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HANDBOOK OF ESTIMATING DATA, FACTORS, AND PROCEDURES

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16. ABSTRACT

This handbook seeks to fulfill the need for a book or collection of aids to assist in estimating cost. It contains a description of a work breakdown structure and briefly treats the necessity of analyzing the requirements for a cost element A part of the handbook is devoted to standards for specific production type standards and to an assemblage of "factors" which can be applied to manufacturing or production cost for determining associated costs.

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HANDBOOK OF ESTIMATING DATA, FACTORS, AND PROCEDURES

I. INTRODUCTION

A. Purpose

This handbook seeks to fulfill a need frequently expressed by cost estimators and by engineers in various disciplines for a book or collection of aids to assist in estimating costs. Especially desirable, as determined from estimators and engineers, are standards such as time to weld an inch of steel or aluminum, time to machine various shapes and sizes of different materials, time to layout and fabricate various shapes and thickness of sheet metal, etc. This handbook provides some of those standards. A considerable amount of the information contained herein is based on the experience of Fred C. Hartmeyer who supplemented his experience with that of many colleagues.

B. Plan (How the Handbook is Organized)

This handbook contains a description of a work breakdown structure (WBS). While use of a WBS is not always mandatory in developing a cost estimate, the principle of fragmenting is beneficial. There is a brief treatment of the necessity to analyze the requirements for a cost element. This leads naturally into the development of the WBS, or alternatively, a breakdown of line items into logical workable subline items. As the analysis of the WBS or line item elements continues, a comprehensive listing of all operations which will be performed should be made, e.g., machining or welding, etc. Similarly if no Bill of Material exists, a listing of materials requirements should be developed.

A separate part of the handbook is devoted to standards for specific production type standards. These standards have been developed from observations of job shop operations and are based on levels of efficiency attainable for production levels in the range of 0 to 1000.

A very important part of this handbook is devoted to an assemblage of "factors." Most of these factors can be applied to manufacturing or production costs for determining associated costs, such as production engineering, inspections, test, quality, etc.

II. PROCEDURES

A. Analysis of Requirement

An inherent difficulty in obtaining the dedication and perseverance which are needed in developing accurate credible government cost estimates is the absence of the profit motive which drives the private sector of the economy. The profitability of a company developing and manufacturing a product depends on estimators analyzing requirements and accurately estimating all costs. Profitability means jobs. Jobs mean motivation.

The primary guideline presented in all literature relating to cost estimating is to begin with a painstaking analysis of the requirements. The purpose of this section is to provide guidelines, objectives, and methods which can be used to assist in more lucid analyses of requirements.

1. Preliminary Cost Estimates. One analytical method which has been used, particularly where a cost estimate is needed before the WBS has been developed, is a components listing. A typical component/percentage listing which could have been used for the Solid Rocket Booster (SRB) Integrated Electronics Assembly (IEA) is given as follows:

Gross Estimate Percentages — IEA

	Percent of Total Cost		
	Max	Min	Median
Housing	6.4	11.6	9
Distributor	13.1	35.2	24.1
Multiplexer	0	1.3	0.6
Signal Conditioner	5.8	12.1	8.9
Manufacturing Support	8.5	28.5	18.5
Test Set	3.8	12.7	8.2
Special Test Equipment	0.7	4.5	2.6
Engineering	12.7	23.1	17.9
Management	8.5	21.2	14.7

Percentages previously given are based on actuals proposed by seven firms seeking a contract for the IEA. These percentages and the table are not intended for actual application to any contemplated program. The purpose here is to give an example of how a cost estimate can be broken to rather gross levels and a preliminary component estimate prepared. It is obvious that the estimator and the responsible engineer will have to study available specifications, drawings, and other documentation to have as good an understanding of the overall requirement as possible . By doing this, they can get a feel for a percentage range for each subitem as it is identified. Several iterations may be required to get the percentage range that is comfortable. Once the ranges are developed, then the median percentage can be used for application to total cost. The particular application of this type of estimating is useful when it is desirable to break down an existing gross budgetary figure.

It is suggested that a preliminary estimate would be a logical takeoff point for the development of the definitive WBS. As will be developed later, the WBS or similar end item breakdown is the recommended format for deriving the definitive estimate. In addition, the early establishment of component percentages could provide check points for more finite iterations of a cost estimate later. This means that a total program cost has been developed by the use of parametric estimating. Now, this total can be broken into components to be used in support of procuring organizations in determining realistic and credible costs proposed for a program.

2. <u>The Six-Tenths Factor in Estimating</u>. A widely used short-cut method used in developing preliminary cost elements is the so-called six-tenths factor. This factor is defined as follows:

> When the cost of a particular item at one capacity is known, and the cost of that particular item at another capacity of X times the known is desired, divide the known capacity into the desired capacity, raise to the power of 0.3 and multiply by the known cost to obtain the cost of the second capacity.

<u>Example:</u>

It is known that a 100 gal/min stainless steel centrifugal pump cost \$ 3000, new. What would the same kind of pump of 200 gal/min capacity cost?

Solution:

Divide 100 into 200 which equals 2. Raise 2 to the 0.6 power which equals 1.516. Multiply 1.516 by \$ 3000 which equals \$ 4548, the estimated cost of the 200 gal/min pump.

The six-tenths rule is widely used in some types of estimating. It is called a rule, but in reality it is a principle and the exponents used in deriving estimates on the basis of capacity and known cost are obtained from experience and are continuously updated by use and further verification by further experience. In Section IV, tables can be found showing some typical six-tenth rule exponents. These may be used in the applications listed and, in the opinion of the author, it is believed the engineer and/or the cost estimator may be able to establish a cost estimating relationship with some of the items listed and thus derive his own exponent for application to his particular item to be estimated.

B. Work Breakdown Structure (WBS)

1. Detail. The WBS is thoroughly defined, described, and illustrated in "Military Standard Work Breakdown Structures for Defense Material Items" (MIL-STD-881). Appendix B of that standard applies particularly to electronics systems and Appendix F applies specifically to space systems.

This section will describe in summary fashion a WBS with emphasis on its application for developing cost estimates. The chief benefit of using a WBS is its capability to be broken down to the lowest practical level. These lower levels can be summed at each next higher level so that at the top level the program is a summation of all the lower levels. In addition, the WBS becomes the contract line item description whenever procurement is effected. This allows an evaluation of costs proposed by potential contractors with the costs estimated by the government on a detailed basis.

The MIL Standard defines WBS (modified) as follows:

> A product-oriented family tree composed of hardware, software, services, and other work tasks which result from project engineering efforts during the development and production of a project/program item, which completely defines that project/program. A WBS displays and defines the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product.

Figure 1 is an example of a WBS breakdown for the IEA. This breakdown illustrates the versatility of the WBS for providing a logical work sequence or a logical basis for developing a cost estimate. Note that the first level of the IEA is numbered 1.4.1.4.2 because the IEA is actually a subitem of the SRB, which in turn is a subitem of the Space Shuttle. The IEA is an item of sufficient complexity and dollar value to warrant a separate procurement and development; therefore, it was separated from the SRB. The numbering scheme noted was used so that it would be identified in the Shuttle program family tree.

