Hand-Calculated Savings:

Case studies in the application of a simplified Boothroyd-Dewhurst Methodology in the design and manufacture of complex assemblies

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Silicon Valley / Boston / China

About Acorn

Acorn was Founded in 1993 in Silicon Valley by product development veterans Ken Haven, CEO (MSME Cornell) and Tim Lau, CTO (MSME UC Berkeley). DFM in our DNA.

Today Acorn is a global team of 30+ product development engineers – BSME and MSME.

ACORN's Goal: Incorporate mechanical **engineering analysis** and **manufacturing considerations** from the earliest stage of development in order to accelerate the path to market and improve outcomes.

Acorn Global Presence

Silicon Valley (HQ) *Boston/Cambridge* *China-Dongguan*

Who we Serve

Clients & Markets

Consumer	Industrial	Communication	Medical
	TERADYNE	CISCO SYSTEMS	SIEMENS
DELL	BostonDynamics	Sun microsystems	inverness medical
DIRECTV	FLEXTRONICS	BROCADE	Medtronic When Life Depends on Medical Technology
hp invent	ROBOTEX robot technology solutions	Juniper NETWORKS	GE
Logitech	GENERAL DYNAMICS	NetApp Go further, faster	BD

Sample Acorn Projects

Sun M5000 SPARC Server

Flip Video Mino & Slide HD Cameras

RoboteX Avatar Micro II Surveillance Robot

Apple G4 Tower

Siemens Acuson Ultrasound Imaging

Teradyne – Automated Disk Drive Test Equipment

Acorn Engineering Services

- Full turnkey product design services
  - Conceptual Design
  - Prototype Design / DVT / Tooling Support
  - Production Design / DMT / Regulatory Support
  - Tooling & First Article Inspections / Ongoing Production Support
- Engineering analysis (thermal, structural, flow, tolerance, mechanism)
- Specific services to fill in gaps/augment existing development team
- Cost optimization services
  - Labor
  - Parts
  - System level

DFMA and Acorn

- DFMA was integrated into our DNA from the start
- DFMA vs. Boothroyd-Dewhurst
- We are proactive about DFMA
  - CMs incentivized differently for DFMA
  - No methodology sell, no baggage
- Boothroyd-Dewhurst gave us a toolkit
  - To share internally
  - To share with clients

DFMA and Our Clients

- Baby Steps
- Doesn't have to be a cultural revolution
- Clients don't always track cost; we drive this metric

Excuses we've heard:

- "Can't estimate cost accurately, especially early in design"
- "Won't affect anything – we already do this"

Assembly Time Modeling

- Case studies presented here focus on assembly time optimization only (other DFM incidental)
- Difference between proto & production-level analyses
- These cases both involve assemblies which are:
  - Produced in medium quantity
  - Manually assembled

MANUAL HANDLING-ESTIMATED TIMES (s)

Key: One hand

			Parts are easy to grasp and manipulate					Parts present handling difficulties (1)				
			Thickness >2 mm			Thickness ≤2 mm		Thickness >2 mm			Thickness ≤2 mm	
			Size >15 mm	6 mm ≤ size >15 mm	Size <6 mm	Size >6 mm	Size ≤6 mm	Size >15 mm	6 mm ≤ size ≤15 mm	Size <6 mm	Size >6 mm	Size ≤6 mm
			0	1	2	3	4	5	6	7	8	9
Parts can be grasped and manipulated by one hand without the aid of grasping tools	(α+β) < 360°	0	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
	360° ≤ (α+β) < 540°	1	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
	540° ≤ (α+β) < 720°	2	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
	(α+β) = 720°	3	1.95	2.25	2.7	2.51	3	2.73	3.06	3.55	3.34	4

Key: One hand with grasping aids

				Parts need tweezers for grasping and manipulation								Parts need standard tools other than tweezers	Parts need special tools for grasping and manipulation
				Parts can be manipulated without optical magnification				Parts require optical magnification for manipulation					
				Parts are easy to grasp and manipulate		Parts present handling difficulties (1)		Parts are easy to grasp and manipulate		Parts present handling difficulties (1)			
				Thickness >0.25 mm	Thickness ≤0.25 mm	Thickness >0.25 mm	Thickness ≤0.25 mm	Thickness >0.25 mm	Thickness ≤0.25 mm	Thickness >0.25 mm	Thickness ≤0.25 mm		
				0	1	2	3	4	5	6	7	8	9
Parts can be grasped and manipulated by one hand but only with the use of grasping tools	α ≤ 180°	0 ≤ β ≤ 180°	4	3.6	6.85	4.35	7.6	5.6	8.35	6.35	8.6	7	7
		β = 360°	5	4	7.25	4.75	8	6	8.75	6.75	9	8	8
	α = 360°	α ≤ β ≤ 180°	6	4.8	8.05	5.55	8.8	6.8	9.55	7.55	9.8	8	9
		β = 360°	7	5.1	8.35	5.85	9.1	7.1	9.55	7.85	10.1	9	10

Assembly Time Model

Simplifying Assumptions:

- Fasteners
- Weight
- Obstructions
- Alignment
- [another example]

$$T = (1 + C_1)C_2H + C_3I$$

H = Handling Time

I = Insertion Time

C1 = Setup Penalty

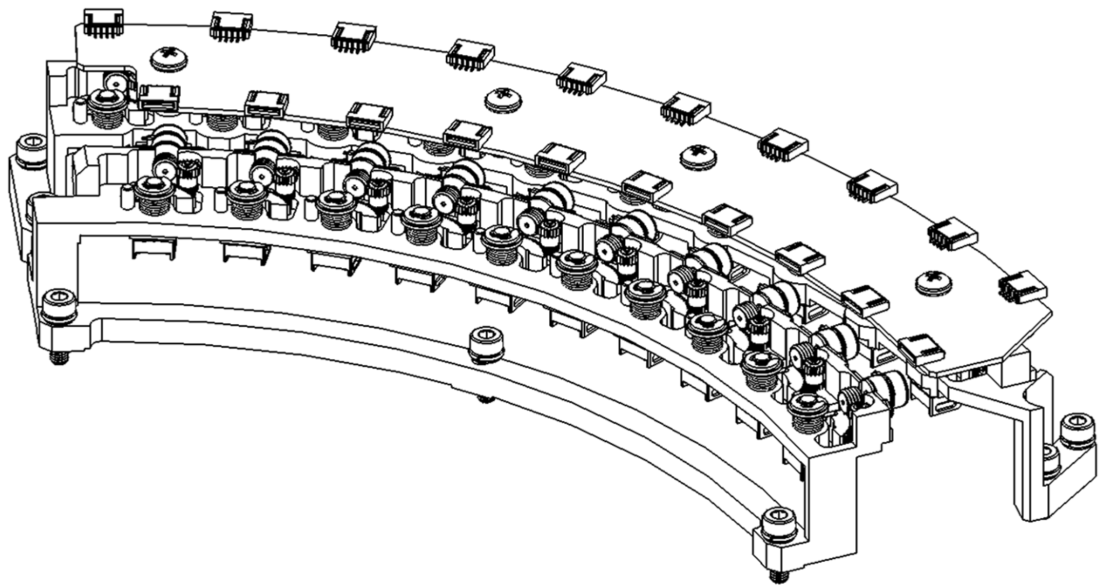
C2 = Number of Setups

C3 = Number of Passes

Simplifying coefficients:

- Chosen based on knowledge of assembly plan
- Tunable to various manufacturing locales
- In cases below clients withheld assembly data until after our model release

Case 1 – Electro-Optical Prototype

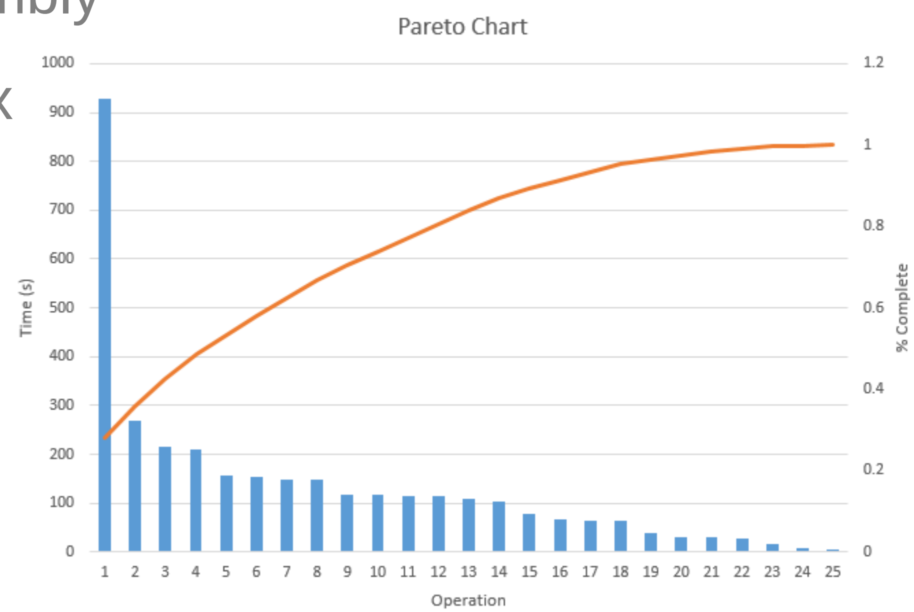


Background:

- Electro-optical test apparatus
- Miniature drive trains move optical elements
- ~12K units/yr
- Early in design process, desired part & assembly-level optimization

Case 1 – Model Development

- Original assembly contains 374 parts, 16.6% DFA index
- 50% of time in ~20% of parts
- Largest single contributor is 28% of total (15 min)
- +/- 8% correlation with client assembly data (.92 hrs)
- First pass opportunity identified:
  - Reduce to .31 hours assembly
  - Increase to 28.6 DFA index



Actual achieved results after design cycle:

- Reduce assembly time to .43 hours
- Increase DFA index to 20.6%

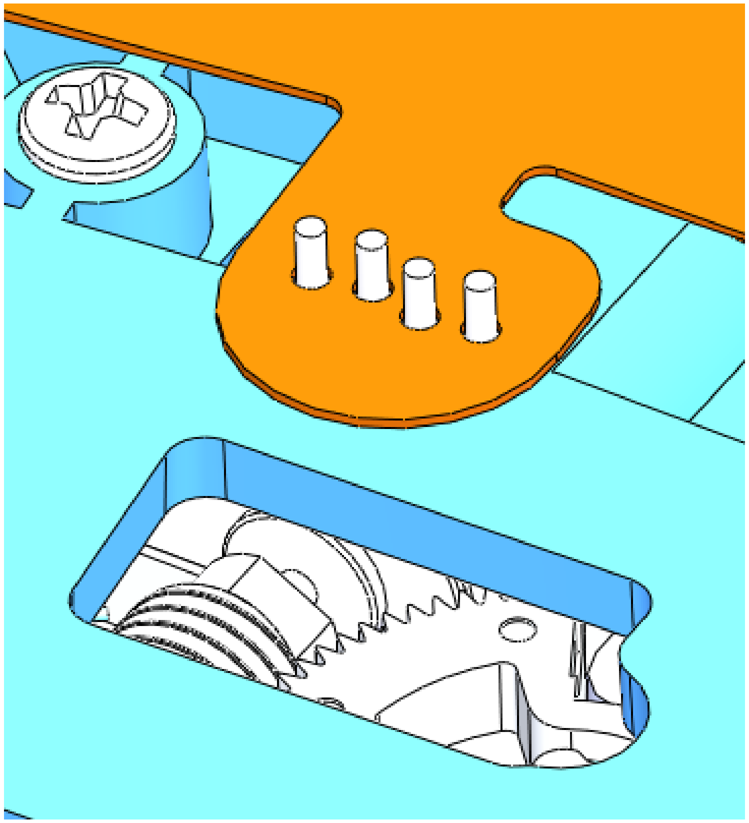
Focusing Module DFM
Touch Labor Rollup

Burdened Labor Rate $/hr		
US:	$50.00	1.39 cents/sec
China:	$11.50	0.32 cents/sec

