

Best paper on topic is "Controlling New Product Cost Through Trend Analysis" by Terry Ayer Teradyne, Inc. May 2004 B&D conference

Product development

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Product Benchmarking

Only the Paranoid Survive"

Andy Grove

Building better products requires a good comparative perspective about other companies to gain insight into other sources of outstanding performance

Product Development Performance
Kim Clark & Takahiro Fujimoto

Definitions

Benchmarking

- Is the continuous process of measuring products,services and practices against the toughest competitors or those recognized as industry leaders.

Competitive Intelligence

- Is the process of gleaming and combining disparate information about a competitor in order to deduce its objectives.

Reverse Engineering

- Is the systematic dismantling of a product to understand its technology with the purpose of replication.

Tape Measures



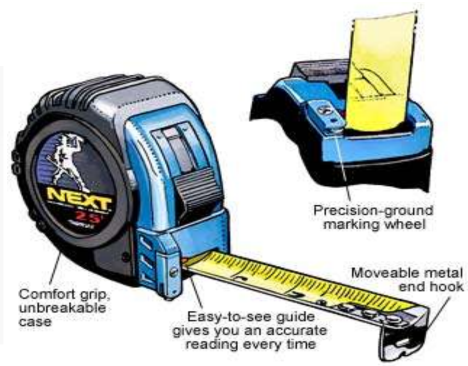












DPV





Submerge

Torpedo



SEA-DOO

Stealth
MAXX

SEA-DOO


Paradon

TIGER RAY

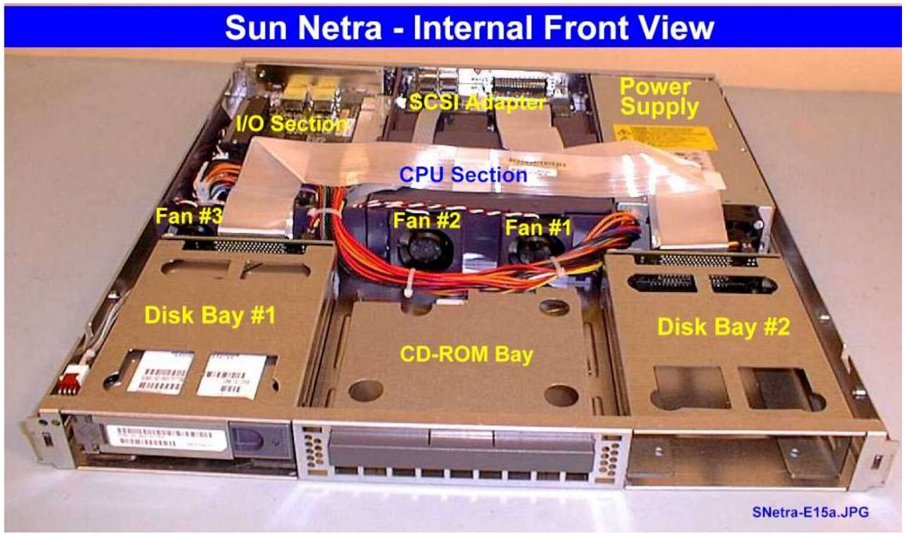


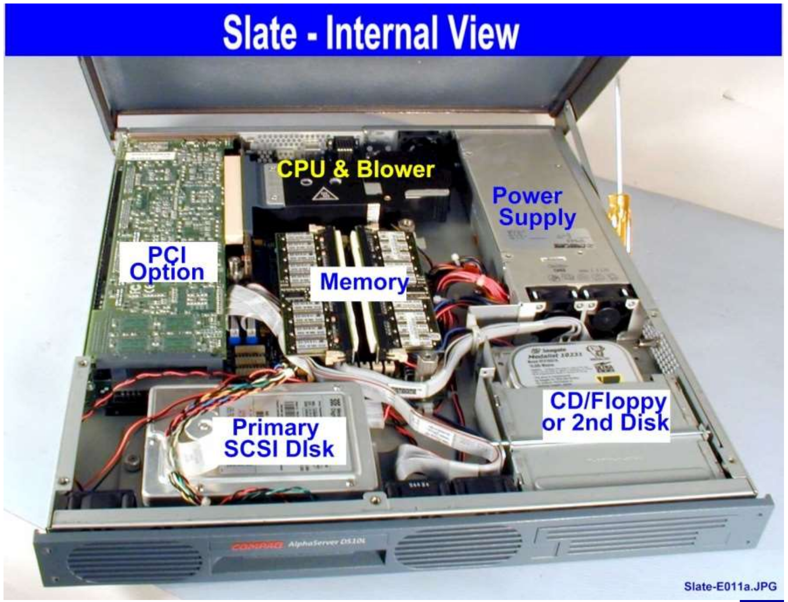
BOB

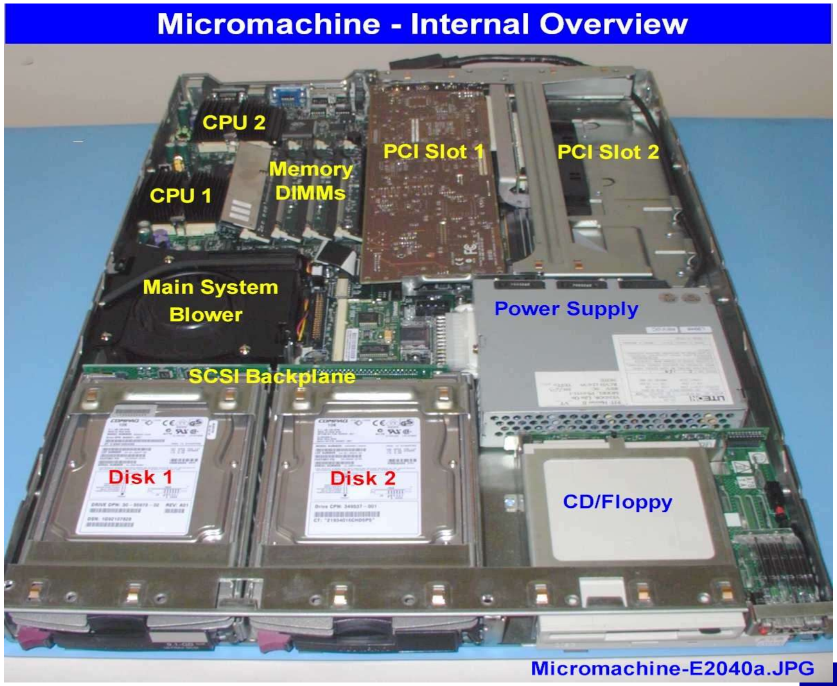

Product Data

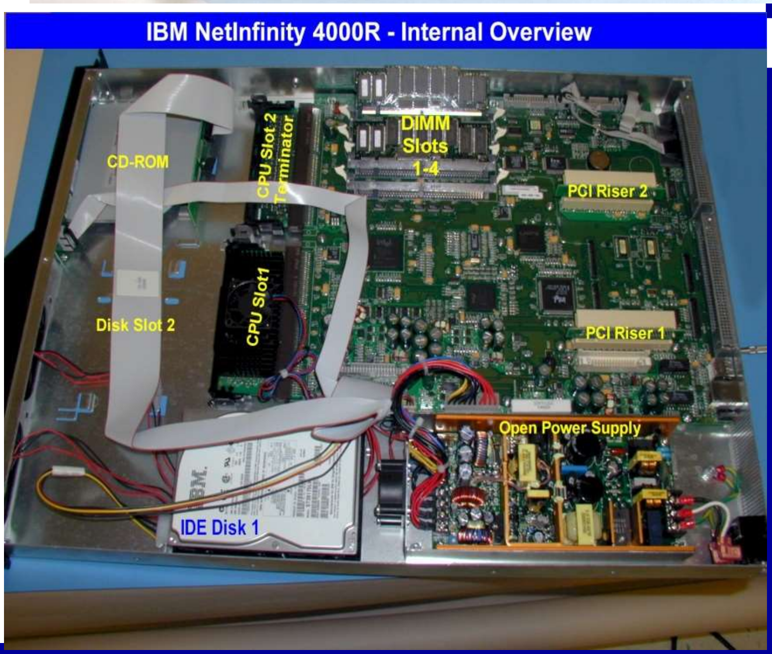
A Comparison of 1U Servers

Whats inside

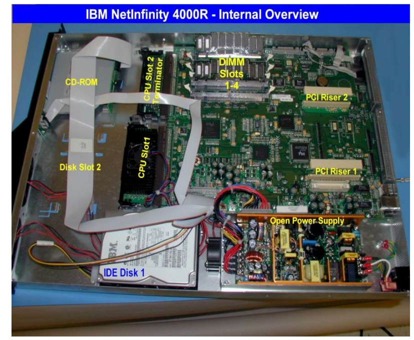


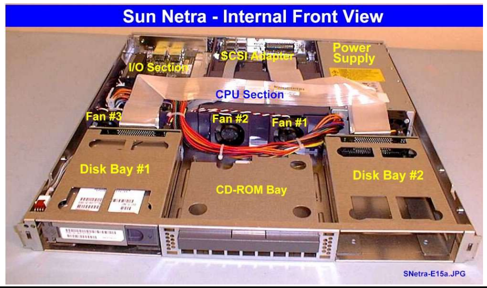






Function Cost Comparison





	Sun Netra t1		IBM NetInfinity 4000R	
	Cost	**% of Total**	**Cost**	**% of Total**
Cooling	$14	0.9%	$9	0.5%
CPU	$675	42.6%	$189	11.2%
Disk	$215	13.6%	$281	16.6%
Enclosure	$50	3.2%	$93	5.5%
I/O	$235	14.8%	$187	11.0%
Memory	$274	17.3%	$410	24.2%
Power	$86	5.4%	$52	3.1%
System	$17	1.0%	$428	25.3%
Pkg/Doc/SW	$19	1.2%	$42	2.5%
Total	**$1,585**		**$1,691**	

Things you can find

MODULE AND SYSTEM LEVEL BENEFITS OF HIGH FLUX HEAT PIPE HEAT SINKS

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ABSTRACT

Higher powers in smaller packages has trended to the point where junction to case resistances are the majority of the overall allowable thermal resistance. This has pressured the sink to ambient resistances to the point where standard cooling solutions are no longer a viable option. Current trends are pushing chip fluxes into the range of 50 to 100 W/cm^2. At these fluxes it is critical to optimize the overall system resistance by studying the tradeoffs between spreading, interface, conduction, and airside resistances.