2. Analysis of WBS Elements. The IEA WBS was introduced to show how a major item of hardware could be divided into finite elements for more detailed analysis for technical description and cost estimating. Note that the subitem, Development and Deliverable Hardware, is further subdivided into eight parts. In developing the technical specifications and the IEA cost estimate, these eight parts were further broken down to elements such as connectors, wiring harness, circuit boards, etc. It becomes apparent that a well-developed WBS provides the outline from which a disciplined analysis and cost estimate can be made. It is also apparent that the principles relating to the family tree approach to the breakdown of a procurement item for technical description and cost estimation can be applied in those instances where a WBS, as such, is not appropriate.

During the iteration process for the WBS, the responsible engineer/cost estimator should concurrently list the operations required to complete each discrete subelement. This will aid immeasurably in synthesizing a credible cost estimate. It will also identify those operations for which a standard exists. For instance, if machining is required, the part should be listed with a notation, "machine." As analysis progresses, a listing of types, kinds, and amounts of materials should be made. The benefits of this listing will allow the application of appropriate materials prices and, in addition, the application of scrap factors. It should be stated that the procedures outlined here are not easy or quick, but they can be effective in developing estimates which can be used to assure that the government is getting realistic procurement estimates from industry. It also should be noted that while the WBS is shown broken down to level 3, if it is desirable, feasible, and/or practical, the level 3 subelements can be further broken down to levels 4, 5, 6, and even 7. (Many contractors account for costs to level 7.) For most instances, however, level 3 or 4 is sufficiently detailed to assure an adequate cost estimate.

1.4.1.4.2 Integrated Electronics Assembly – DDT&E

1.4.1.4.2.1 IEA Management

- 1.4.1.4.2.1.1 Project Planning and Direction
- 1.4.1.4.2.1.2 Configuration Management
- 1.4.1.4.2.1.3 Information Management and Deliverable Data
- 1.4.1.4.2.1.4 Procurement Management
- 1.4.1.4.2.1.5 GFE Management

1.4.1.4.2.2 Project Engineering and Integration

- 1.4.1.4.2.2.1 System Requirements, Analysis and Integration
- 1.4.1.4.2.2.2 Safety, Reliability and Quality/Assurance
- 1.4.1.4.2.2.3 Maintainability

1.4.1.4.2.3 IEA Development and Deliverable Hardware

- 1.4.1.4.2.3.1 Mechanical Housing
- 1.4.1.4.2.3.2 Distributor
- 1.4.1.4.2.3.3 Multiplexer-Demultiplexer
- 1.4.1.4.2.3.4 Signal Conditioning
- 1.4.1.4.2.3.5 Development Testing
- 1.4.1.4.2.3.6 Assembly and Inspection
- 1.4.1.4.2.3.7 Acceptance Testing
- 1.4.1.4.2.3.8 Refurbishment

1.4.1.4.2.4 Support Equipment and Tooling

- 1.4.1.4.2.4.1 IEA Test Set and Manual
- 1.4.1.4.2.4.2 Special Test Equipment

Appendix 1 IEA SRB Specification

Figure 1. Example WBS for IEA.

3. Synthesis of Man-Hours/Materials. The task of synthesizing the total estimate is relatively simple when the analysis of the WBS has been completed. Generally, estimates for subelements are made in terms of man-hours and materials. In the synthesis process, these man-hours have the appropriate cost per man-hour applied. Also, appropriate overhead charges are applied, usually stated as a percentage of labor costs. Basic materials costs will have applicable scrap factors applied. In general, these factors are based on contractors' experience with how much material or parts are spoiled during manufacturing or assembly. In most cases, a so-called "material burden" will be applied to the estimated material cost, including the scrap factor. These various cost elements will be summed at each level of the WBS which will then allow the cost of each WBS element to be identified. One caution, up to this point, general and administrative (G&A) expenses or fee have not been included, so the WBS element cost would not include these costs. As a matter of practice these items are calculated at the total cost level (level 1 of the WBS). If a total cost of an element is desired, there is no reason why the appropriate G&A and fee cannot be applied at this level.

After all subelements of the WBS have been summed to level 1, the appropriate G&A is applied to all costs, labor, overhead, material, material burden, travel, computer, or whatever else has been estimated. G&A is usually applied as a percentage to all of the previously cited costs. G&A expenses are those costs which will be experienced by a company for such items as executive salaries, operation of home office, independent research, bid and proposal expense, depreciation expense, etc. When all costs are totaled (including G&A), then an appropriate fee should be calculated. Theoretically, the fee which will be paid for any project/program/procurement depends upon several factors, the most influential of which is complexity and/or state-of-the-art advancement. A higher fee would be paid for things which require the most initiative, highest capital use, and aggressiveness in problem-solving. The fee is usually calculated for the cost estimate by applying a percentage to the total cost which has been developed. Generally, the figure (percentage) used has been 7 or 8 percent.

4. Learning/Cost Improvement Curve Application. The application of the learning curve to cost estimates can become an important aspect if there are several units of production under consideration. For a single unit, the cost estimate would not involve the learning curve application, but for a project involving two or three (or more) units of production, built to a fairly consistent configuration, application of the learning curve would be justified.

For purposes of comparison, the application of learning/cost improvement curve principles to items such as procedures or office practice can be as effective as the application to manufacture/assemble such hardware items as solid rocket motors or tanks. The chief criterion is whether or not the manual portion of the job is of a "repetitive" nature. The configuration of the "unit of production" is the next most important aspect--whether the unit of production is software or hardware. Naturally, if the configuration of an item changes drastically from one unit of production to another, there will be little or no learning in the process.

If the analyst/estimator decides that a bona fide application of the learning/cost improvement curve is in order, he should review the information included in the appendix entitled "Guidelines for Application of Learning/Cost Improvement Curves," TM X-64968.

III. STANDARDS

The term "standards" is in reality used to indicate standard time data; i.e., all possible elements of work are measured, assigned a standard time for performance, and documented. When a particular job is to be estimated, all of the applicable standards for all related operations are added together to determine the total time.

The use of standards in estimating has certain advantages. Properly used, it produces more accurate estimates which are easier to justify. Standards also promote consistency between estimates as well as among estimators. Personal experience is not necessary where standards are used. It is desirable or beneficial but not mandatory. Generally, the standards which follow have been developed over a number of years through the use of time studies and synthesis of methods analysis. They are based on the level of efficiency which could be attained by a job shop working in the 1 to 1000 unit range.

A. Machining

The standards set forth in this section are actually synoptical values of more detailed time. They are adaptation or extracts, actually bench mark time values for each type of machining operation. The loss of accuracy occasioned by summarization and/or averaging (bench mark) is believed to be acceptable when the total time for a system is being developed. In other words, if the values given here are used with judgment and interpolations for varying stock sizes, reasonably accurate results can be obtained. Values listed are "soft" and "hard." Soft values are for aluminum, magnesium, and plastics. Hard values are for stainless steel, drill rod, beryllium, copper, etc. In between would be values for brass, bronze, and medium steel. Standards not included herein, but which are available, are grinding of internal and external surfaces and gear hobbing, as well as some recommended surface finishes and tolerances.