Setup Penalty 25 %

	Description	Operation	Qty	Min Qty	# Pass	# Setup	Handling (s)	Insertion (s)	Total Time (s)	Operation Cost
1	Base	Manipulate	1	1	1	1	3	0	3.75	5.208333333
2	Mounting Bar	Snap	2	2	1	1	1.95	5.5	15.3875	21.37152778
2.1	Spring Pin	Press	0	0	0	0	2.18	3.5	0	0
2.2	Rocker Gear	Place	20	20	1	2	1.8	5.5	146.9	204.0277778
2.2.1	Optical Element	Bond	20	20	1	1	1.43	4	108.9575	151.3298611
2.2.2	Shaft	Bond	0	0	0	0	1.8	4	0	0
2.3	Bushing	Place/Press	20	20	1	1	2.35	5	147.5875	204.9826389
2.4	Bushing	Place	0	0	0	0	2.35	1.5	0	0
2.5	Spring	Snap	1	1	1	1	5.1	9	15.375	21.35416667
2.6	Washer	Hold	20	0	1	1	1.69	1.5	64.2225	89.19791667
2.7	Washer	Hold	0	0	0	0	1.69	1.5	0	0
2.8	Snap Ring	Snap	0	0	0	0	2.18	3.5	0	0
2.9	Pinion Shaft	Press	0	0	0	0	1.69	3.5	0	0
2.10	Pinion	Place	20	20	1	1	1.88	3	98.07	136.2083333
2.11	Snap Ring	Snap	0	0	0	0	6.85	3.5	0	0
2.12	Stepper Motor	Snap	20	20	1	4	2.25	4.5	137.25	190.625
2.12.1	Worm Gear	Bond	0	0	0	0	1.88	4	0	0
2.12.2	Motor Plate	N/A	20	0	1	1	0	0	0	0
2.13	Phillips Screw	Screw	0	0	0	0	2.35	11	0	0
3	Washer	Hold	0	0	0	0	2.18	1.5	0	0
4	Lock Washer	Hold	0	0	0	0	2.18	1.5	0	0
5	Hex Screw	Screw	0	0	0	0	2.35	11	0	0
6	Stepper Board	Snap	1	1	1	1	1.95	5.5	7.9375	11.02430556
7	Standoff	Screw	0	0	0	0	2.35	7	0	0
8	Phillips Screw	Screw	0	0	0	0	1.8	11	0	0
9	Motor Cables	Solder	80	0	1	1	3.6	3.5	568.9	790.1388889
10	Top Cover	Snap	1	1	1	1	1.95	4.5	6.9375	9.635416667
11	Shoulder Screw	Screw	20	0	1	1	2.35	8.5	217.5875	302.2048611
								Totals:	**0.427461806 (man-hours)**	**21.37309028 (dollars)**
								Asm Eff:	**20.66461428 %**	

Case 1 – Model Application

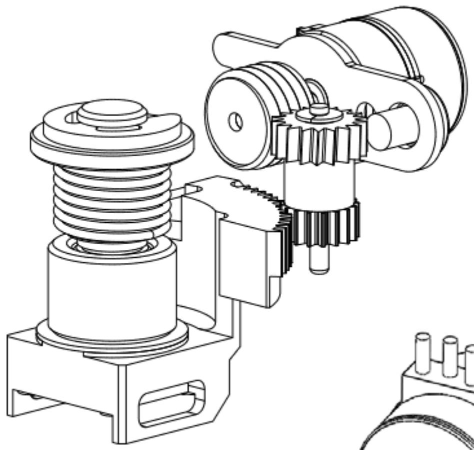


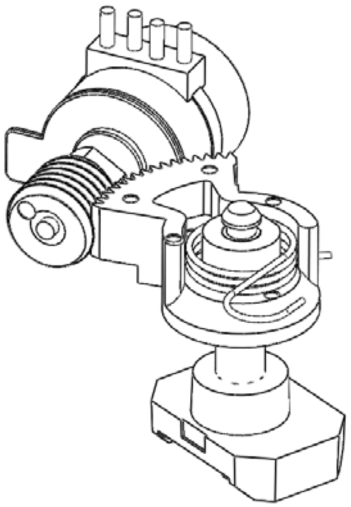
Unique challenges:

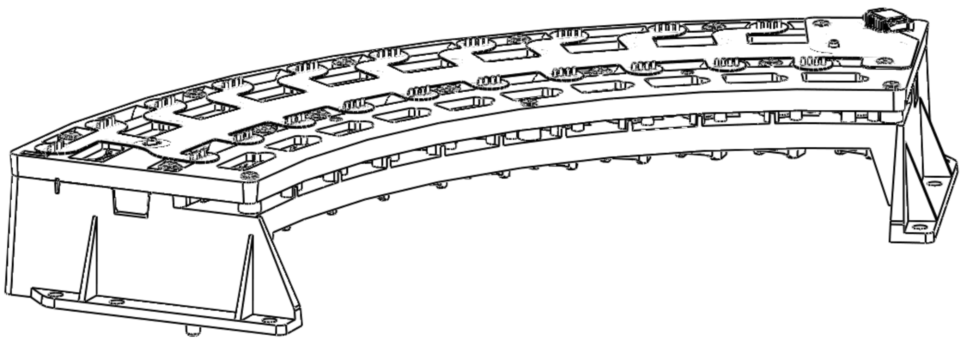
- High tolerance (optics, thermal sensitivity)
- Harsh environment limited material choices
- Completed tolerance analysis to assure motor placement for soldering operation