This paper discusses one case study and outlines the module and system levels benefits of heat pipe heat sinks capable of handling high heat fluxes. At the module level the heat pipe uses two phase boiling heat transfer from the large specific surface area of a powder metal wick structure to remove the high heat fluxes generated at the die level. This minimizes conduction and spreading resistances. At the system level, heat pipes isothermalize the entire fin area, allowing designers to make optimum use of fin volume and flow areas to achieve minimum thermal resistances with lower velocity and lower pressure drops.

INTRODUCTION

Although this case study is specific to a single application, the problem solved is typical of current and future processor power levels and fluxes. The approach used to get from problem definition to end solution is applicable to a broad range of applications and the conclusions drawn should expedite solutions for similar applications. The solution selected in this case study a "tower" heat pipe heat sink, was dictated by the allowable fin geometry. The chip level and system level benefits are applicable to a family of heat pipe assisted heat sinks including vapor chambers and towers.

PROBLEM DEFINITION

Figure 1 and the data listed in the Table 1 sufficiently define the requirements and provide enough information to begin the process of evaluating alternative solutions

Don’t have to Buy to Look

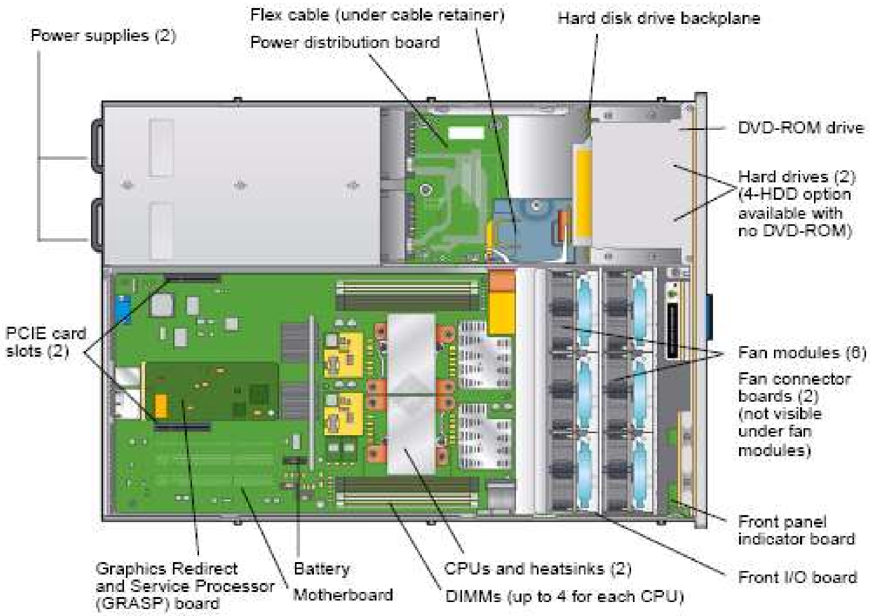


FIGURE 1-4 Sun Fire X4100 M2 Replaceable Component Locations

1.2.1 Sun Fire X4100/X4100 M2 Server Front Panel

FIGURE 1-1 shows the features of the front panel.

FIGURE 1-1 Sun Fire X4100/X4100 M2 Server Front Panel

1.2.2 Sun Fire X4100/X4100 M2 Server Back Panel

FIGURE 1-2 shows the features of the back panel.

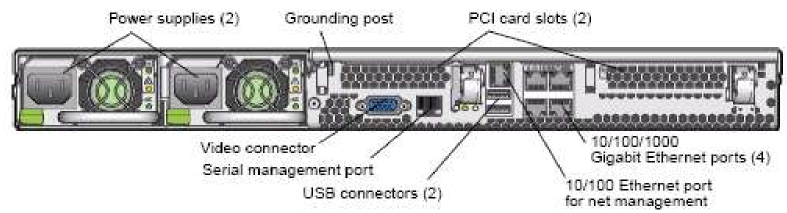


FIGURE 1-2 Sun Fire X4100/X4100 M2 Server Back Panel

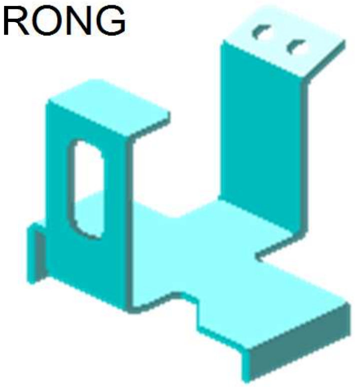
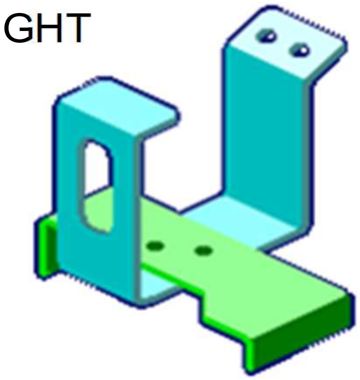
Often service manuals, product reviews provide excellent reference material with enough detail to calculate costs.

Product development

DFMA can be used throughout the entire Product Development Process

- •Early Product Costing
- •Competitive product benchmarking
- **•Concept selection**
- •Creation of time standards
- •Assembly Instructions
- •Deign Simplification
- •Cost reduction
- •Quality
- •Vendor quote verification
- •Estimate hard tooling

Traditional Concept Selection of Design Alternatives

GUIDELINE	WRONG	RIGHT
Avoid complex bent parts (material waste); rather split and join		

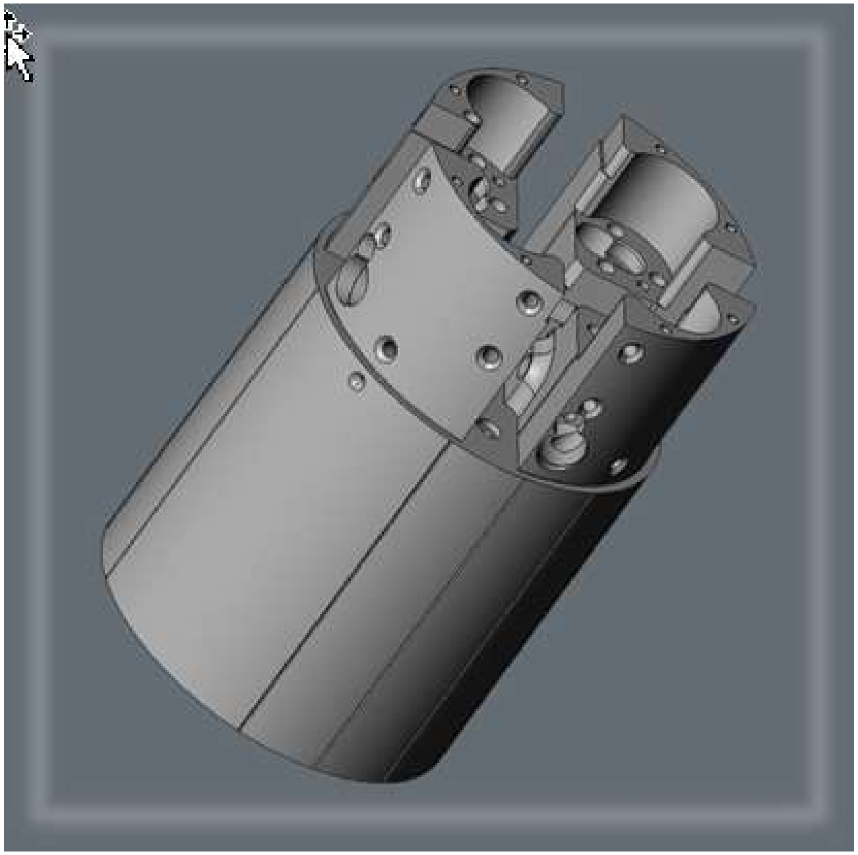
(a) Misleading producibility guideline for the design of sheet metal parts

Set-up	0.015	0.023
Process	0.535	0.683
Material	0.036	0.025
Piece part	0.586	0.731
Tooling	0.092	0.119
Total manufacture	0.678	0.850
Assembly	0.000	0.200
Total	0.678	1.050