Raw Material Cut

	Minutes per Inch	
	Soft	Hard
Set up on band saw or power hacksaw, 0.1 h.		
Pick up material, position to saw, take out of saw		
Part size — 1 in. to 2 ft.	0.05–0.50	0.05–0.50

Do-All Band Saw

	Minutes per Inch	
	Soft	**Hard**
Time is that required to cut 1 in. of metal of the given thickness:		
1/8 in. thick stock	0.02	0.50
1/2 in. thick stock.	0.04	1.25
Weld Blade for Internal Cut		
Open saw guard, break blade, remove slide, put blade through, grind ends of saw blade, clamp blade in weld fixture, weld, anneal, unclamp, smooth weld, put saw on pulleys and guides, adjust saw, close guard.	3.50	3.50

Power Hack Saw

	Minutes per Inch	
	Soft	Hard
Times are minutes to cut 1 in. of metal of the given thickness:		
1 in. thick stock	0.30	1.15
3 in. thick stock	2.55	10.50
6 in. thick stock.	10.40	42.50

Lathe — Warner Swasey — Type 3

	Minutes per Job
Setup	
Fill in time slip, check in.	1.00
Analyze job from blueprint	1.00
To tool crib.	5.00
Set up measuring instruments — avg. 3 (0.70 min each).	2.10
Install collet or chuck.	2.00
Install and square off stock.	3.00
Deliver first part to inspection.	0.70
Tear Down	
Remove collet or chuck.	1.50
Clean and store measuring tools.	1.00
Total constant (setup minutes)	17.3
Multiplier	0.022
Setup hours	0.4
Add per Cutting Tool	
Install hex turret tools — avg. 6 (3 min each).	18.00
Install cross slide tools — avg. 2 (5 min each).	10.00
Tear down, clean, store — avg. 8 (2 min each).	16.00
Total	44.00
Multiplier	0.022
Setup hours	1.0
Total setup (8 tools) hours	1.4

	Minutes per Inch	
	Soft	Hard
Run Time		
Handling Time per Part (1 in. diameter stock)		
Release collet chuck, advance bar to stop.		
Tighten collet chuck.	0.105	0.105
Start machine.	0.02	0.02
Position coolant.	0.05	0.05
Change spindle speed.	0.10	0.10
Cut off, remove part, and set aside.	0.035	0.035
Check part.	0.04	0.04
Total	0.35	0.35

	Minutes per Inch	
	Soft	Hard
Turn, Bore, etc. (1 in. diameter stock)*:		
Back box turret from work, index to next station, advance tool to work.	0.110	0.110
Turn, bore, etc., 0.0075 in.feed × 0.125 in. depth**.	0.096	0.700
Total	0.206	0.810
Tap		
Handling Time		
Change to slower spindle speed.	0.066	0.066
Reverse spindle direction backout.	0.031	0.031
Change spindle direction to tap.	0.026	0.026
Change spindle speed to selected work speed.	0.066	0.066
Brush oil on tap.	0.070	0.070
Blow tap clean.	0.120	0.120
Total	0.379	0.379
Machine Time		
(Noncollapsing taps) (includes backout at 2 × tap):		
1/8 in. diameter × NS40 threads per in.	0.240	0.240
Total	0.619	0.619
Thread		
Handling Time		
Change to slower spindle speed.	0.066	0.066
Change speed back to selected work speed.	0.066	0.066
Position collet.	0.048	0.048
Blow die head clean.	0.120	0.120
Total	0.300	0.300
Machine Time (Based on automatic or self-opening dies):		
1/4 in. diameter × NS32 threads per in.	0.128	0.208
Total	0.428	0.508

*The time to bore or turn 1 linear in. of 1 in. diameter stock may be used as a basic time unit in estimating small machined parts. Used with discretion, it serves as an average time per cut to turn, bore, drill, ream, knurl, form, and cut off.

**Feeds for aluminum vary from 0.002 in. to 0.030 in. Steel from 0.003 in. to 0.010 in. 0.0075 in. feed represents a light rough cut. Double the times shown for rough and finish cut.

	Minutes per Inch	
	Soft	Hard
Taper		
Handling Time		
Release compound rest, swing to proper angle, secure.	0.500	0.500
Advance tool to work.	0.100	0.100
Back tool from work.	0.100	0.100
Release compound rest, swing back to normal position, secure.	0.400	0.400
Total	1.100	1.100
Machine Time		
0.0075 in. feed × 0.125 in. depth.	0.096	0.700

Engine Lathe — Monarch 10 in. × 20 in. Lathe or Equivalent

	Hours
Setup	
With 6 in. diameter stock, insert materials, tighten chucks*.	0.4
Per additional tool, 0.1 h.	
Average additional tools per job, 2 × 0.1 h.	0.2
Total	0.6

	Minutes per Inch Soft	Minutes per Inch Hard
Handling Time per Part (stock cut approximate length)		
Pick up, install in universal chuck, align by hand, secure for work.	0.60	0.60
Miscellaneous clean burr, check.	0.40	0.40
Total	1.0	1.0
Align with dial gauge for concentricity.	1.0	1.0
Move cross slide into position, set tool to proper cut depth, advance tool to work, engage feed.	0.20	0.20
Trial cut, 1/4 in.	0.05	1.00
Mike diameter	0.30	0.30
Total	0.55	1.50
Turn, Bore, etc.		
0.0075 in. feed × 0.125 in. deep	0.21	4.17
Tap or Thread		
Handling Time per Part		
Release compound rest, swing into position, secure.	0.40	0.40
Change tool in holder.	0.40	0.40
Position tool, set for proper depth, start, engage feed at proper lead.	0.20	0.20
Position cross slide into clear.	0.10	0.10
Blow threads clean.	0.10	0.10
Check with go gauge.	0.40	0.40
Check with no go gauge.	0.20	0.20
Clean up threads (with emery cloth).	0.40	0.40
Total	2.20	2.20

*Basic setup time is approximately the same as for the turret lathe. Tools are generally fewer for the engine lathe, but adjustments made during the operation consume more time.

	Minutes per Inch	
	Soft	Hard
Machine Time (single point tool)		
External or internal V thread, 12 threads/in.	0.302	3.690
Position tool, set to proper depth, engage feed at 0.15 min per pass	(4) 0.600	(8) 1.200
Total	0.902	4.890
Taper		
Handling Time		
Same as handling time for taper under turret lathe.	1.100	1.100
Machine Time		
0.0075 in. feed × 0.250 in. depth.	0.210	4.170

Milling (Milwaukee No. 2 or Equal)

	Minutes per Job
	Soft or Hard
Setup	
Charge time on card and check in.	1.00
Analyze drawing.	1.00
To tool crib for tools and return tools for previous task.	5.00
Clean T-slots and table.	3.00
Assemble and align vise or holding fixture.	5.00
Install cutter to collet.	8.00
Adjust table to locate initial cut.	2.00
Use various measuring devices.	
Deliver first piece to inspection.	3.00
Total	28.00
Multiplier	0.022
Setup hours	0.6

	Minutes per Inch	
	Soft	Hard
Handling Time per Part		
Pick up and clamp in vise.	0.20	0.20
Release after cut.	0.05	0.05
Check part with micrometer.	0.05	0.05
Part to tray.	0.05	0.05
Clean vise for next.	0.05	0.05
Total	0.40	0.40

NOTE: If a complex fixture is used, or if alignment of part with a dial indicator is required, double the above.