Case 1 – Results

- Cost savings > $ 500K (parts & asm)
- 100% realized
- Part Count: 374 → 148
- DFA index: 16.6% → 20.6%
- Assembly time: .92 hrs → .43 hrs



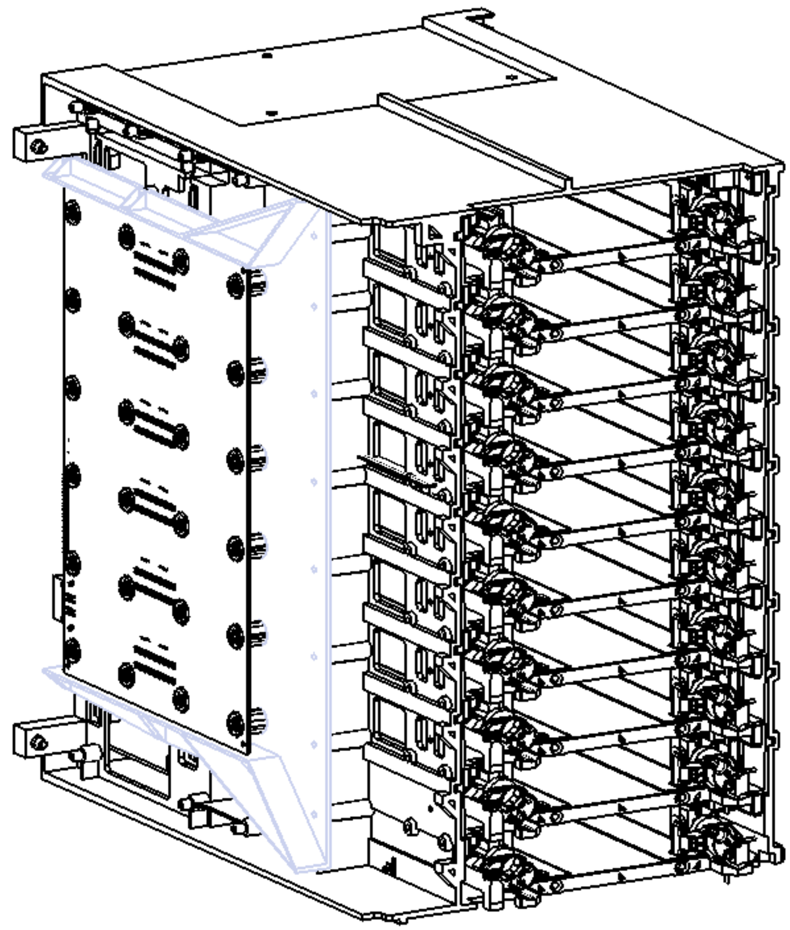




Case 2 – Tooled Test Assembly

Background:

- Electro-mechanical test apparatus
- ~14K unit build cycle
- ~3 hour anticipated build
- Actually took technicians 6.5 hrs
- Already had tooled plastic parts, had to work within constraints