(b) Estimated costs in dollars for the two examples if 100,000 are made

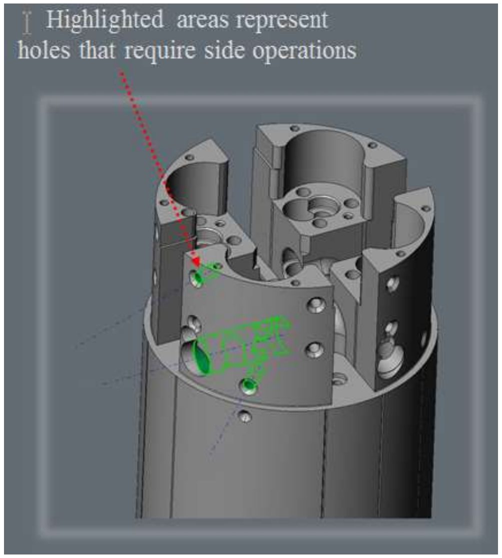
Source: B & D example

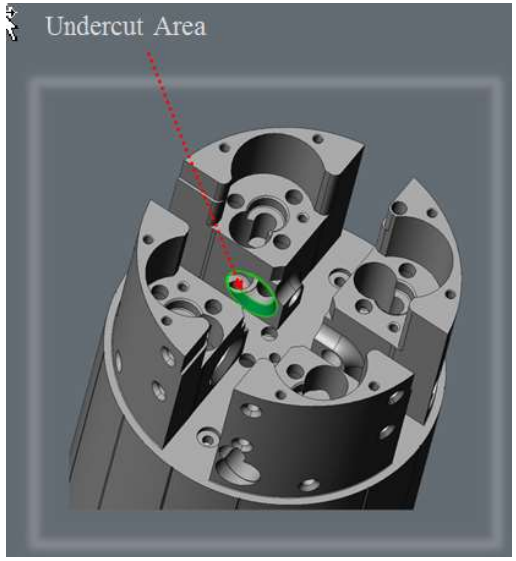
Cost Estimating Example

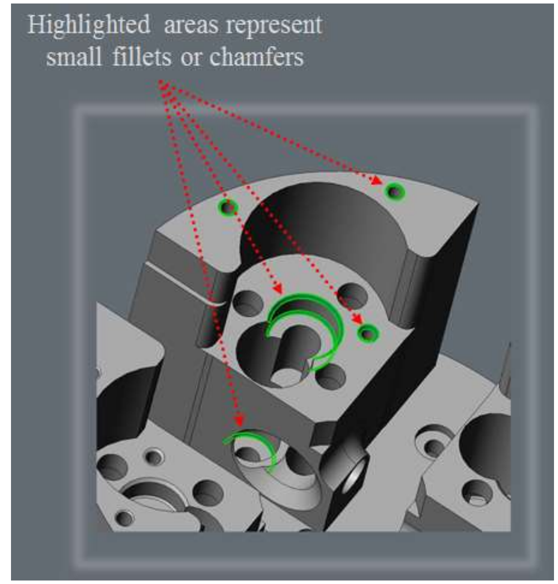


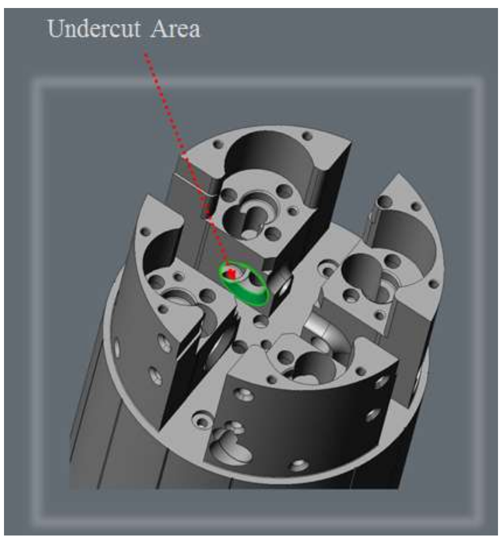
- Machining estimate
- Machining estimate with recommendations
- Alternative manufacturing methods

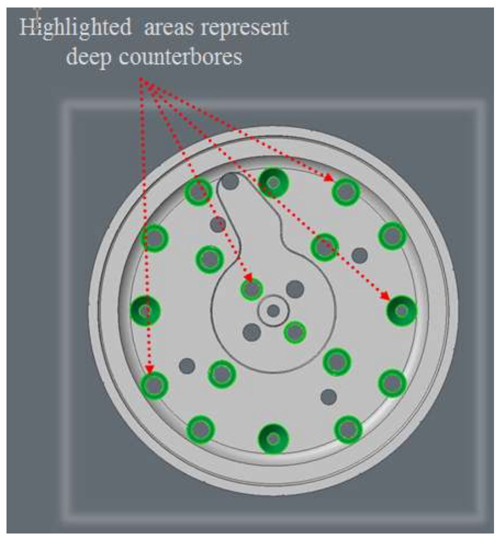
Machining issues

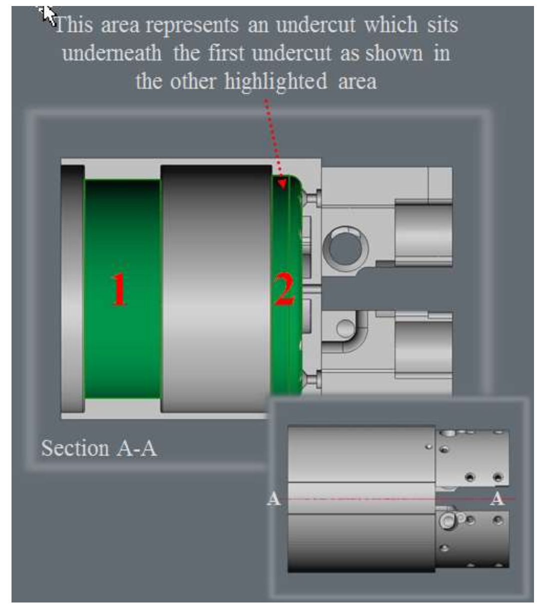




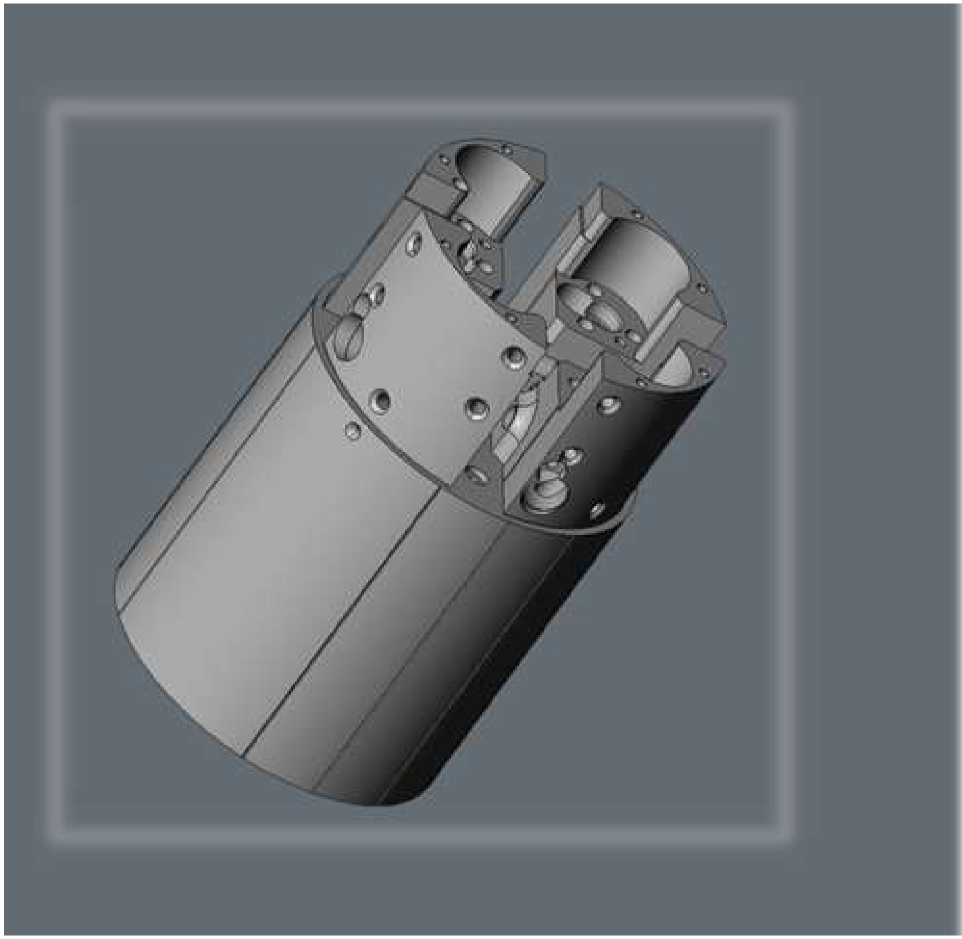








Machining Estimate



Current:

Time = 12 - 15 hrs

Cost = $ 780 - 975

With Recommendations:

Time = 7 - 10 hrs

Cost = $ 455 - 650

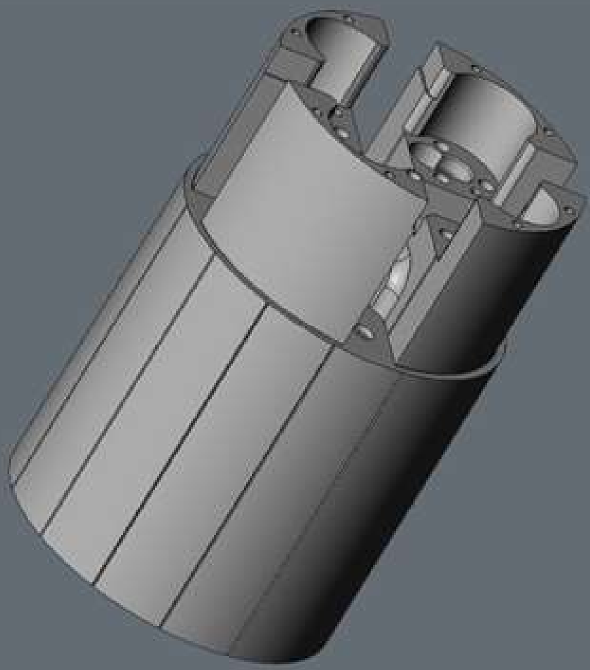
Total Savings = <u>$ 325 / part</u>

Alternative Methods Estimates (investment cast)

Investment Casting

DaTuM 3D
Design To Manufacture

Re-designed for Investment Casting:



Investment Cast Part:

- Initial Tooling Investment of
  $22,000 - $25,000

- Cast parts will cost:
  $16.00 - $22.00 / part
  (in lots of 100)

- CNC Machine side features with 4th axis machine center
  < 2 hours = $110.00

Total Part Cost:

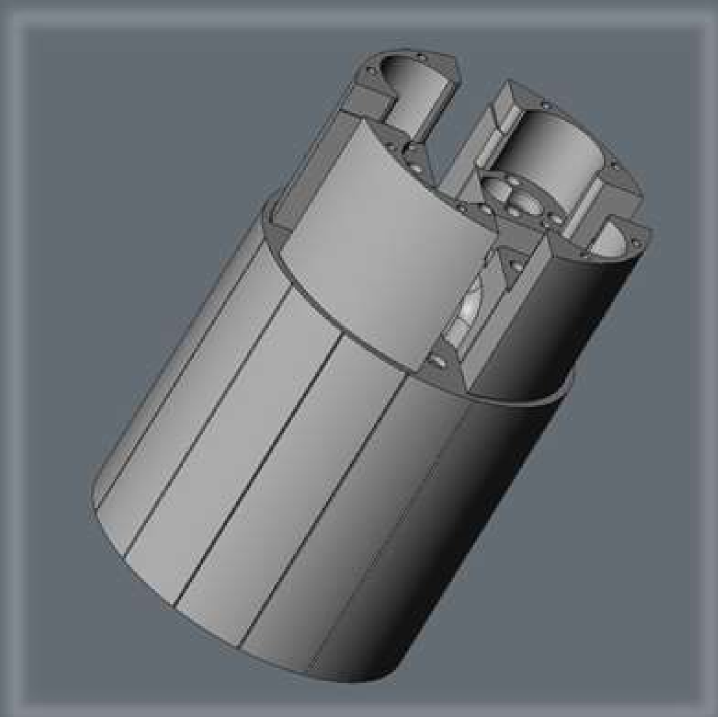
< $135.00 each

Alternative Methods Estimates (Metal Injection Molded)

Metal Injection Molding

DaTuM 3D

Some Re-design Required:



Metal Injection Molded Part:

- Initial Tooling Investment of
  $45,000 - $50,000
- Molded parts will cost:
  $\$45^{.00}$ - $\$50^{.00}$ / part
  (in lots of 100)
- CNC Machine side features with 4th axis machine center
  < 2 hours = $\$110^{.00}$

Total Part Cost:

< $\$160^{.00}$ each

Product development

DFMA can be used throughout the entire Product Development Process

- •Early Product Costing
- •Competitive product benchmarking
- •Concept selection
- **•Creation of time standards**
- •Assembly Instructions
- •Deign Simplification
- •Cost reduction
- •Quality
- •Vendor quote verification
- •Estimate hard tooling

Time Standard Project

The Challenge

•Needed six time standards completed in under two weeks

- Update legacy time standards.
- Create new product time standards.
- Low cost and quick creation time

Compaq Time Standard Project

Alternative methods

- MTM, MOST,Lucas,Westinghouse method,Assembly View,SEER,LASeR,XPI….
- When evaluated against time, $$, training, software investment.

Chose B&D

- Established tool for assembly operations
- Some flexibility to capture non assembly operations

DFA Customized Operation Libraries

DFMA Libraries are a storage mechanism for customized-operations.

Category ▾ Add

No.	Type	Name	Comment
1	**Category**	**Example:CORE Operation library**	
2	Misc Op	MTM: Place approximate <= 8 in	MTM:PA1
3	Assembly Op	AA1 g&p_2lbs_easy_app_code1	MTM-AA1 <8 in get and place command
4	**Category**	**Ex: Standard Macro library**	
5	Assembly Op	Typing process function	Macro: Key strokes, looks, reads combined
6	Assembly Op	Detrash operations	Macro: Various detrash operations
7	**Category**	**Ex: Specific Macro library**	
8	Assembly Op	Desk side pick to light procss	Macro: time to pick-to-light all necessary objects
9	Assembly Op	Wrapping machine	Macro: Time to wrap 1 cab using machine
10	**Category**	**Ex: Standard Process Library**	
11	Assembly Op	Deskside Final test time	B&D:sidefinl.dfa Deskside final test time
12	Assembly Op	Deskside Packing process	B&D:sidepack.dfa Deskside drawer packing p

B&D Design Analysis

(1) B&D Design Analysis	111.30	
1.1 (2) Assembly	1	
2.1 (3) Photo Cell assembly	1	
3.1 Install plastic cover: PN 1	1	4.60
3.2 Install rubber protector; PN 2	1	4.60
3.3 Install Photo Cell: PN 3	1	6.10
3.4 Inst. Back rubber protect PN 4	1	4.60
2.2 Install LCD: PN 5	1	4.60
2.3 Install PCA board: PN 6	1	14.40
2.4 Install Key pad: PN 7	1	4.60
2.5 Install flex cable: PN 8	1	6.10
2.6 Install flex cable support:PN9	1	4.60
2.7 (4) Install Back of unit	1	
4.1 Place back on unit PN 10	1	6.80
4.2 Screw down back PN 11-17	6	50.30

B&D Time Standard Tool

(1) Calculator Assembly	235.52	
1.1 (2) Kitting Operation	1	
2.1 Get tote	1	1.80
2.2 Walk to pick face	1	2.88
2.3 Pick part & place in tote	17	21.42
2.4 Check off on paperwork	11	17.82
1.2 (3) Deliver units to assembly area	1	
3.1 Walk to assembly bench	1	3.78
1.3 (4) Assembly	1	
4.1 (5) Photo Cell assembly	1	
5.1 Install plastic cover: PN 1	1	3.4
5.2 Install rubber protector; PN 2	1	3.4
5.3 Install Photo Cell: PN 3	1	4.9
5.4 Inst. Back rubber protect PN 4	1	3.4
4.2 Install LCD: PN 5	1	3.45
4.3 Install PCA board: PN 6	1	7.45
4.4 Install Key pad: PN 7	1	3.45
4.5 Install flex cable: PN 8	1	4.95
4.6 Install flex cable support:PN9	1	3.45
4.7 (6) Install Back of unit	1	
1.4 (7) Close out paperwork process	1	
7.1 Scan serial number	1	5.40
2.1 Get paperwork	1	1.80
7.3 Sign complete name	1	7.92
7.4 Turn page	1	1.51
7.5 Initial paperwork	1	3.96
1.5 (8) Test	1	
8.1 Check Add button	1	3.37
8.2 Check off on paperwork	1	2.52
8.3 Check Subtract button	1	3.37
8.4 Check off on paperwork	1	2.52
8.5 Check Divide button	1	3.37
8.6 Check off on paperwork	1	2.52
8.7 Check Multiply button	1	3.37
8.8 Check off on paperwork	1	2.52
8.9 Sign off on test	1	7.92
1.6 (9) Pack	1	
9.1 Place calculator in bag	1	9.72
9.2 Tape the end of the bag	1	5.40
9.3 Place syrophom sides	2	9.90
9.4 Open box	1	3.96
9.5 Place unit in box	1	2.70
9.6 Close box	1	7.92
9.7 Staple box using foot stapler	1	10.08
1.7 Place paperwork in bin	1	1.80

Calculator Build

	Standard creation time (minutes)	Calculator build standard time (minutes)	Complete assembly Kit, build, test, pack (minutes)
B&D Standard tool	19.94	1.40	3.93
MTM	48.15	1.31	3.54
Time study AVG.	-	1.78	4.42
Time study A	-	1.80	4.58
Time study B	-	1.85	4.34
Time study C	-	1.70	4.33

Historical Statistics

Creation Time Historical Results

B&D tool Historical	3 - 1*
MTM-UAS	10 - 1
Most	10 - 1**
MTM-1	40 - 1**

* Historical data based on total number of systems analyzed over 8 months.

** Historical data: Zjell B. Zandin Most work measurement Systems Book, Marcel Decker Inc. Copyright 1990 pg.14

Process Time Historical Results

B&D standard tool accuracy with generic macros to within 5-15% of MTM-UAS times.

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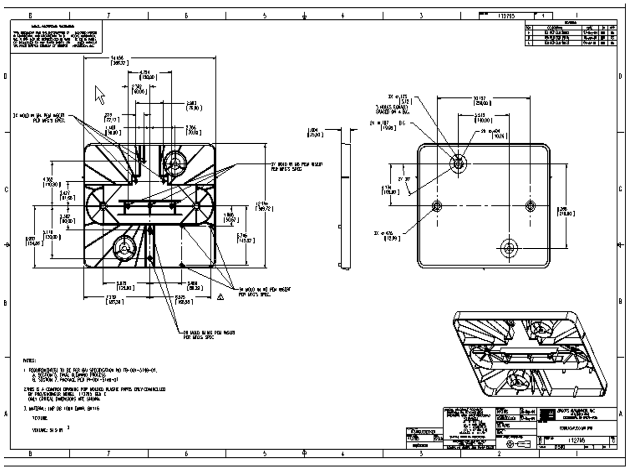
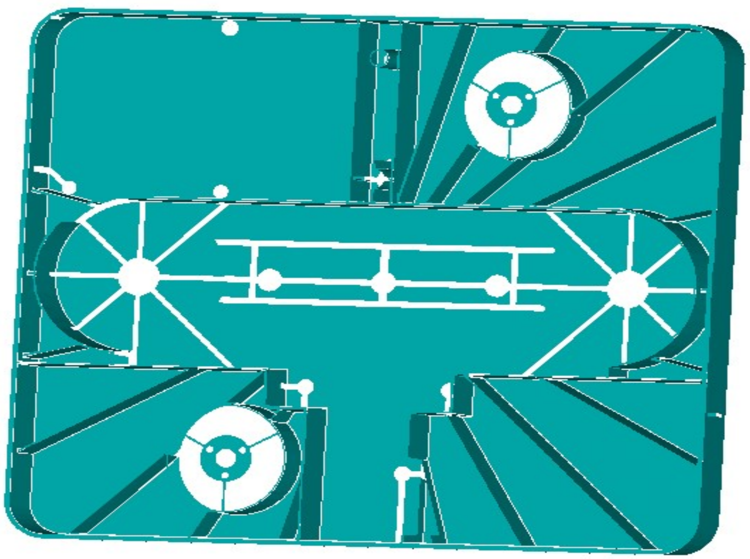
DFMA Example-Comparing Estimates Against Vendor Quotes

B&D Estimates Against Actual Quotes

•Item Description	QTY	Cost	B&D Estimate
• DOOR,	1	$22.34	$9.40





DFMA Example-Vendor Quote

Item Description	QTY	Cost	B&D Estimate
DOOR,	1	$22.34	$9.40

112795

		2,500	1,500	1,000	500	250
FOUP Door	**$55,000.00**	**$14.17/ea.**	**$15.59/ea.**	**$17.30/ea.**	**$18.74/ea.**	**$22.34/ea.**
Delivery: (8) weeks ARO		Resin: LNP DB 1004 EMMR, BK115				

Tooling Description: Single cavity self-contained *pre-hardened steel mold*, tri-plate gating with (4) pin-point gates, pin ejection, flat parting line, and bead blast cavity finish.