	Soft	Hard
Operations per cut		
Start machine and advance work to cutter.	0.10	0.10
Back work from cutter and stop.	0.10	0.10
Set table at proper position for work by moving up, down, or in saddle.	0.20	0.20
Index dividing head.	0.15	0.15
Total	0.55	0.55

	Minutes per Inch	
	Soft	Hard
Profile or End Mill		
Rough profile, 1/2 in. deep × 3/4 in. wide cutter.	0.067	0.260
Finish profile, 1/2 in. deep × 3/4 in. wide cutter.	0.033	0.130
Total	0.100	0.390
Surface or face mill		
Cutters — plain, helical, slab, or shell end		
Diameters of cutters — 2 1/2 in. to 4 1/2 in.		
Face width of cutters - 2 in. to 6 in.,		
1/2 in. depth × 6 in. wide.	0.034	1.000
Total	0.034	1.000
Side Mill, Straddle Mill, Slotting		
Cutters — stagger tooth, helf-side.		
Diameters — 4 in. to [illegible] in.		
Width of face — 1/4 in. to 1 in.,		
1/2 in. depth × 1 in. cutter face.	0.067	2.000
Total	0.067	2.000
Corner, Groove, Slot		
Round corner — 1/2 in. radius.	0.031	0.527
V-groove or chamfer — 1/2 in. deep × 1/2 in. wide.	0.050	0.588
Key slot — 1/2 in. deep × 3/8 in. wide.	0.052	0.410

Drill

	Minutes per Job
Setup	
Fill in job card and check in.	1.00
Analyze drawing.	1.00
Tool crib for tools.	5.00
Handle jigs, fixtures, and vises.	1.50
Adjust machine, change speeds, and feeds.	0.80
Adjust feed stop.	0.50
Insert drill bit in spindle.	2.75
Deliver first piece to inspection.	0.70
Total	13.25
Multiplier	0.022
Setup hours	0.3

	*Constant	Minutes per Inch Soft	Minutes per Inch Hard
Operation			
General purpose press (spindle RPM 500-2000)			
Drill 1/8 in. diameter hole.	0.05	0.140	0.556
Tap 1/8 in. × NS40.	0.05	0.119	0.240
Countersink 1/8 in. × 1/16 in. deep	0.05	0.009	0.009
Heavy duty press (spindle RPM 1-1000)			
Drill 2 in. diameter hole.	0.05	0.250	1.170
Tap 2 in. × 4 1/2 threads/in.	0.05	0.240	0.356
Countersink 2 in. × 1/4 in. deep.	0.05	0.035	0.555

*Constant is the value for moving the part to align for next hole plus lowering the drill to surface.

Broach

	Minutes per Job
Setup	
Time is for setting up for cutting keyways and splines.	30.0
Total	30.0
Multiplier	0.022
Setup hours	0.7

		Minutes per Inch	
		Soft	Hard
Handling			
Pick up part, release, and aside.		0.25	0.25
Remove broach tool from head, return head to start.			
Insert broach in work and install in head.		0.15	0.15
Start.			
Blow fixture/table clean for next.		0.05	0.05
Total		0.45	0.45
	*		
Operation (for broaching internal keyways)			
Keyway 1/16 in. deep × 1/8 in. key width.	32 in.	0.067	0.267
Keyway 1/4 in. deep × 1/2 in. key width.	50 in.	0.209	0.834
Keyway 1/2 in. deep × 1 in. key width.	56 in.	0.233	0.932

*This column denotes the length of the broach and the time shown in the "time" column is for the entire broach. The minutes per inch does not apply. The first keyway value shown requires one pass. The other two require two passes.

B. Sheet Metal Operations

Steel is the least expensive kind of material for use in making electronics cabinets and chassis. It requires less cleaning and finishing than either aluminum or magnesium; however, the lighter weight of the latter two make them indispensable for use in airborne equipment. In addition, magnesium requires the heating of parts and dies in shaping and forming. This adds time to the fabrication of parts. In addition, the heating increases fire hazard. The standards herein are for three representative sizes, and it is expected that intermediate sizes or special configurations will require an intelligent deviation from the values shown.

Handling time for parts is included in operation time unless it is shown as a specific break-out.

In general, the sequence in which the various operations are given is the shop operating sequence of events.

In the following section "Sm" is 3.3 in.; "Med" is 18.18 in.; and "Lge" is 30.30 in.

Sheetmetal Blank Cut

	Hours
Equipment-Power Gate Shear	
Setup	
Set stops (front or rear) for gauging.	
Test cut and check measurements.	
Periodically check holddowns.	0.2
Total	0.2

	Minutes per Operation		
	Sm	Med	Lge
Run time*			
Average time per cut.	0.10	0.20	0.40
Total	0.10	0.20	0.40

*Maximum cuts for a rectangular blank would be four; however, in actual practice, one cut is all that is required because each cut along one side of a blank is also the side of another. Also, on initial cuts, one cut actually cuts several blank sides.

Notch

	Hours		
Equipment — Power Notcher			
Setup			
Set stops.			
Trial cut.			
Check measurements	0.1		
Total	0.1		

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Pick up part and position.			
Depress foot pedal.			
Lay aside or position for next cut.	0.10	0.20	0.40
Total	0.10	0.20	0.40

Holes*

Equipment-Turret Punch — Weideman RA41P with pantograph stylus, template, and work holder

	Hours
Setup	
To tool crib for template.	0.1
Locate template and secure.	
Line up and adjust holding device.	0.1
Total	0.2
Add for each change of punch size.	0.05

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Pick up blank, match tooling holes to locator pins.			
Clamp.			
Rotate turret to right punch size.			
Unclamp piece after piercing and remove.	0.20	0.40	0.80
Total	0.20	0.40	0.80
Punch holes.			
Move stylus to template hole.			
Remove stylus and transfer to next.	0.05	0.05	0.05
Total	0.05	0.05	0.05

*Various methods may be used in making holes. There are punchers, drills, fly cutters, circle shears, hole saws, profilers, routers, and milling machines.

Drill

The setup time is given in the section on machine shop operations. The drilling in the machine shop did not include the time relative to drilling using a jig.

	Minutes per Operation		
	Sm	Med	Lge
Handling (with jig)			
Install piece to jig.			
Unfasten from jig and lay aside.	0.20	0.40	0.80
Total	0.20	0.40	0.80

Hole Drilling Time Values

Hole Size (Diameter)	Number of 1/16 in. Aluminum Sheets in Stack	Move Time (Hole to Hole)	Machine Time	Total	Per Sheet
1/16 in. to 1 in.	1 (No Template)	0.075	0.024	0.099	0.099
	1 (Template)	0.047	0.024	0.071	0.071
	2 (Template)	0.047	0.037	0.084	0.042
	3 (Template)	0.047	0.049	0.096	0.032
	4 (Template)	0.047	0.064	0.111	0.028
2 in. to 4 in.	1 (No Template)	0.075	0.400	0.475	0.475

NOTE: Holes 1/16 in. to 1 in. in diameter require a fairly constant run time. Less than 1/16 in. feed time has to be carefully regulated to avoid breaking the drill. One-and two-inch holes can be drilled in approximately the same time since drill bits are stout, heavy-duty presses are used, and high feed rates can be accommodated. It takes more time to drill without a template since the operator must sight the exact point of drilling.