Case 2 – Model Development

Assembly
Touch Labor Rollup ## 1.39 cents/sec
0.36 cents/sec

Setup Penalty 25 %

											Handling Process Tree					Physical Features								
		Operation	Qty	Min	# Pa	# Se	Part Added?	Access/Fastening	Operation	Align/Insert	Hands Require	Handling To	Manipula	Major Axis	Minor Axis	Thickness/Size	A	B	A/B	Handling	Insertion	Total	Cost	% Pack
Sub-Asm	1	Position slider	2	2	1	[illegible]	1. Part Added but Not Secure	1. Easy Access	1. Place	1. Easy Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	2. 2 Directions	1. T >2mm, S >15mr	360	180	3	1.8	1.5	7.5	2.71	0.68%
(2x heate	2	Apply epoxy onto slider	8	0	1	[illegible]	3. Sepearate Operation	2. Non-Mech. Fasten	4. Chemical Proc	1. UNUSED	1. One Hand	1. UNUSED	1. Easy	1. Any Direction	1. Any Direction	1. T >2mm, S >15mr	0	0	1	1.13	12	146	52.6	13.12%
	2.1	Position pads onto slide	8	8	1	[illegible]	1. Part Added but Not Secure	1. Easy Access	1. Place	3. Hard Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	2. 2 Directions	2. T >2mm, S =6~15	360	180	3	2.1	2.5	37.9	13.7	3.41%
	2.2	Check epoxy pad seatir	2	0	1	[illegible]	3. Sepearate Operation	3. Non-Fastening	1. Manipulation	1. UNUSED	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	2. 2 Directions	1. T >2mm, S >15mr	360	180	3	1.8	9	22.5	8.13	2.03%
	3	Install O-rings onto shol	4	4	1	[illegible]	2. Part Secured Immediately	1. Easy Access	1. No Screw or D	2. Easy Align w/ Resis	1. One Hand	1. UNUSED	1. Easy	2. 2 Directions	1. Any Direction	1. T >0.25mm	180	0	1	1.13	5	24.8	8.96	2.24%
	4	Install sholder nuts in sl	4	4	1	2	1. Part Added but Not Secure	1. Easy Access	1. Place	1. Easy Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	1. Any Direction	2. T >2mm, S =6~15	360	0	2	1.8	1.5	14.1	5.09	1.27%
	5	Connect ribbon cables t	2	2	1	1	2. Part Secured Immediately	1. Easy Access	1. No Screw or D	2. Easy Align w/ Resis	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	2. T >2mm, S =6~15	360	360	4	2.25	5	15.1	5.44	1.36%
	5.1	Solder connector to hea	2	2	1	2	3. Sepearate Operation	2. Non-Mech. Faste	2. Soldering	1. UNUSED	3. Two Hands	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	2. S =6~15mm	360	360	2	6.75	8	32.9	11.9	2.96%
	6	Position heater strips	2	2	1	2	1. Part Added but Not Secure	2. Medium Access	2. Hold	3. Hard Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	4. T <=2mm, S >6mm	360	360	4	2.51	9	24.3	8.77	2.19%
	7	Screw down heater strip	4	0	1	2	2. Part Secured Immediately	2. Medium Access	4. Screw	4. Hard Align w/ Resist	1. One Hand	1. UNUSED	2. Difficult	4. 1 Direction	1. Any Direction	5. T <=2mm, S <=6m	360	0	2	3.38	10.5	57.2	20.7	5.16%
	8	Install left spring into lef	1	1	1	1	2. Part Secured Immediately	1. Easy Access	1. No Screw or D	3. Hard Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	2. T >2mm, S =6~15	360	360	4	2.25	5	7.81	2.82	0.70%
	9	Install right spring into r	1	1	1	1	2. Part Secured Immediately	1. Easy Access	1. No Screw or D	3. Hard Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	2. T >2mm, S =6~15	360	360	4	2.25	5	7.81	2.82	0.70%
	10	Install latch onto cam	2	2	1	2	1. Part Added but Not Secure	1. Easy Access	1. Place	1. Easy Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	1. Any Direction	2. T >2mm, S =6~15	360	0	2	1.8	1.5	7.5	2.71	0.68%
	11	Install knob onto cam	2	2	1	2	1. Part Added but Not Secure	1. Easy Access	2. Hold	1. Easy Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	1. T >2mm, S >15mr	360	360	4	1.95	5.5	15.9	5.73	1.43%
	12	Screw knob onto cam	2	0	1	1	2. Part Secured Immediately	1. Easy Access	4. Screw	2. Easy Align w/ Resis	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	1. Any Direction	4. T <=2mm, S >6mm	360	0	2	2.06	8	20.6	7.45	1.86%
	13	Place springs in block	4	4	1	2	1. Part Added but Not Secure	1. Easy Access	1. Place	1. Easy Align, No Resi	1. One Hand	1. UNUSED	2. Difficult	2. 2 Directions	1. Any Direction	5. T <=2mm, S <=6m	180	0	1	2.98	1.5	19.4	7.01	1.75%
	14	Place block on slider	2	2	1	2	1. Part Added but Not Secure	1. Easy Access	2. Hold	1. Easy Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	1. T >2mm, S >15mr	360	360	4	1.95	5.5	15.9	5.73	1.43%
	15	Slide in cam assembly	2	0	1	2	2. Part Secured Immediately	2. Medium Access	1. No Screw or D	2. Easy Align w/ Resis	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	1. Any Direction	1. T >2mm, S >15mr	360	0	2	1.5	7.5	18.8	6.77	1.69%
PCB	1	Install grommets into P	5	0	1	1	2. Part Secured Immediately	2. Medium Access	1. No Screw or D	2. Easy Align w/ Resis	2. One hand +	3. Standard	1. Easy	2. 2 Directions	1. Any Direction	1. T >0.25mm	180	0	1	7	7.5	74.3	26.8	6.69%
	2	Position ground cable	1	1	1	1	1. Part Added but Not Secure	1. Easy Access	2. Hold	3. Hard Align, No Resi	1. One Hand	1. UNUSED	1. Easy	2. 2 Directions	4. 1 Direction	2. T >2mm, S =6~15	180	360	3	2.1	6.5	9.13	3.3	0.82%
	2.1	Position washer	1	0	1	1	1. Part Added but Not Secure	1. Easy Access	2. Hold	1. Easy Align, No Resi	1. One Hand	1. UNUSED	1. Easy	2. 2 Directions	1. Any Direction	5. T <=2mm, S <=6m	180	0	1	2.18	5.5	8.23	2.97	0.74%
	3	Screw in ground cable	1	0	1	1	2. Part Secured Immediately	1. Easy Access	4. Screw	2. Easy Align w/ Resis	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	1. Any Direction	4. T <=2mm, S >6mm	360	0	2	2.06	8	10.6	3.82	0.95%
Sub-Asm	1	Position base	1	1	1	1	[illegible] Sepearate Operation	3. Non-Fastening	1. Manipulation	1. UNUSED	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	1. Any Direction	1. T >2mm, S >15mr	360	0	2	1.5	9	10.9	3.93	0.98%
	2	Place heater assemblie	2	0	1	1	1. Part Added but Not Secure	1. Easy Access	1. Place	3. Hard Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	3. 4 Directions	1. T >2mm, S >15mr	360	90	2	1.5	2.5	8.38	3.02	0.75%
	2.1	Orient latches, seat spr	2	0	1	[illegible]	3. Sepearate Operation	3. Non-Fastening	1. Manipulation	1. UNUSED	1. One Hand	1. UNUSED	1. Easy	1. Any Direction	4. 1 Direction	2. T >2mm, S =6~15	0	360	2	1.8	9	22.1	7.96	1.99%
	3	Place rear bearing cove	2	2	1	1	1. Part Added but Not Secure	1. Easy Access	1. Place	1. Easy Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	2. T >2mm, S =6~15	360	360	4	2.25	1.5	8.06	2.91	0.73%
	4	Screw center blocks &	6	0	1	1	2. Part Secured Immediately	1. Easy Access	4. Screw	2. Easy Align w/ Resis	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	1. Any Direction	2. T >2mm, S =6~15	360	0	2	1.8	8	59.3	21.4	5.34%
	5	Place front bearing cove	2	2	1	1	1. Part Added but Not Secure	1. Easy Access	1. Place	1. Easy Align, No Resi	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	4. 1 Direction	2. T >2mm, S =6~15	360	360	4	2.25	1.5	8.06	2.91	0.73%
	6	Screw front bearing cov	4	0	1	1	2. Part Secured Immediately	1. Easy Access	4. Screw	2. Easy Align w/ Resis	1. One Hand	1. UNUSED	1. Easy	4. 1 Direction	1. Any Direction	2. T >2mm, S =6~15	360	0	2	1.8	8	39.7	14.3	3.57%
	7	Clip spring leads	4	0	1	1	3. Sepearate Operation	3. Non-Fastening	2. Other	1. UNUSED	2. One hand +	3. Standard	[illegible] Easy	1. Any Direction	1. Any Direction	1. T >0.25mm	0	0	1	7	12	77.8	28.1	7.01%

