

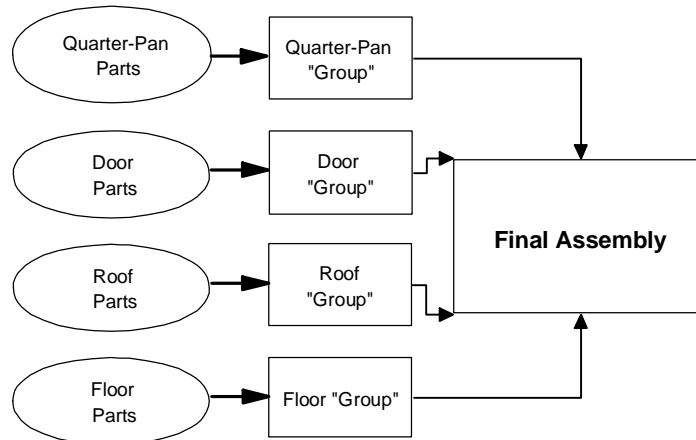
Introduction

- Topics of Analysis
 - Body-in-white Designs
 - Materials
 - Architectures
 - Technologies
 - Part Fabrication
 - Assembly
- Analysis Tools
 - Manufacturing Cost Models
 - Assembly Cost Model

Body-in-White Assembly Model

- **Assembly Sequence**
 - Realism
 - Specification of Subassembly Composition, Lengths, Methods
- **Joining Methods**
 - Modification of Joining Methods
 - Addition of New Methods
 - Methods Specific to Material, Mode of Application

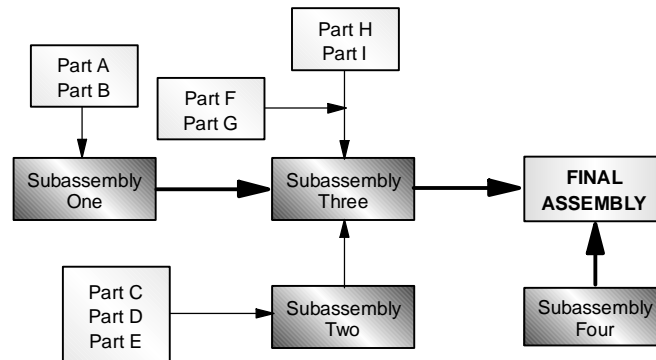
Previous Assembly Model



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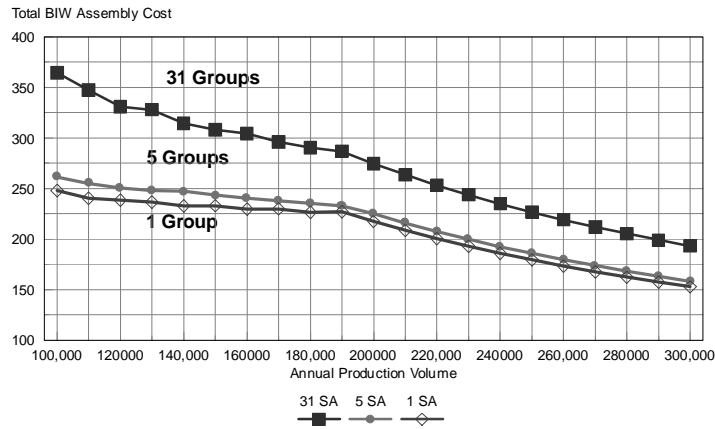
New Assembly Model



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Modeling of Subassemblies



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Joining Technologies

Model Methods

RSW (robot)(S)
RSW (robot)(A)
RSW (manual)(S)
RSW (manual)(A)
Tack-RSW (robot)(S)
Tack-RSW (robot)(A)
Weldbond (robot)(S)
Weldbond (robot)(A)
Weldbond (manual)(S)
Weldbond (manual)(A)

MIG Weld (robot)(S)
MIG Weld (robot)(A)
MIG Weld (manual)(S)
MIG Weld (manual)(A)

Riveting (robot)(S)
Riveting (robot)(A)
Riveting (manual)(S)
Riveting (manual)(A)
Riv-bond(manual)(S)
Riv-bond(manual)(A)
Riv-bond(robot)(S)
Riv-bond(robot)(A)

AB(1comp-robot)(S)
AB(1comp-robot)(A)
AB(2comp-robot)(S)
AB(2comp-robot)(A)
AB (1comp-manual)(S)
AB (1comp-manual)(A)
AB (2comp-manual)(S)
AB (2comp-manual)(A)