A fly cutter is essentially a boring bar attached to a drill shank.

Press

	Hours
Equipment – 20-ton to 75-ton Press	
Blank and pierce	
Setup	
The punch and die elements are mounted in a common die shoe-guide post-punch holder. The punch and die elements are permanently aligned in the die set.	
Trip to tool crib.	
Fasten die shoe to press bed.	
Adjust height of press bed to achieve desired depth.	0.4
Total	0.4

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Pick up blank.			
Place on die.			
Activate			
Remove piece to tray.			
Clear scrap.	0.20	0.30	0.50
Total	0.20	0.30	0.50

NOTE: Handling of parts to the die on an individual basis is the most time consuming blank and pierce operation. When raw material can be fed from strip or coil, the output is a function of the steady run RPM. Generally, press cycles are in the range of 10 to 200 RPM, which means that theoretically with continuous stock feed one could expect 10 to 200 pieces per minute output. The full theoretical output, however, can never be reached because of the necessity to set up new stock, remove scrap, and other maintenance.

Dimple or Joggle

	Hours
Setup	
Same as blank and pierce.	0.4
Total	0.4

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Same as blank and pierce.	0.20	0.30	0.50
Total	0.20	0.30	0.50

NOTE: Dimple and joggle are done on the same kind of machine as blank and pierce, the difference being that dimple and joggle use a form die. Dimples are formed around lightening hole to give added stiffening to a flat surface. Joggles are used to make lap joints so that the surface at the lap is more or less flush.

Brake Form

	Hours
Equipment — Power Brake	
Setup	
Adjust position stops.	
Adjust ram blade for proper thickness.	0.2
Change dies.	0.4
Total	0.6

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Same as blank and pierce.	0.20	0.30	0.50
Total	0.20	0.30	0.50

Roll Form

	Hours		
Equipment — Three Roll Power Mangle			
Setup			
Adjust front rolls to metal thickness.	0.1		
Adjust rear roll to desired radius.	0.1		
Total	0.2		
	Minutes per Operation		
	Sm	Med	Lge
Run time			
Activate rolls.			
Feed blank into mangle.	0.20	0.90	1.50
Total*	0.20	0.90	1.50

*This is the time for one pass through the rolls. Usually after the first few pieces are run, the mangle will be adjusted so that the desired radius can be formed in one pass (including a complete cylinder). If more than one radius is involved, multiply this value by the number of radii.

Deep Draw*

	Hours		
Equipment — 70 ton Hydraulic Press, Male and Female Dies			
Setup			
Install dies on platform and ram.	0.5		
Total	0.5		

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Pick up and position blank to die.			
Trip hand actuator buttons.			
Remove part to pallet.			
Blow die clear.	0.50	0.70	1.00
Total	0.50	0.70	1.00

*Deep drawing is done with relatively expensive dies, the cost of which will not be warranted unless significant quantities are involved. Three controlling factors are important in drawing: height to diameter ratio, ductility of metal to be formed, and the corner radius. Where more than one draw is necessary to completely form the part, the metal may have to be annealed between each draw. If a new design is being estimated, the following can be used as a guide:

1 draw — if depth is 1/3 of the punch diameter.
2 draws — if depth is 1/2 of the punch diameter.
3 draws — if depth is 3/4 of the punch diameter.
4 draws — if depth is equal to the punch diameter.

Annealing

	Hours
Equipment — Controlled Heat Furnace	
Setup	
Change temperature setting.	0.1
Total	0.1

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Place part on conveyor rack.			
Close door.			
Remove.	0.10	0.20	0.40
Total	0.10	0.20	0.40

Hydro Form*

	Hours
Equipment — 70-ton Press, Male Die	
Setup	
Install male die on lower press platen.	0.2
Install caged rubber mat on upper platen.	0.1
Total	0.3

	Minutes per Operation		
Run time	Sm	Med	Lge
Pick up and position blank.			
Actuate.			
Remove part to pallet.			
Blow die clear.	1.40	1.70	2.40
Total	1.40	1.70	2.40

*The chief advantage of this kind of forming is the lower cost of tooling involved. Only the male portion of the die is required. A caged rubber mat forces the blank to take the form of the male die as pressure is applied.

Burr

	Hours		
Equipment — Belt Sander, Portable Power Vibrator			
Setup			
Trip to tool crib.	0.1		
Total	0.1		

	Minutes per Operation		
	Sm	Med	Lge
Handling time			
Pick up and position.			
Place in tray.	0.10	0.20	0.40
Total	0.10	0.20	0.40
Burr edge — aluminum, epoxy laminate, belt sander, file, and emery cloth.			
Machine time per inch.	0.02	0.02	0.02
Burr flat surface — portable sander.			
Machine time per square foot.	0.20	0.50	0.50
Burr hole — hand scraper or end file, per hole.			
Time per hole.	0.03	0.03	0.03

Weld

	Hours		
Equipment — Oxy-Acetylene R'g.			
Clean and degrease (aluminum only)			
Setup			
Obtain degreaser.	0.1		
Position exhaust duct.	0.2		
Total	0.3		

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Clean faying or butt surfaces.	0.25	0.70	1.80
Welding (steel, aluminum, magnesium)			
Handling			
Place part on fixture and remove.	0.10	0.20	0.40

	Hours
Setup	
Dog down on slab or clamp in fixture.	0.3
Total	0.3

Run time

Weld with 0.062 in. rod/in. — 0.25 min.

Weld with 0.125 in. rod/in. — 0.40 min.

Weld with 0.250 in. rod/in. — 0.75 min.

Stress Relieve

	Hours
Equipment — Controlled Heat Furnace	
Setup	
Adjust furnace temperature	0.1
Total	0.1

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Put parts in furnace and remove	0.10	0.20	0.40
Total	0.10	0.20	0.40

Grind Fillet Weld

	Hours
Equipment — Floor Grinder or Portable Sander	
Setup	
Clamp part to bench.	0.1
Total	0.1

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Handle parts.	0.10	0.20	0.40
Machine time per inch — 0.03 min.			

Spot Weld

	Hours
Equipment — Single Head Spot Welder, 10 amp.	
Setup	
Install and adjust contact points, current timing, and holding fixture.	0.4
Total	0.4

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Handle parts to welder*.			
Remove and place in tray.	0.10	0.20	0.40
Weld			
Move from spot to spot.			
Press foot pedal.			
Machine cycle.	0.05	0.05	0.05

*If more than one size is being joined, the proper handling values should be used.

EXAMPLE: If three small parts are being welded to one medium part, the handling time would be 0.50 min.

Rivet

	Hours		
Equipment — Hammer, Rivet Set, Anvil			
Setup			
Obtain hammer, rivet set, and anvil.	0.4		
Total	0.4		

	Minutes per Operation		
	Sm	Med	Lge
Run time			
Handle parts*.	0.10	0.20	0.40
Pick up and insert rivet.	0.05	0.05	0.05
Upset and tighten rivet.	0.05	0.05	0.05

*If more than one size is being joined, the proper handling value should be used.