lder (s)	Part Added?	Access/Fastening	Operation	Align/Insert
	1. Part Added but Not Secure	. Easy Access	1. Place	1. Easy Align, Nc
		Non-Mech. Fasten	4. Chemical Process	1. UNUSED
		Easy Access	1. Place	3. Hard Align, No
	3. Sepearate Operation	3. Non-Fastening	1. Manipulation	1. UNUSED

1. Part Added but Not Secured
2. Part Secured Immediately
3. Seperate Operation

Insertion Process Tree

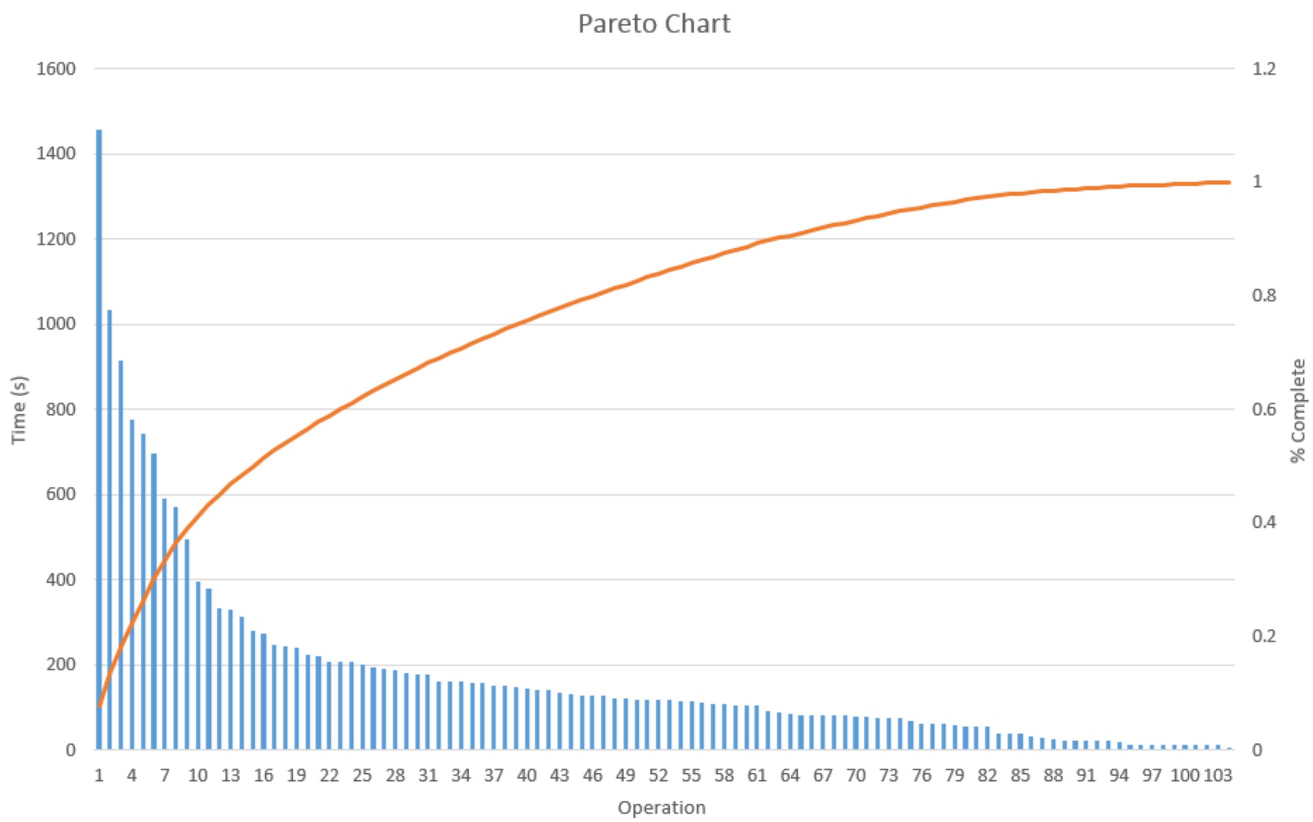
Part Added?	Access/Fastening	Operation	Align/Insert
1. Part Added but Not Secure	1. Easy Access	1. Place	1. Easy Align, No
3. Sepearate Operation	2. Non-Mech. Fasten	4. Chemical Process	UNUSED
1. Part Added but Not Secure	1. Easy Acces		Hard Align, No
3. Sepearate Operation	3. Non-Fasten		UNUSED
2. Part Secured Immediately	1. Easy Acces		Easy Align w/ I
1. Part Added but Not Secure	1. Easy Access	1. Place	1. Easy Align, No

1. No Mat'l Required
2. Soldering
3. Weld/Braze
4. Chemical Process

Assembly Time Estimator for Large Assemblies

Case 2 – Model Development

- Original assembly contains 1709 parts, 7.6% DFA index
- 60% of time in ~25% of parts
- Largest single contributor is 8% of total (24 min)