Notes:

- The molding material is a suggestion by our contact at LNP Corporation, based upon the need for optimum flatness. (*20% glass bead filled polycarbonate*)
- The flatness is difficult to predict. We are proposing a "tri-plate" gating design with (4) pin-point gates for help in improving flatness. A flatness specification of .010 cannot be guaranteed. We feel reasonably confident that we could mold between .012" and .020" flatness.
- "Sink" marks may be evident because of the intersecting wall section ratios. Any "sink" mark would not be part of the measured flatness.

148 Christian Street
Oxford, CT 06478
203-888-0585

PTA CORP
www.ptacorp.com

7350 Dry Creek Parkway
Longmont, CO 80503
303-652-2500

DFMA Example-Data Collection for estimate refinement

Questions were asked to gather further information

- Material parameters and material cost from vendor, tonnage machine, and process information.
  PTA $7.35/lb GE $7.65/lb PTA is passing their material cost saving.

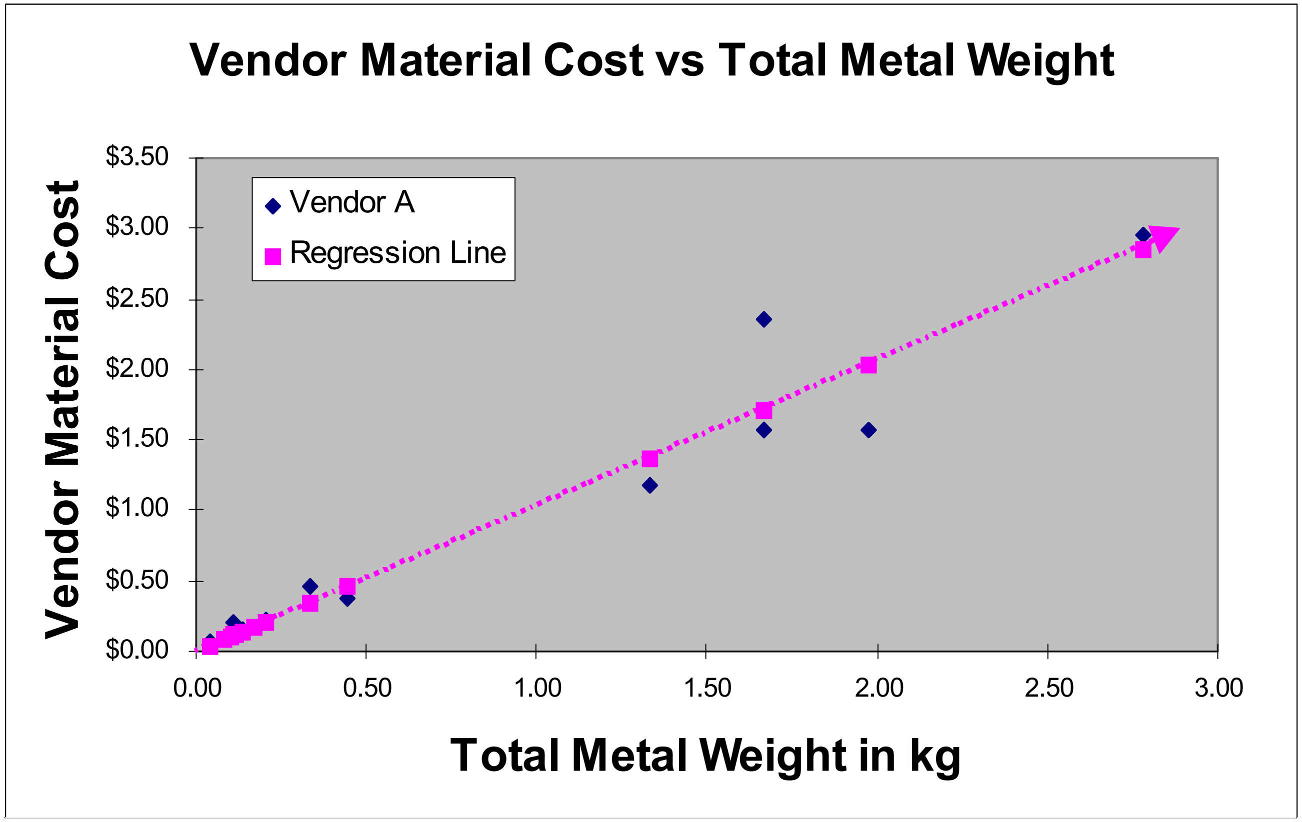
- New Plastic Material database created

- The cost estimate was revised using the above information.

- New B&D estimate is $23.30 VS. Vendor Quote $22.34

Regression Analysis

Total Weight to Metal Only Material Charge



Regression Coefficient

$r^2 = 86.9\%$

Zero Crossing Slope

$1.026/kg

Standard Error

$0.228/kg

- Indicates Strong Correlation
- Based on believed market rates = a material adder of 30-40%

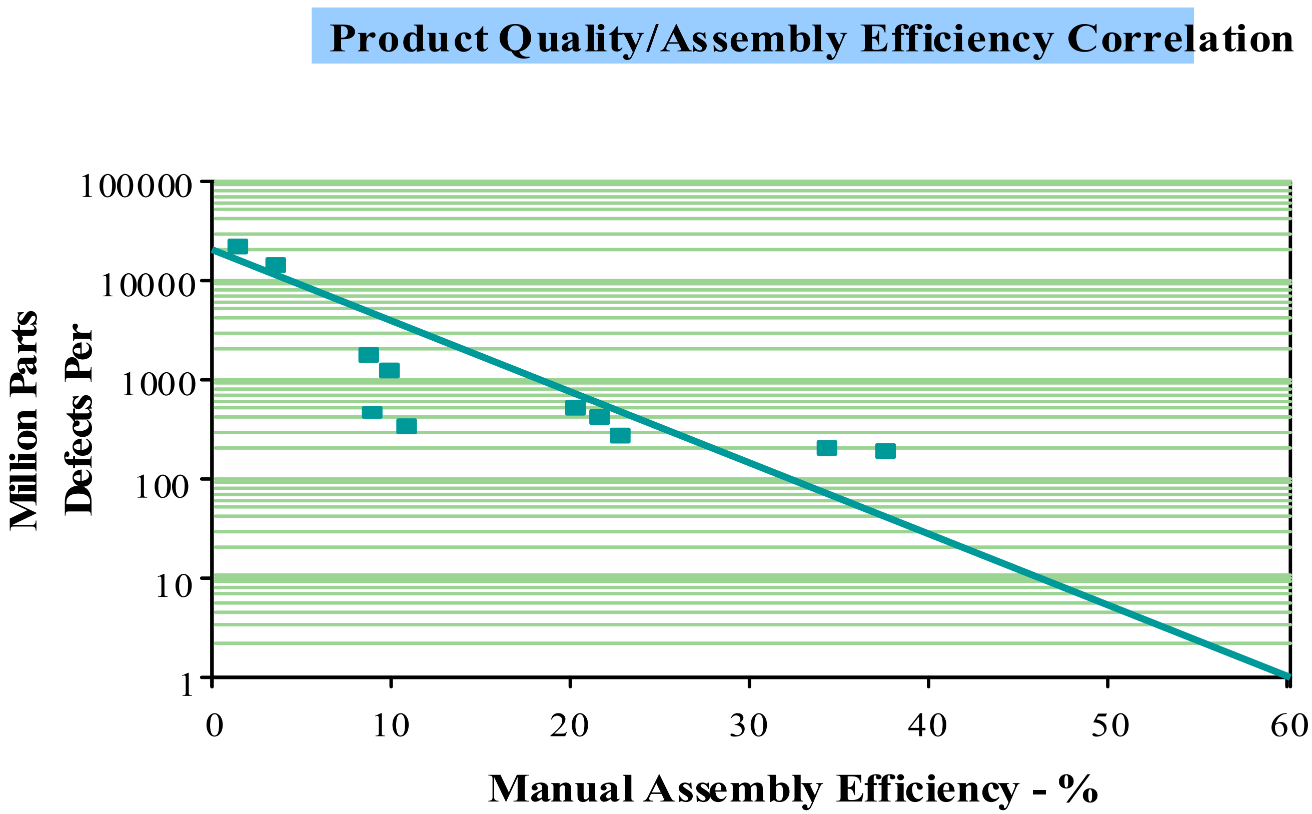
Product development

DFMA can be used throughout the entire Product Development Process

- Early Product Costing
- Competitive product benchmarking
- Concept selection
- Creation of time standards
- Assembly Instructions
- Deign Simplification
- Cost reduction
- **Quality**
- Vendor quote verification
- Estimate hard tooling