EXAMPLE: If three small parts are being riveted to one medium part, the handling time would be 0.50 min.

C. Electroplating and Metal Treating

This section is concerned with the electroplating and/ or heat treating of various metals. It gives the purpose of the treatments and the applicable military or other specifications. There are two time values given in the listings which follow. The value in column "1" is the time each batch should remain in the bath or in treatment. The value in column "2" is the time required (man-minutes) to handle the batch in the given operation.

The source from which the time values listed were obtained states that a "bath" value (column 1) and a "man time" value were given so that waste or lost time caused by the operator having to standby for the difference in time between "bath" and "man time" could be calculated. As a practical matter, for those applications of electroplating which are likely in space programs (low numbers of items) the time values shown in column 1 should be the most applicable in most cases.

The values herein are based on a typical plating job shop operation. A shop of this type typically has rows of open top tanks 1 to 3 ft deep by 2 to 6 ft^2.

These values are based on averages; i.e., they consider average amounts of corrosion on parts to be cleaned, average plating thickness, average time per bath, etc. While individual cases may vary from the given values, over a period of time, the actual values will coincide with those of the listings.

It should be noted also that the time values listed are based on manually dipping the parts as opposed to using automatically cycled plating machines.

Aluminum — Anodize Clear

Baths	Minutes/Batch 1	Minutes/Batch 2
Alkaline cleanse	4.0	2.5
Rinse	0.5	0.5
Deoxidize	7.0	2.5
Rinse	0.5	0.5
Anodize	30.0	2.5
Rinse	0.5	0.5
Seal	15.0	2.5
Rinse	0.5	0.5
Total	58.0	12.0

NOTE: Purpose — Paint base and corrosion resistance (salt spray 240 h).
Specification — MIL-A-8625, anodic coating for aluminum, Type II.
Thickness — 600 mg/ft^2.
Time — Based on tank size, 36 in. × 30 in. × 36 in., 15 ft^2 of parts plated (10 amps/ft^2 at 150 amps).

Aluminum — Anodize Color

	Minutes/Batch	
	1	2
Total	73.5	1.5

NOTE: Operations are identical to clear rinse, with time values the same. However, before sealing there are two additional steps: dye and rinse.

Time treatment for dye — 15.0 min.
Rinse — 0.5 min.

Handling time for dye — 2.5 min.
Rinse — 0.5 min.

Coating thickness — 2500 mg/ft^2

Steel and Iron — Black Oxide Coat

Baths	Minutes/Batch 1	Minutes/Batch 2
Alkaline clean	4.0	2.5
Rinse	0.5	0.5
Acid pickle	15.0	2.5
Rinse	0.5	0.5
Rinse	0.5	0.5
Black oxide	4.0	2.5
Rinse	0.5	0.5
Wax coat	2.5	2.5
Total	27.5	12.0

NOTE: Purpose — Decorative black oxide coating for ferrous metals.
Specification — MIL-C-13924, black oxide coating for ferrous metals, Class I.
Thickness — Not specified.
Time — Based on tank size, 30 in. × 18 in. × 36 in.

Steel — Cadmium Plate

Baths	Minutes/Batch 1	2
Electroclean	3.0	2.0
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Cad plate	15.0	2.5
Rinse	0.5	0.5
Post treat	0.5	1.0
Rinse	0.5	0.5
Total	21.0	8.5

NOTE: Purpose — Corrosion resistance (salt spray 192 h).
Specification — QQP-416, Type I, without supplemental phosphate treatment
Thickness -- 0.0003 in. to 0.0010 in.
Time — Based on tank size, 36 in. × 30 in. × 36 in.

Aluminum — Chemical Film (Iridite)

Baths	Minutes/Batch 1	2
Alkaline clean	4.0	2.5
Rinse	0.5	0.5
Dioxidize	7.0	2.5
Rinse	0.5	0.5
Iridite	2.0	2.5
Rinse	0.5	0.5
Total	14.5	9.0

NOTE: Purpose — Paint base and corrosion resistance (salt spray 168 h).
Specification — MIL-C-5541, chemical films for aluminum and aluminum alloys.
Thickness — Not specified

Copper — Chrome Plate

Baths	Minutes/Batch 1	2
Electroclean	3.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Chrome plate	180.0	2.5
Rinse	0.5	0.5
Total	185.0	7.5

NOTE: Purpose — Decorative, creates wear resistance.
Specification — QQ-C-320, Cl. I, bright and stain.
Thickness — 0.001 in. to 0.010 in.
Time — Based on tank size, 18 in. × 12 in. × 18 in., or 50 in.^{2} area parts (1 amp/1 in.^{2} at 50 amps).

Steel — Chrome Plate

Baths	Minutes/Batch 1	2
Electrocleaner	3.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Chrome reverse etch	1.0	1.5
Chrome plate	180.0	2.5
Rinse	0.5	0.5
Total	186.0	9.0

NOTE: Purpose — Decorative, creates wear resistance.
Specification — QQC-370, Cl. I, bright and stain.
Thickness — 0.001 in. to 0.010 in.
Time — Based on tank size, 18 in. × 12 in. × 18 in., 50 in.^{2} area of parts (lamp/in.^{2} at 50 amps).

Copper — Copper Plate

	Minutes/Batch	
Baths	1	2
Electrocleaner	3.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Copper plate	60.0	2.5
Rinse	0.5	0.5
Total	65.0	7.5

NOTE: Purpose — For conductivity or base for further plating.
Specification — None.
Thickness — 0.001 in. to 0.002 in.
Time — Based on tank size, 36 in. × 30 in. × 36 in.

Magnesium Dichromate (Dow 7)

Baths	Minutes/Batch 1	2
Electrocleaner	3.0	2.5
Rinse	0.5	0.5
Acid pickle	15.0	2.5
Rinse	0.5	0.5
Dichromate immerse	15.0	2.5
Rinse	0.5	0.5
Total	34.5	9.0

NOTE: Purpose -- For paint base and corrosion resistance.
Specification — MIL-M-3171A, Type III.
Thickness — Not specified.
Time — Based on tank size, 18 in. × 30 in. × 32 in.