6kW CO2 LBW (r)(S)
6kW CO2 LBW (r)(A)
6kW CO2 LBW (g)(S)
6kW CO2 LBW (g)(A)
3kW CO2 LBW (r)(S)
3kW CO2 LBW (r)(A)
3kW CO2 LBW (g)(S)
3kW CO2 LBW (g)(A)
3kW Nd:YAG LBW (r)(S)
3kW Nd:YAG LBW (r)(A)

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Overall Costs @ 100,000 Vehicles/Year

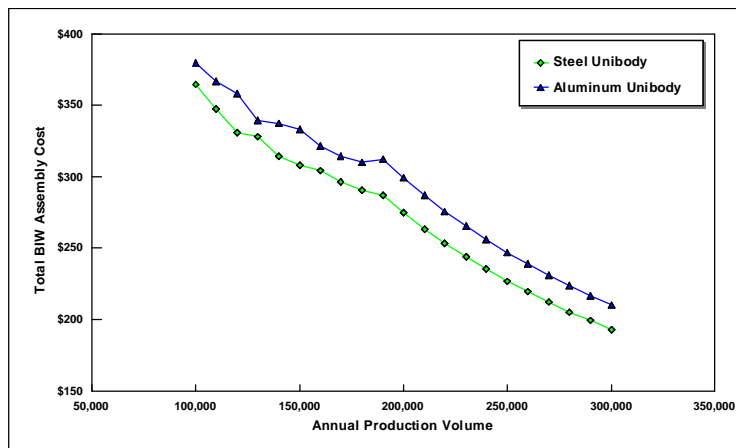
	Ultralight Aluminum	Aluminum Unibody	ULSAB	Steel Unibody
Number of Parts	82	167	82	167
Weight	120 kg	151 kg	208 kg	280 kg

Material	\$570	\$770	\$250	\$370
Parts Fabrication	\$460	\$700	\$430	\$650
Assembly	\$350	\$380	\$330	\$360
Total	\$1380	\$1850	\$1010	\$1380

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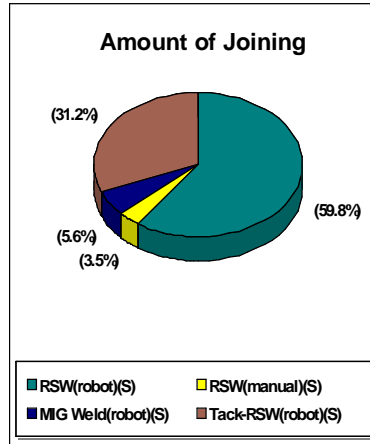
Unibody Production Volume Sensitivity



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Unibody Assembly Cost Breakdown



Assembly @ 100,000

Fixed Costs ~69%
Variable Costs ~31%

Line-Related Equipment ~50%

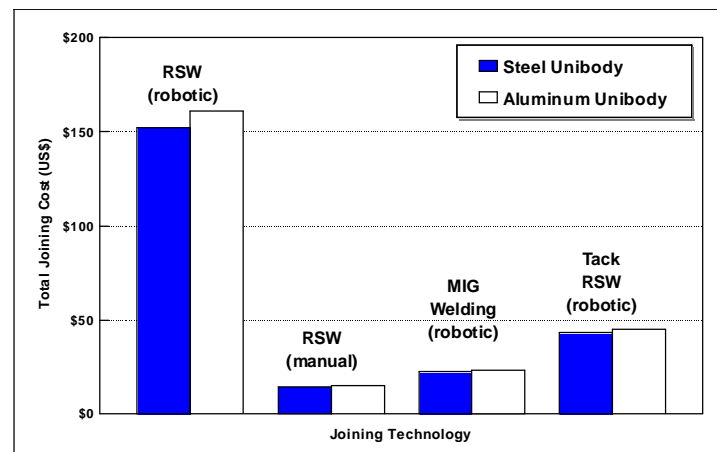
Joining Methods ~50%

Joining Equipment ~18% (total)
Labor ~30% (total)
Material ~1-2% (total)