Quality Tool

Design for Assembly



Every one second of assembly penalty time causes an average of 100 DPM

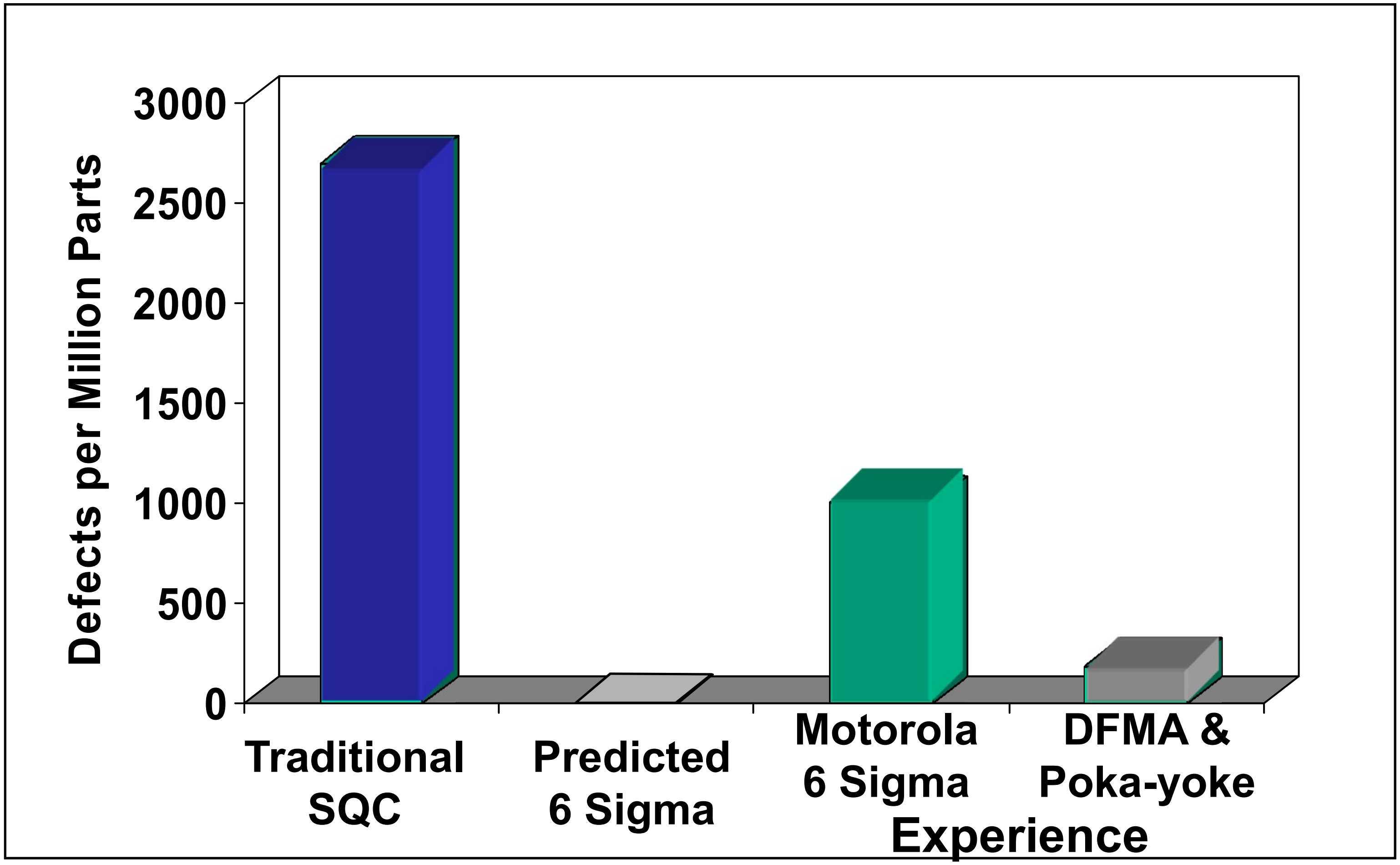
Quality Assessment Conclusions

- **For many corporations part variability is no longer the quality issue; quality problems arise mainly in assembly**
- **Assembly quality problems seem to correlate strongly with assembly difficulties**
- **The key to quality improvement is to reduce both the number of assembly steps, and the average time per operation**

BOOTHROYD DEWHURST

Source Dr. Peter Dehewhurst URI.

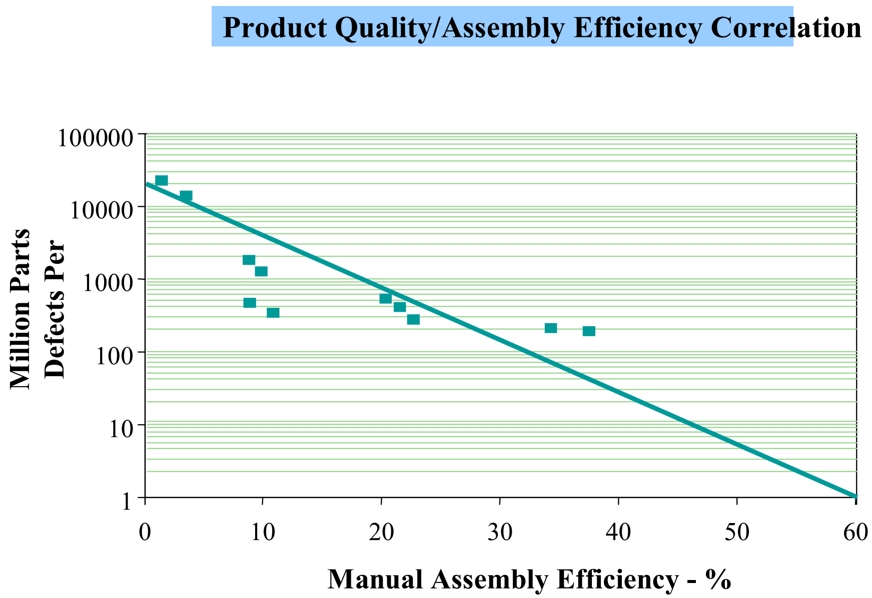
Mistake-proofing achieves superior results, faster, and with less efforts.

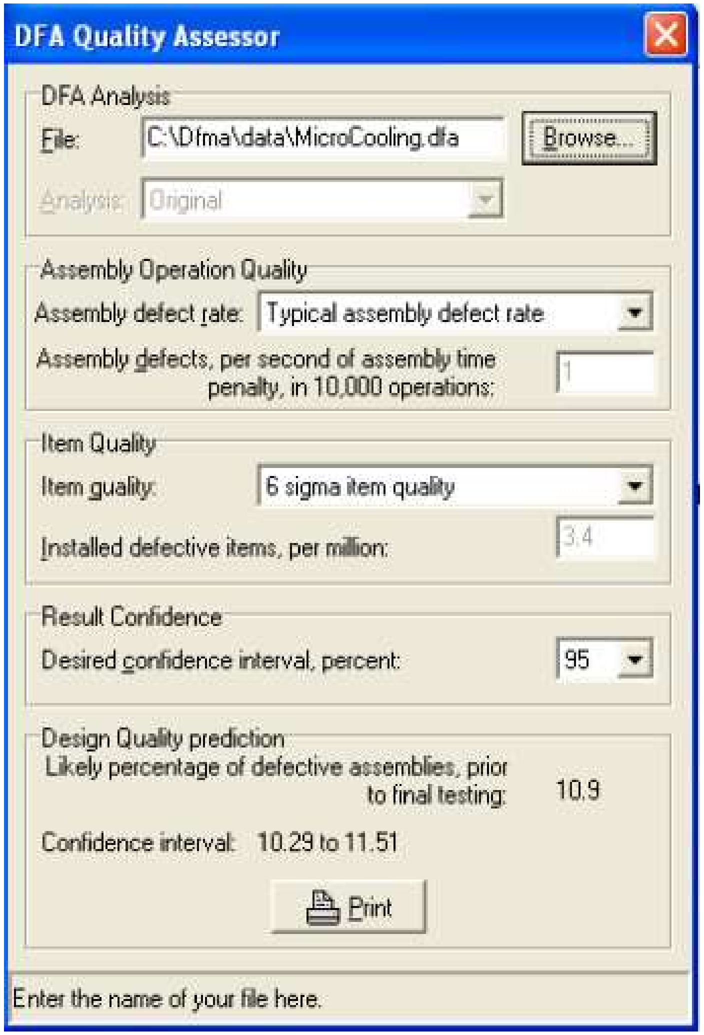


Source: Make NO Mistake – A Mistake – Proofing Methodology C. Martin Hinckley B&D conference June 2003