Aluminum — Gold Plate

Baths	Minutes/Batch 1	Minutes/Batch 2
Alkaline cleaner	4.0	2.5
Rinse	0.5	2.5
Dioxidize	7.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Zinc immersion	1.5	2.0
Rinse	0.5	0.5
Copper strike	0.5	1.0
Rinse	0.5	0.5
Silver strike	0.5	1.0
Rinse	0.5	0.5
Gold plate	10.0	2.5
Rinse	0.5	0.5
Rinse	0.5	0.5
Total	28.0	18.5

NOTE: Purpose — Conductivity, solderability, and corrosion resistance.
Specification — None.
Thickness — 50 to 100 millionths of an inch.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

Copper — Gold Plate

Baths	Minutes/ Batch 1	2
Electrocleaner	3.0	2.5
Rinse	0.5	0.5
Cyanide dip	0.5	1.0
Rinse	0.5	0.5
Silver strike	1.0	1.5
Rinse	0.5	0.5
Gold plate	10.0	2.5
Rinse	0.5	0.5
Rinse	0.5	0.5
Total	17.0	10.0

NOTE: Purpose — Conductivity, solderability, and corrosion resistance.
Specifications — None.
Thickness — 59 to 110 millionths of an inch.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

Copper — Nickel Plate

Baths	Minutes/Batch 1	Minutes/Batch 2
Electrocleaner	3.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Nickel plate	10.0	2.5
Rinse	0.5	0.5
Total	15.0	7.5

NOTE: Purpose — Corrosion resistance, abrasion resistance, under plate for further plating, and decoration.
Specification — QQ-N-290, Cl. I or II, Type I to VII (semibright).
Thickness — 0.0001 in. to 0.0005 in.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

Copper — Nickel — Rhodium Plate

Baths	Minutes/ Batch 1	2
Electrocleaner	3.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Nickel plate	10.0	2.5
Rinse	0.5	0.5
Rhodium plate	15.0	2.5
Rinse	0.5	0.5
Rinse	0.5	0.5
Total	31.0	11.0

NOTE: Purpose — Corrosion and wear resistance.
Specification — None.
Thickness — Nickel base — 0.0004 in.
Rhodium base — 10 to 20 millionths inch.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

Steel, Stainless — Passivate

Baths	Minutes/Batch 1	Minutes/Batch 2
Vapor degrease	1.5	2.0
Passivate	60.0	2.5
Rinse	0.5	0.5
Total	62.0	5.0

NOTE: Purpose — Corrosion resistance.
Specification — MIL-S-5002, treatment for metal parts.
Thickness — Not specified.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

Steel — Phosphate Treat

Baths	Minutes/Batch 1	2
Electrocleaner	4.0	2.5
Rinse	0.5	0.5
Oxalic acid	1.5	2.0
Rinse	0.5	0.5
Phosphate treat	4.02	2.5
Rinse	0.5	0.5
Phosphate seal	1.0	1.5
Total	12.0	10.0

NOTE: Purpose — Corrosion resistance, paint adhesion, and dry film lubricant adhesion.
Specification — MIL-C-490, Grade I.
Thickness — 300 mg/ft^2.
Time — Based on tank size, 30 in. × 18 in. × 36 in.

Aluminum — Silver Plate

Baths	Minutes/Batch 1	Minutes/Batch 2
Alkaline cleaner	4.0	2.5
Rinse	0.5	0.5
Dioxidize	7.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Zinc immersion	1.5	2.0
Rinse	0.5	0.5
Copper strike	0.5	1.0
Rinse	0.5	0.5
Silver strike	0.5	1.0
Rinse	0.5	0.5
Silver plate	20.0	2.5
Rinse	0.5	0.5
Total	37.5	16.0

NOTE: Purpose — Conductivity, corrosion resistance, and solderability.
Specification — QQ-S-365, Type III (bright).
Thickness — 0.0005 in. to 0.0010 in.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

Copper — Silver Plate

Baths	Minutes/Batch 1	2
Electrocleaner	3.0	2.5
Rinse	0.5	0.5
Cyanide	0.5	1.0
Rinse	0.5	0.5
Silver strike	0.5	1.0
Silver plate	20.0	2.5
Rinse	0.5	0.5
Rinse	0.5	0.5
Total	26.0	9.0

NOTE: Purpose — Conductivity, corrosion resistance, and solderability.
Specification — QQ-S-365, Type III (bright)
Thickness — 0.0005 in. to 0.0010 in.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

Aluminum — Tin Plate — Hot Oil Fuse

Baths	Minutes/Batch 1	2
Alkaline cleaner	4.0	2.5
Rinse	0.5	0.5
Deoxidize	7.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Zinc immersion	1.5	2.0
Rinse	0.5	0.5
Copper strike	0.5	1.0
Rinse	0.5	0.5
Tin plate	40.0	2.5
Rinse	0.5	0.5
Hot oil fuse	2.0	2.5
Vapor degrease	1.5	2.0
Total	60.0	19.0

NOTE: Purpose — Solderability.
Specification — MIL-T-10727, Type I.
Thickness — 0.005 in. to 0.0010 in.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

Copper — Tin Plate

Baths	Minutes/Batch 1	2
Electrocleaner	3.0	2.5
Rinse	0.5	0.5
Acid dip	0.5	1.0
Rinse	0.5	0.5
Tin plate	40.0	2.5
Rinse	0.5	0.5
Total	45.0	7.5

NOTE: Purpose — Solderability.
Specification — MIL-T-10727, Type I.
Thickness — 0.0005 in. to 0.0010 in.
Time — Based on tank size, 18 in. × 12 in. × 18 in.

D. Painting

The standards included herein are limited to typical operations required to paint metal chassis, panels, and cabinets. It is anticipated, however, that larger surface areas could be estimated by using the data given. The time values are based on using an individual spray booth type of operations as opposed to a continuous conveyor method.

Primers require one pass. A high gloss finish coat will usually require two passes. The thinner the paint or primer, the more quickly a coat can be applied.

Time values are for a cube-shaped item of the dimension given. Each item is assumed to have a minimum of four sides to be covered. Assuming a cube, as many as six sides could require paint. The values given would cover this. If inside surfaces must be coated, the given values must be doubled. The values given include time for picking up parts off the pallet, moving to and from the turntable in the booth, and replacing on the pallet.

The following is a listing of representative piece sizes and time values for cleaning in preparation for painting. They are for grit blasting or power wire brushing.

Part Size	Minutes per Part
1 1/2 in. × 1/2 in.	0.20
2 in. × 2 in.	0.40
4 in. × 4 in.	0.60
4 in. × 12 in.	0.90
4 in. × 18 in.	1.00
12 in. × 18 in.	1.5

	Minutes
Per square foot.	1.00
Sand by hand per square foot.	2.00
Surface wash w/ solvent per square foot.	0.05
Surface spray paint (primer-one coat) per square foot.	0.05
Surface spray paint (two coats gloss finish) per square foot.	0.10
Compressed air blow down per square foot.	0.05
Brush paint per coat per square inch.	0.20

Mask and Unmask

	Minutes
Apply	
Pick up tape.	0.015
Pick end loose.	0.020
Pull off 10 in. tape.	0.010
Position to part.	0.015
Apply to 10 linear in.	0.050
Tear tape.	0.010
Lay aside tape roll.	0.010
Total Apply	0.130
Remove	
Pick end loose.	0.020
Grasp and pull off (avg. 1 1/2 pulls).	0.045
Dispose of tape.	0.030
Wipe surface with solvent rag.	0.060
Total remove	0.155
Total apply and remove/10 in.	0.285
Per inch	0.03

Plugs, stencils, and shields for masking.
Install and remove average each 0.10 min.

Painting
Equipment — paint booth, turntable, spray gun.
Setup
Obtain paint.
Obtain liquid tank.
Thin paint as required.
Transfer to tank.
Obtain air and paint hoses.
Clear air hose and attach spray gun.
Attach nozzle.
Adjust and try out.
Upon job completion, clean paint apparatus with solvent.
Put up.