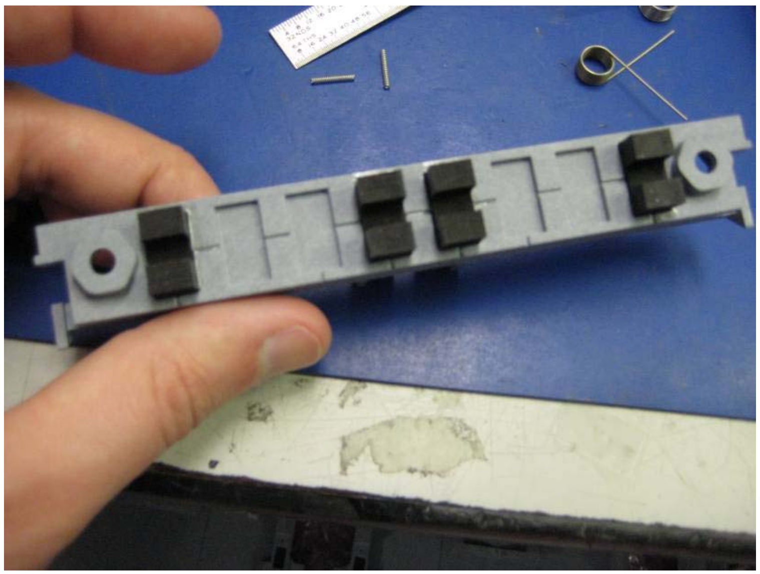


Model correlation with client assembly times:

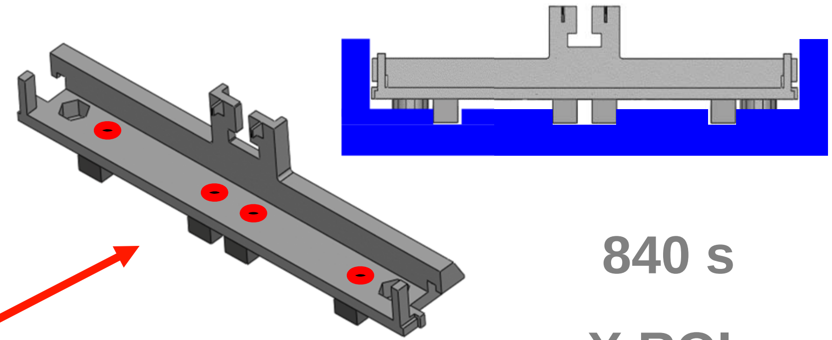
- +/- 20% on process level common (up to 200%)
- +/- 5% on sub-assembly level
- +/- 2% on top assembly level
- Higher assemblies have averaging effect

Step	Actual Time	Model Time	Notes
BLOWERS:			
apply epoxy to flap base	15	13.5	without epoxy mixing time
position flap base onto fan	13	15	Clean up operation not in model
backfill gaps	17	26	
place PSA onto jig	20	26	
press fan onto PSA	20	29	
orient blower weldment	5	10.8	
install first blower	24	4.4	Include PSA mask removal?
re-orient blower weldment	5	12.7	
install second blower	21	4.4	
route cables	16	23	
route ribbon cables	17	24	
place blower assembly into duct cover	12	12.7	
screw assembly	93	55	manual driver, check cables
flip assembly over	3	13	
screw assembly	31	23	
check cable movement	7	22	
snap on blower flaps	15	14	
check blower flap movement	4	11	
Totals	**338**	**339.5**	