Quality Prediction

Design for Assembly

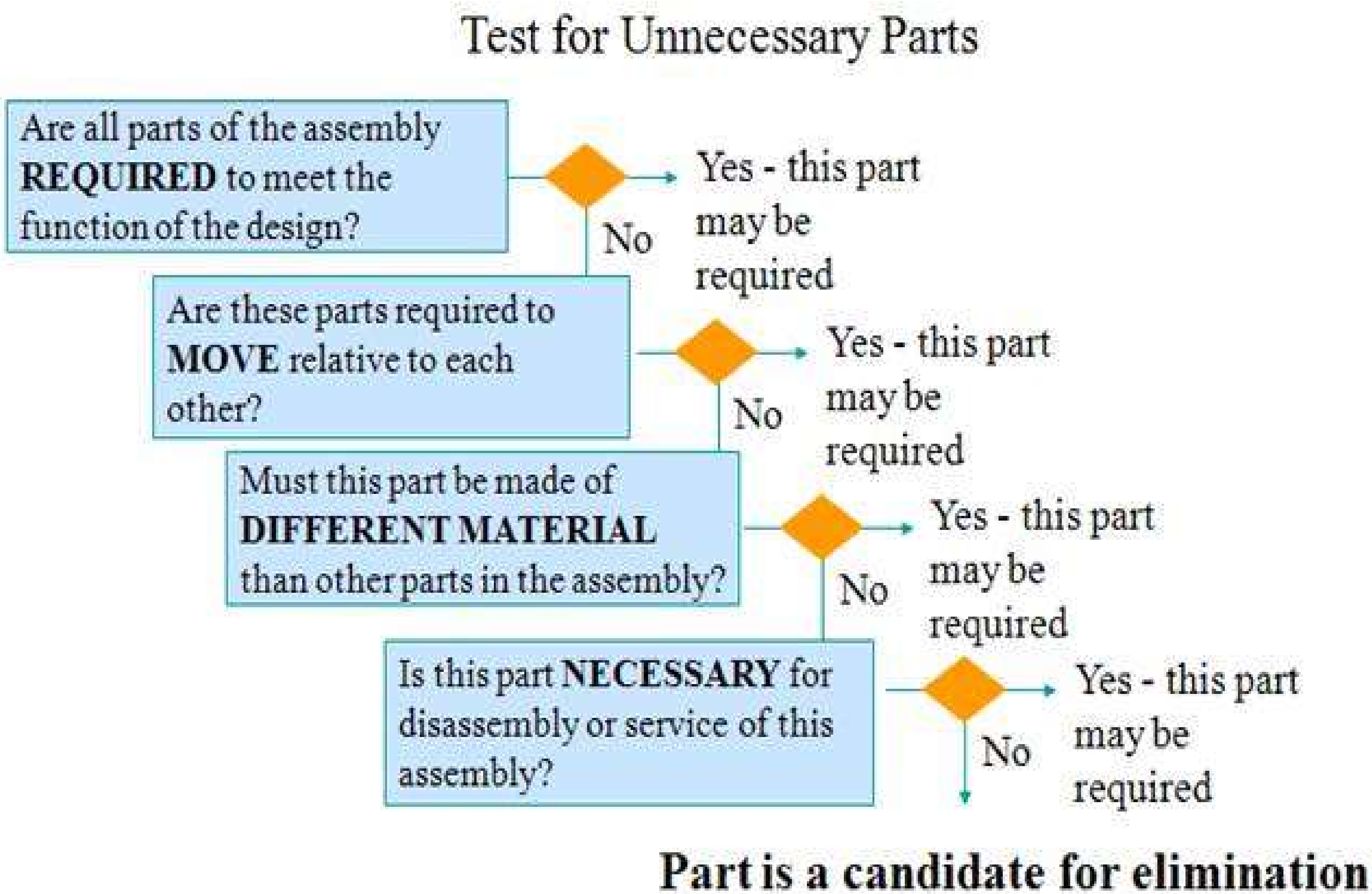




- Biggest bang for the buck
- Theoretical Minimum Part Count (TMPC)

How to get rid of parts

Theoretical Minimum Part Count



Designing Differently

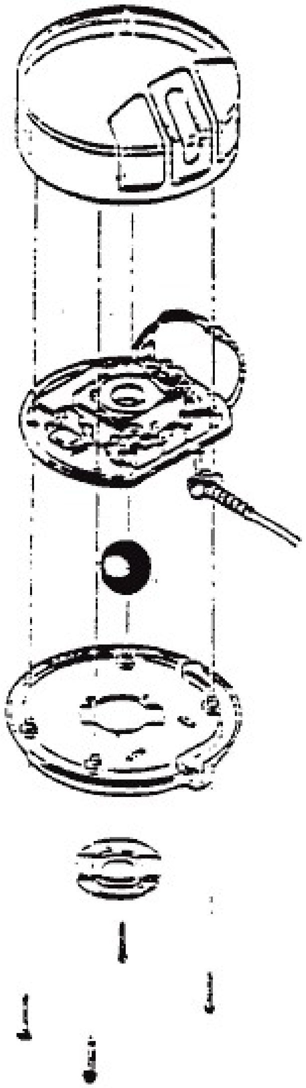
Harbor Freight Flashlight

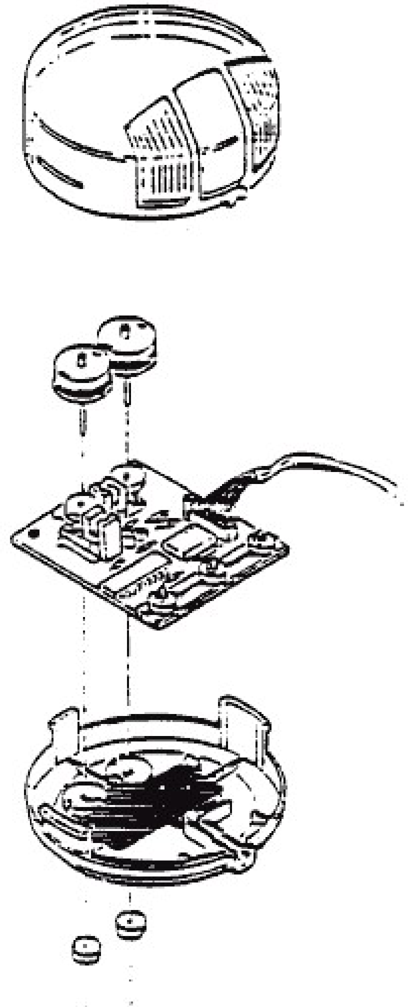
	Name	Quantity	Min. Part Criteria	Min. Part Count
1	Chassis	1	Base	1
2	Battery Terminal - dual	2		
3	Battery Terminal - single pos	1		
4	Battery Terminal - single neg	1		
5	3 LED Lens	1		
6	3 LED Board & wires	1		
7	3 LED Reflector	1		
8	Battery Wire	2		
9	24 LED Board	1		
10	Screws - small	6		
11	24 LED Reflector	1		
12	Cover - Lens	1		
13	24 LED Lens	1		
14	Button	1		
15	Batteries - AAA	3		
16	Cover - Hook/Mag	1		
17	Magnet	1		
18	Hook	1		
19	Hook retainer	1		
20	Screws - retainer	2		
21	Screws	3		
22	Labels	3		

Cautionary Note - Pitfalls

- DFMA is oversold and early results do not materialize
- Poor selection of projects to implement the process on
- The champion gets promoted and things die
- Didn’t renew the software
- Doesn’t become part of the culture

Digital Corporate Mouse





	Old	New
Part count	61	44
Mechanical	31	16
Electrical	28	30
Assm. Time	17 min.	6
Assm. Oprs.	83	56
Adjustments	11	0
Fasteners (3 types)	10	0
Material Cost Reduction		>40%

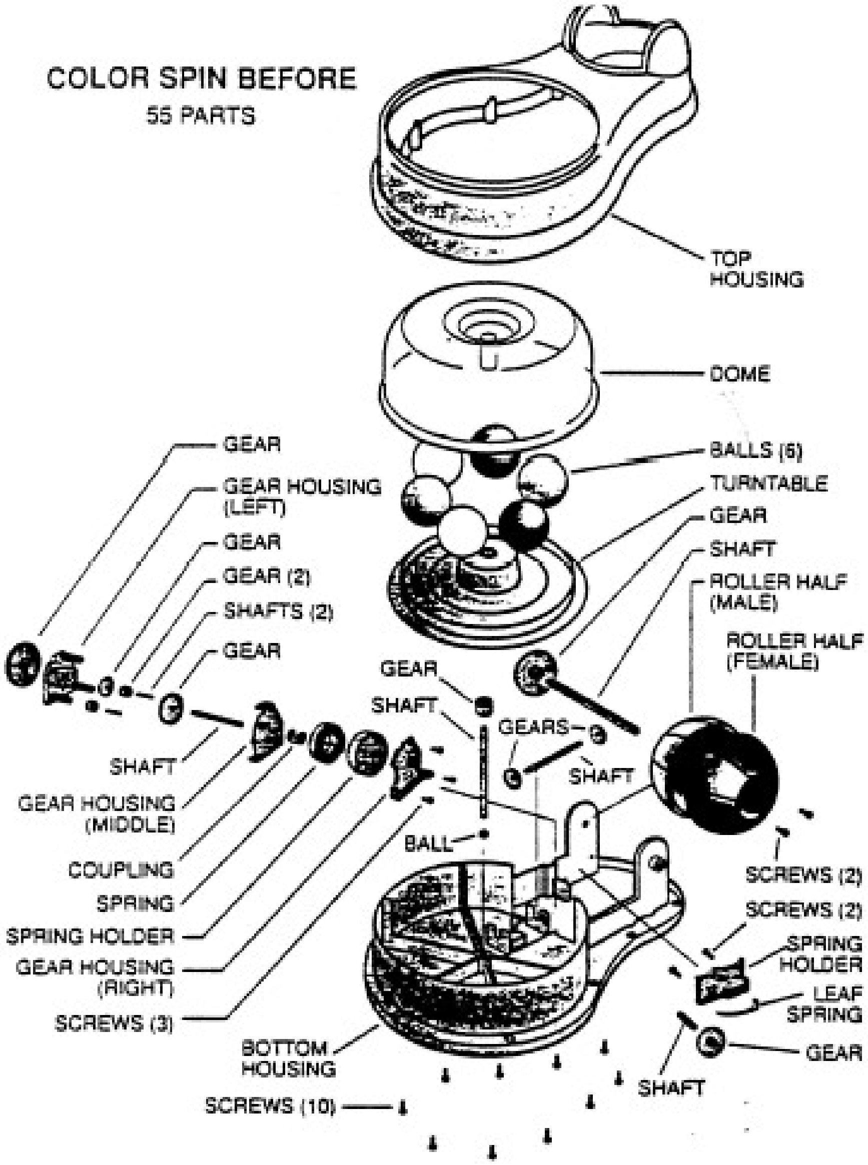
Case Study

Respironics BagEasy III

- 84% reduction in assembly time
- 65% reduction in the number unique parts
- 81% reduction in assembly operations
- 6 patent applications