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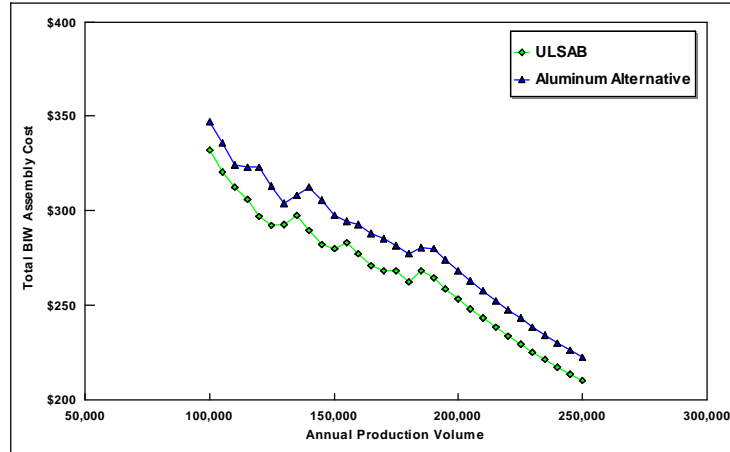
Unibody Joining Costs



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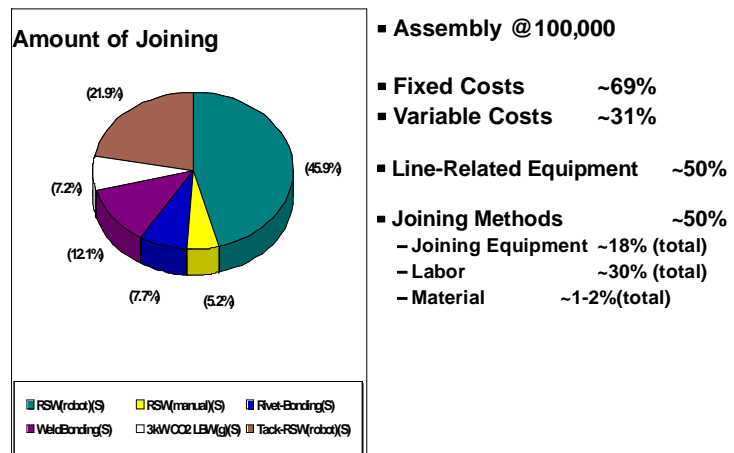
ULSAB & Aluminum Alternative Production Volume Sensitivity



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ULSAB & AI Alternative Assembly Cost Breakdown

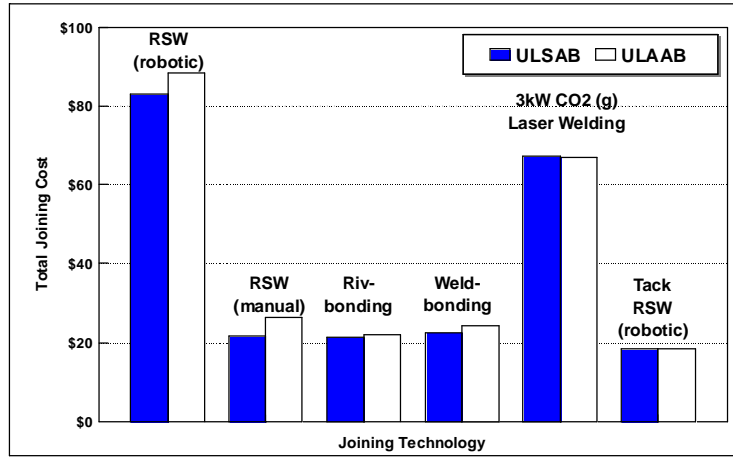


- Assembly @ 100,000
- Fixed Costs ~69%
- Variable Costs ~31%
- Line-Related Equipment ~50%
- Joining Methods ~50%
 - Joining Equipment ~18% (total)
 - Labor ~30% (total)
 - Material ~1-2%(total)

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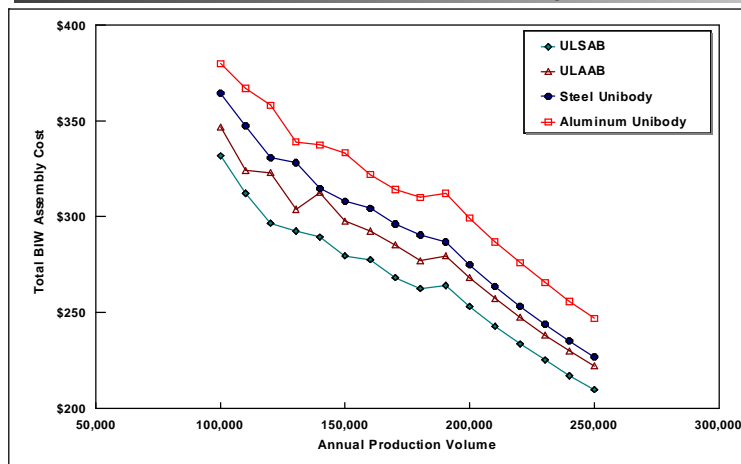
ULSAB and AI Alternative Joining Costs