Case 2 – Model Application

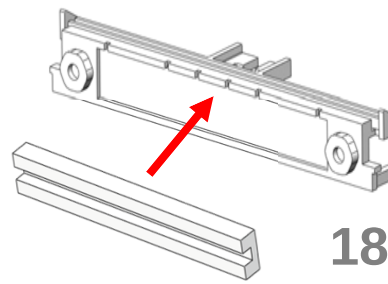


Original Design: Epoxied Bumpers



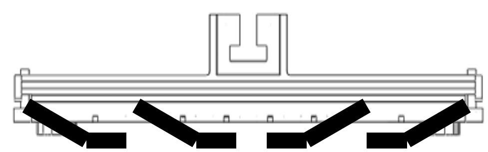
840 s

X ROI



1860 s

2X ROI



2060 s

2X ROI

Case 2 – Model Application

ROI Rollup

Selected Option	Description	Est. Time Savings (s)	% Total	Est. Assembly Cost Savings	Est. Tooling	Est. NRE	Part Cost Delta	Est. ROI	Risk	Part cost notes
1.1	Assembly fixture, epoxy through holes	840	4.2%	GOOD	$4,000	$5,000	$0.00	OK	Low	
1.2	Single bumper, simplified attachment	1860	9.3%	BETTER	$8,000	$10,000	$0.00	BEST	Low	
1.3	New slider with integrated springs	2060	10.3%	BEST	$20,000	$20,000	$3.00	GOOD	High	+integrated springs
2.c	Integrate cables into flex heaters	520	2.61%	GOOD	$8,000	$5,000	$10.00	VERY BAD	Low	+flex heater -separate cable
2.1	PSA heater to bumper	740	3.71%	GOOD	$2,000	$10,000	-$1.00	BEST	Low	-screws&shoulder nuts
2.2	Modify heater with snap-in standoffs	1000	5.01%	GOOD	$10,000	$15,000	$0.00	GOOD	Med	-screws&shoulder nuts +heater snap
2.3	Key slots in heater for positioning	250	1.25%	BEST	$3,000	$3,000	$0.00	OK	Low	
3.s	Modify spring to cut length	780	3.91%	GOOD	$1,000	$0	$0.00	BEST	Low	
3.1	Snap-in cam assembly covers	1110	5.6%	BEST	$30,000	$10,000	$0.00	OK	Med	-screws +slot plastics
3.2	Latch/Cam design changes	430	2.2%	OK	$20,000	$15,000	-$1.00	BAD	Med	-latch & springs
3.3	Assembly fixture, base modification	510	2.6%	OK	$10,000	$15,000	$0.00	BAD	Low	-screws&springs +slot plastics
pm	One-way snap to retain pusher	485	2.4%	GOOD	$10,000	$5,000	$0.00	OK	Low	-screws +pusher plastics
4.1	Isolation washers, snap-on wireform	1530	7.7%	BEST	$10,000	$10,000	$0.00	BEST	Low	-screws&washers + wireframe
4.2	Slot board layout changes	810	4.1%	GOOD	$10,000	$5,000	-$0.20	GOOD	Low	-grounding cable
5.1	Customize blowers	520	2.6%	BEST	$8,000	$5,000	$0.00	BEST	Low	
5.2	Symmetric blower floap	425	2.1%	OK	$5,000	$10,000	$0.00	GOOD	Low	
6.1	PSA strips	95	0.5%	OK	$0	$2,000	-$0.50	BEST	Low	-diecut psa
6.2	Snap-in blowers to weldment	245	1.2%	GOOD	$5,000	$3,000	$0.00	GOOD	Low	
6.3	Wireform snap over blowers	245	1.2%	GOOD	$0	$5,000	$0.50	OK	Med	+wireform
6.c	Cable routing clips in weldment	105	0.5%	OK	$5,000	$5,000	$0.00	BAD	Low	
7.1	Snap-on covers to blowers	560	2.8%	GOOD	$5,000	$10,000	$0.00	GOOD	Low	
7.2	Custom install of blowers into weldment	1220	6.1%	BEST	$30,000	$15,000	-$1.00	BEST	Med	-duplicate blower shroud
8	Frame tool change	900	4.5%	GREAT	$20,000	$0	$0.00	GREAT	Low	
cr.1	Change PCBA layout & mounting	972	4.9%	GOOD	$20,000	$10,000	$1.00	OK	Low	+sheetmetal hinged frame
cr.2	Route slot cables between blowers	831	4.2%	GOOD	$20,000	$10,000	$0.50	OK	Low	+overmold
cr.3	Route slot cables out side of pack	1155	5.8%	BEST	$30,000	$15,000	$0.20	BEST	Med	+slot cable retainer
si.1	Assembly fixture	126	0.6%	OK	$0	$2,000	$0.00	OK	Low	
si.2	Slot divider tray modifications	1014	5.1%	GOOD	$10,000	$10,000	$0.00	BEST	Low	-screws, +wireframe
si.3	Sheetmetal wall adapter	1246	6.2%	BEST	$40,000	$20,000	$1.00	VERY BAD	High	+sheetmetal adapter

Representative section of options menu

Case 2 – Results

Recommended Options

Selected Option	Description	Est. Time Savings (s)	% Total	Est. Assembly Cost Savings	Est. Tooling	Est. NRE	Part Cost Delta	Est. ROI	Risk	Part cost notes
1.2	Single bumper, simplified attachment	1860	9.3%		$8,000	$10,000	$0.00		Low	
2.1	PSA heater to bumper	740	3.71%		$2,000	$10,000	-$1.00		Low	-screws&shoulder nuts
3.s	Modify spring to cut length	780	3.91%		$1,000	$0	$0.00		Low	
3.1	Snap-in cam assembly covers	1110	5.6%		$30,000	$10,000	$0.00		Med	-screws +slot plastics
pm	One-way snap to retain pusher	485	2.4%		$10,000	$5,000	$0.00		Low	-screws +pusher plastics
4.1	Isolation washers, snap-on wireform	1530	7.7%		$10,000	$10,000	$0.00		Low	-screws&washers + wireframe
5.1	Customize blowers	520	2.6%		$8,000	$5,000	$0.00		Low	
6.1	PSA strips	95	0.5%		$0	$2,000	-$0.50		Low	-diecut psa
7.1	Snap-on covers to blowers	560	2.8%		$5,000	$10,000	$0.00		Low	
7.2	Custom install of blowers into weldment	1220	6.1%		$30,000	$15,000	-$1.00		Med	-duplicate blower shroud
8	Frame tool change	900	4.5%		$20,000	$0	$0.00		Low	
cr.1	Change PCBA layout & mounting	972	4.9%		$20,000	$10,000	$1.00		Low	+sheetmetal hinged frame
cr.3	Route slot cables out side of pack	1155	5.8%		$30,000	$15,000	$0.20		Med	+slot cable retainer
si.2	Slot divider tray modifications	1014	5.1%		$10,000	$10,000	$0.00		Low	-screws, +wireframe
	Totals	12941.00			184000.00	112000.00	-1.30			
		3.59472222 hours								

Client-selected mitigation plans:

- Prioritized development risk and ROI
- Cost savings > $ 500 K; ROI > $300 K
- Part Count: 1709 → 814
- DFA index: 7.6% → 14.9%
- Assembly time: 6.5 hrs → 2.9 hrs

If assembly time is prioritized:

- Time savings increase to 4 hrs
- ROI decreases to < $150 K

Conclusions

- Good first-order estimate of assembly cost early in design process
- Provides a way to make design tradeoffs & optimize assembly time
- Clients use tool for design metric, quote verification, removes “black box”
- **Use DFMA early & often in design to achieve maximum ROI**
- **But, better late than never**

	Case 1 - Optical Assembly	Case 2 - Test Assembly
Initial Assembly Time (hrs)	0.92	6.5
Optimized Assembly Time (hrs)	0.43	3.6
Assembly Time Reduction	29.4 min	2.9 hrs
Assembly Cost Savings (per unit)	~$5	~$50
COGS Cost Savings	$40 (35%)	N/A
Build Quantity	12,000/yr	14,000/yr
Total Client ROI	~500K	>$300K
Model Correlation	10-14%	2-5%

Hand-Calculated Savings:

Case studies in the application of a simplified Boothroyd-Dewhurst Methodology in the design and manufacture of complex assemblies

International Forum on Design for Manufacture and Assembly

Providence, RI, 6/14/2013

Silicon Valley / Boston / China