COLOR SPIN BEFORE

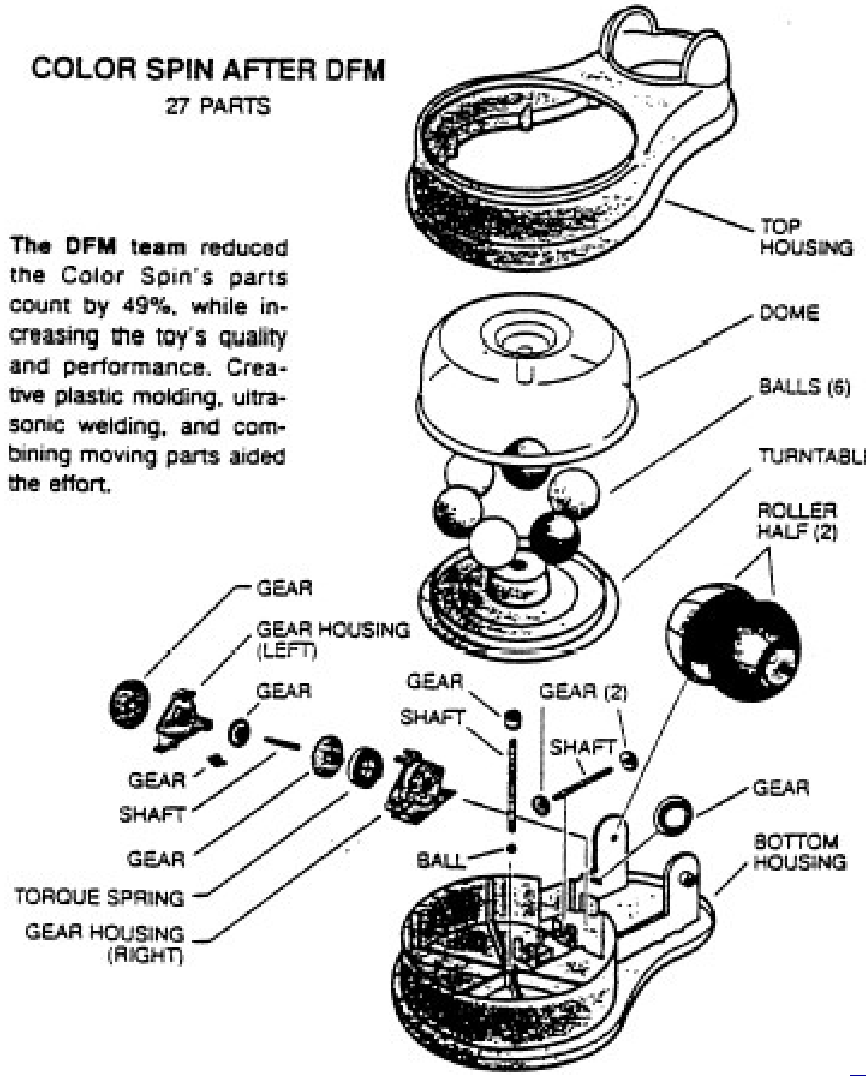
55 PARTS



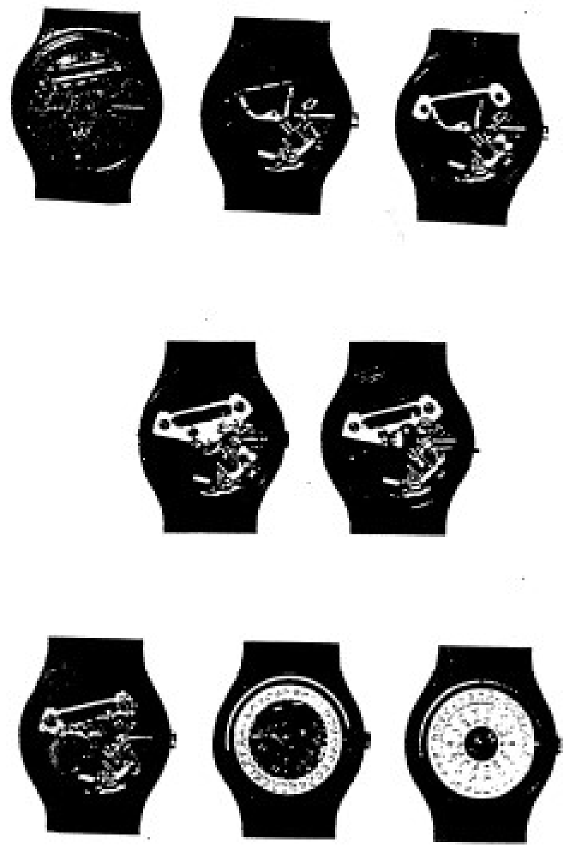
COLOR SPIN AFTER DFM

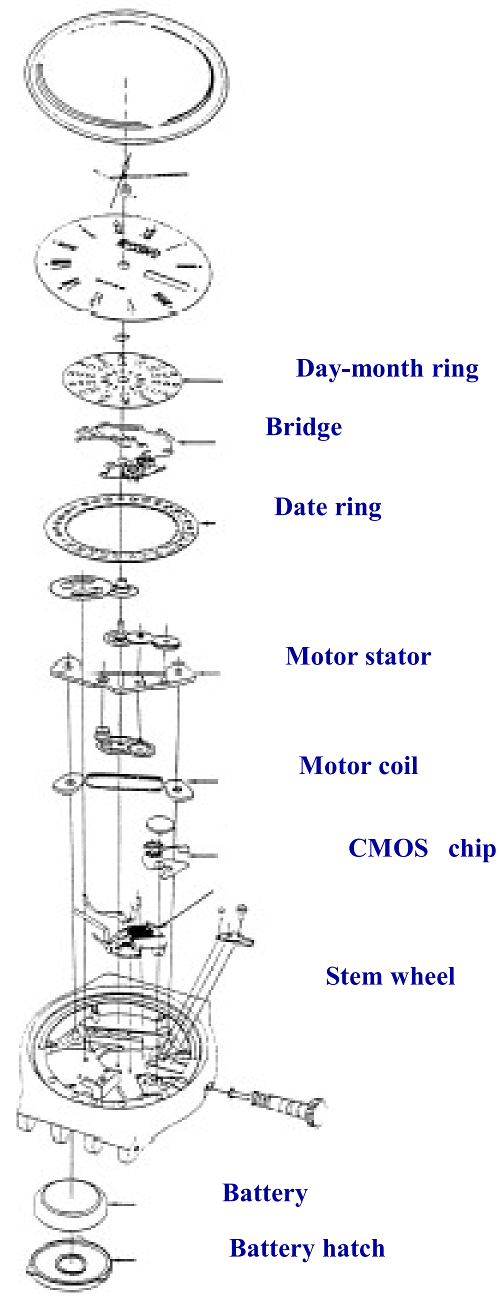
27 PARTS

The DFM team reduced the Color Spin's parts count by 49%, while increasing the toy's quality and performance. Creative plastic molding, ultrasonic welding, and combining moving parts aided the effort.



SWATCH





Day-month ring
Bridge
Date ring
Motor stator
Motor coil
CMOS chip
Stem wheel
Battery
Battery hatch

Mechanical Chronograph

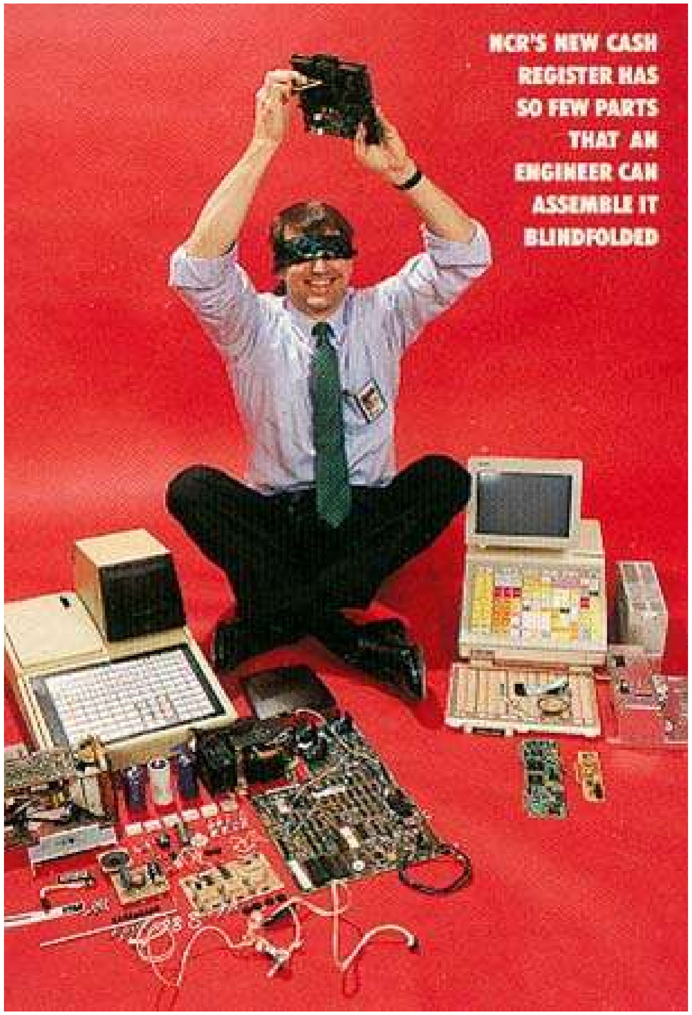
SISTEM51 is 100 percent Swiss made and features an exceptional 90 hour power reserve. Hermetically sealed within its case, the 3 Hz movement delivers precise, long-lasting, maintenance-free performance.

There is much to explore in this intriguing new world. Unprecedented technological innovation (17 pending patents) enabled the development, in less than two years, of a self-winding mechanical movement with only 51 parts in five modules.

Design has only one screw !

NCR 2670 Point of Sales Terminal

- 85 % Part count reduction
- 75 % Assembly time reduction
- 44 % Reduction in labor cost
- 65 % Fewer suppliers
- No assembly tooling
- No fasteners
- $1.1 Mil. dollars lifetime labor savings
- 1/3 Mfg. floor space saved



Design for Assembly DFA

“Perfection is reached not when there is no more to add but when there is no more to take away."

Antoine de St. Exupery


LOONEY TUNES
"That's all Folks!"
A WARNER BROS. CARTOON