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Production Volume Sensitivity



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Analysis of Joining Technologies

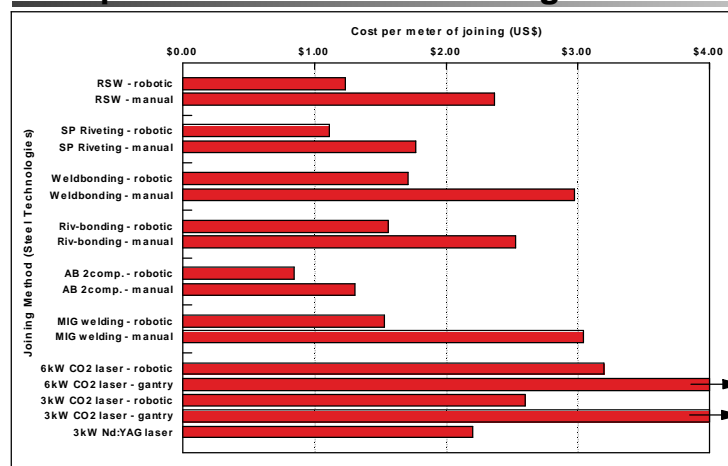
- **Cost Comparison of Various Technologies**
 - Discontinuous processes
 - Continuous processes
 - Hybrid processes

- **Scenario: Cost per Meter for Fully Utilized Equipment**
 - One part - one large subassembly
 - Long, straight joint
 - Approximately 100m of joining
 - 50mm welding segments

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Cost per Meter - Steel Technologies



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Steel & Aluminum Cost per Meter Comparison

Steel Methods	Cost/meter	Aluminum Methods	Cost/meter	Difference	% Greater
RSW - robotic	\$1.24	RSW - robotic	\$1.37	\$0.13	10.83%
RSW - manual	\$2.37	RSW - manual	\$2.64	\$0.27	11.21%
Riveting - robotic	\$1.12	Riveting - robotic	\$1.23	\$0.11	9.87%
Riveting - manual	\$1.77	Riveting - manual	\$1.89	\$0.11	6.43%
MIG welding - robotic	\$1.54	MIG welding - robotic	\$1.54	\$0.01	0.46%
MIG welding - manual	\$3.04	MIG welding - manual	\$3.06	\$0.02	0.53%
AB 1comp. - robotic	\$0.71	AB 1comp. - robotic	\$0.74	\$0.03	4.38%
AB 1comp. - manual	\$1.18	AB 1comp. - manual	\$1.22	\$0.03	2.70%
AB 2comp. - robotic	\$0.84	AB 2comp. - robotic	\$0.87	\$0.03	3.78%
AB 2comp. - manual	\$1.31	AB 2comp. - manual	\$1.34	\$0.03	2.45%
Weldbonding - robotic	\$1.71	Weldbonding - robotic	\$1.86	\$0.15	8.65%
Weldbonding - manual	\$2.98	Weldbonding - manual	\$3.20	\$0.22	7.45%
Riv-bonding - robotic	\$1.57	Riv-bonding - robotic	\$1.67	\$0.10	6.32%
Riv-bonding - manual	\$2.52	Riv-bonding - manual	\$2.64	\$0.12	4.68%
6kW CO2 laser - robotic	\$3.20	6kW CO2 laser - robotic	\$3.03	(\$0.17)	-5.38%
6kW CO2 laser - gantry	\$8.77	6kW CO2 laser - gantry	\$8.78	\$0.01	0.10%
3kW CO2 laser - robotic	\$2.60	3kW CO2 laser - robotic	\$2.43	(\$0.17)	-6.53%
3kW CO2 laser - gantry	\$8.51	3kW CO2 laser - gantry	\$8.53	\$0.01	0.16%
3kW Nd:YAG laser	\$2.21	3kW Nd:YAG laser	\$2.61	\$0.41	18.37%

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Steel & Aluminum Cost per Meter Comparison

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RSW - robotic	\$1.24	RSW - robotic	\$1.37	\$0.13	10.83%
Riveting - robotic	\$1.12	Riveting - robotic	\$1.23	\$0.11	9.87%
Weldbonding - robotic	\$1.71	Weldbonding - robotic	\$1.86	\$0.15	8.65%
Riv-bonding - robotic	\$1.57	Riv-bonding - robotic	\$1.67	\$0.10	6.32%
AB 2comp. - robotic	\$0.84	AB 2comp. - robotic	\$0.87	\$0.03	3.78%
MIG welding - robotic	\$1.54	MIG welding - robotic	\$1.54	-\$0	0.00%
3kW Nd:YAG laser	\$2.21	3kW Nd:YAG laser	\$2.61	\$0.41	18.37%
3kW CO2 laser - gantry	\$8.51	3kW CO2 laser - gantry	\$8.53	-\$0	0.00%
6kW CO2 laser - gantry	\$8.77	6kW CO2 laser - gantry	\$8.78	-\$0	0.00%
6kW CO2 laser - robotic	\$3.20	6kW CO2 laser - robotic	\$3.03	(\$0.17)	-5.38%
3kW CO2 laser - robotic	\$2.60	3kW CO2 laser - robotic	\$2.43	(\$0.17)	-6.53%

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Process Parameter Sensitivity

Resistance Spot Welding			
STEEL		ALUMINUM	
Spot Weld Spacing	Steel Cost/meter	Spot Weld Spacing	Aluminum Cost/meter
35mm	\$1.24	31.5mm	\$1.37
40mm	\$1.07	36mm	\$1.21

Spot Welding Rate (robotic)	Steel Cost/meter	Aluminum Cost/meter
0.33 welds/sec	\$1.24	\$1.37
0.50 welds/sec	\$0.92	\$1.03

MIG Welding		
Welding Speed	Steel Cost/meter	Aluminum Cost/meter
13mm/s	\$1.54	\$1.54
9mm/s	\$1.90	\$1.92
17mm/s	\$1.34	\$1.34

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Process Parameter Sensitivity

Laser Beam Welding			
Process	Equipment Cost	Steel Cost/meter	Aluminum Cost/meter
6kW CO2 (r)	\$600,000	\$3.20	\$3.03
6kW CO2 (r)	\$540,000	\$3.05	\$2.88
6kW CO2 (r)	\$450,000	\$2.82	\$2.67

3kW Nd:YAG	\$480,000	\$2.21	\$2.61
3kW Nd:YAG	\$432,000	\$2.11	\$2.50
3kW Nd:YAG	\$360,000	\$1.97	\$2.33

Process	STEEL		ALUMINUM	
	Welding Speed	Steel Cost/meter	Welding Speed	Aluminum Cost/meter
6kW CO2 (r)	100mm/s	\$3.20	150mm/s	\$3.03
6kW CO2 (r)	90mm/s	\$3.25	135mm/s	\$3.07
6kW CO2 (r)	75mm/s	\$3.36	113mm/s	\$3.14

3kW Nd:YAG	70mm/s	\$2.21	40mm/s	\$2.61
3kW Nd:YAG	63mm/s	\$2.27	36mm/s	\$2.73
3kW Nd:YAG	53mm/s	\$2.42	30mm/s	\$2.95

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Process Parameter Sensitivity

Resistance Spot Welding			
Spot Weld Spacing	ULSAB Cost	Spot Weld Spacing	ULAAB Cost
35mm	\$332	31.5mm	\$347
40mm	\$321	36mm	\$328

Spot Welding Rate (robotic)	ULSAB Cost	ULAAB Cost
0.33 welds/sec	\$332	\$347
0.50 welds/sec	\$303	\$320

MIG Welding		
Welding Speed	Steel Uni Cost	Alum Uni Cost
13mm/s	\$364	\$380
9mm/s	\$372	\$386
17mm/s	\$364	\$379

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Process Parameter Sensitivity

Laser Beam Welding		
3kW CO2 (gantry) Welding Speed	ULSAB Cost	ULAAB Cost
60mm/s	\$332	\$347
45mm/s	\$332	\$347
75mm/s	\$332	\$347

Laser Process	ULSAB Cost	ULAAB Cost
3kW CO2 (gantry)	\$332	\$347
3kW CO2 (robotic)	\$287	\$302
6kW CO2 (robotic)	\$294	\$308
3kW Nd:YAG (robotic)	\$290	\$308

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