Total setup hours	0.3

Primer

	Minutes/ Unit/ Coat			
	3 in.	8 in.	30 in.	30 in.
Time value analysis.				
To booth turntable				
Pick up and position on table.	0.05	0.10	0.15	0.20
Pick up and put down spray gun.	not reqd.	0.10	0.10	0.10
Lay aside part.	0.05	0.10	0.15	0.20
Subtotal	0.10	0.30	0.40	0.50
To drying rack or oven				
Pick up and position part.	0.05	0.10	0.15	0.20
Lay aside part.	0.05	0.10	0.15	0.20
Subtotal	0.10	0.20	0.30	0.40
Total handling per part	0.20	0.50	0.70	0.90
Spray time				
Varies by paint type.	0.10 ←	— to	—	→ 1.25
Total wash primer.	0.30	0.65	1.00	1.30
Total chromate (zinc).	0.60	1.10	1.70	2.15

Surfacer

A surfacer is used where a high gloss finish is wanted. It is a filler to fill in minor tooling and other marks on cabinets and face plates. It is applied by brush or spray. A very smooth base for the finish coat is obtained by hand rubbing or buffing.

	Minutes/ Unit/ Coat			
	3 in.	8 in.	20 in.	30 in.
Time value analysis				
Handle (as in primer).	0.20	0.50	0.70	0.90
Spray paint.	0.60	0.90	1.00	1.25
Buff (power).	1.40	2.00	2.40	3.85
Total	2.20	3.40	4.10	6.00

Lacquer

	Minutes/Unit/Coat			
	3 in.	8 in.	20 in.	30 in.
Time value analysis				
Flat finish				
Handle (as in primer).	0.20	0.50	0.70	0.90
Spray time.	0.40	0.60	1.00	1.25
Total	0.60	1.10	1.70	2.15
Gloss				
Handle (as in primer).	0.20	0.50	0.70	0.90
Spray time.	0.70	1.20	1.80	2.30
Total	0.90	1.70	2.50	3.20

Enamel

	Minutes/Unit/Coat			
	3 in.	8 in.	20 in.	30 in.
Time value analysis				
Flat finish				
Handle (as in primer).	0.20	0.50	0.70	0.90
Spray time.	0.40	0.60	1.00	1.25
Total	0.60	1.10	1.70	2.15
Gloss hammertone, wrinkle				
Handle (as in primer).	0.20	0.50	0.70	0.90
Spray time.	0.70	1.20	1.85	2.30
Total	0.90	1.70	2.55	3.20

Varnish

	Minutes/Unit/Cost			
	3 in.	8 in.	20 in.	30 in.
Time value analysis				
Clear				
Handle (as in primer).	0.20	0.50	0.70	0.90
Spray time.	0.50	0.80	1.30	1.60
Total	0.70	1.30	2.00	2.50
Pigmented (16 oz. paste/gal)				
Handle (as in primer).	0.20	0.50	0.70	0.90
Spray time.	0.70	1.20	1.85	2.30
Total	0.90	1.70	2.55	3.20

Plastic Protective Film — Strippable

	Minutes/Unit/Coat			
	3 in.	8 in.	20 in.	30 in.
Time value analysis*				
Handling (as in primer).	0.20	0.50	0.70	0.90
Spray time.	0.30	0.50	0.85	1.00
Total	0.50	1.00	1.55	1.90

*Does not include time for peeling off the hardened film.

Fungicide (Spray Application)

	Minutes/ Unit/ Coat			
	3 in.	8 in.	30 in.	30 in.
Time value analysis				
Handling (as in primer).	0.20	0.50	0.70	0.90
Spray time.	0.50	0.80	1.30	1.60
Total	0.70	1.30	2.00	2.50

E. Silk Screen, Etch, and Encapsulate

There are several operations included in this section, anyone of which comprises a distinct art or line of business in itself. Many manufacturers or producers, however, perform these functions as incidental to the main thrust of their businesses. The treatment of these various functions and resulting time values are treated as service type functions within a larger operation.

Photographic Operations

Equipment

Darkroom with developer, fix and rinse baths, industrial copy camera, contact printer enlarger, viewing table, and drying cabinet.

NOTE: For convenience, the following listing gives time values for preparation of negatives, positives, and halftone negatives.

Element	Machine Time	Man Time (min) Line Negative	Positive from Negative	Halftone Negative
Expose film				
Assemble copy to camera board.		1.00		1.00
Turn light switch and adjust.		0.30	0.30	0.30
Set lens opening.		0.50		0.50
Set timer.		0.30	0.30	0.30
Adjust lens board to center image.		0.50		0.50
Cut film				
Position to vacuum holder.		0.70	0.70	0.70
Position halftone contact screen over film.				1.00
Position negative over film.			0.50	
Position glass over negative.	0.6 to 5.0	0.60	0.60	2.50
Disassemble film from camera.		0.30	0.30	0.30
Subtotal		4.20	2.70	7.10
Develop film				
Place film in developer bath.	2.5	2.50	2.50	2.50
Rinse.	0.2	0.20	0.20	0.20
Place film in fix bath.	3.0	3.00	3.00	3.00
Place film in wash bath.	10.0	2.50	2.50	2.50
Dry in film dryer.	25.0	0.50	0.50	0.50
Subtotal		8.70	8.70	8.70
Total expose and develop		12.90	11.40	15.80

	Machine Time	Man Time (min) Line Negative	Positive from Negative	Halftone Negative
Halftones				
Add 33% for highlight, adjust, reexposure				5.40
Multiplier		0.022	0.022	0.022
Setup and run hours/job		0.29	0.26	0.48

Fabricate Silk Screen Stencil

Included are two methods. One is the PC board for presensitized screen process film and the other is letter artwork for unsensitized screen process film.

	Minutes/Job PC Boards	Minutes/Job Letter Artwork
Sensitize		
Cut film to size.	1.00	1.00
Immerse in sensitizing solvent.		
Rub surface.		
Remove air bubbles.		1.00
Transfer file to transparent vinyl support, emulsion side down.		0.50
Squeegee excess sensitizer and air bubbles from film.		0.50
Wipe dry.		0.50
Expose		
Place vinyl support with film on emulsion side of positive.	0.50	0.50
Place support and positive in vacuum frame.	0.50	0.50
Cut to length and assembly opaque tape around border of positive.	1.00	1.00
Expose film.	3.00	5.00
Develop film in "A" and "B" developer solution.	2.50	
Wash out		
Immerse film and support in 110°F water.	0.50	0.50
Soak 0.5 min and peel backing.	1.00	1.00
Agitate and dissolve unexposed gelatin.	1.00	1.00
Attach developed film to screen		
Clean silk screen with cleaner or solvent and brush under running water.	4.00	4.00
Place silk screen over film.	0.50	0.50
Place paper towel over screen to absorb moisture.		
Remove.	1.00	1.00
Weigh frame down and allow to air dry	2.00	2.00
Peel vinyl support from screen stencil	2.00	2.00
Total	20.50	22.50
Multiplier	0.022	0.022
Setup and run hours	0.46	0.50

NOTE: Recall that the multiplier incorporates a factor for unproductive time as well as converts minutes to hours.

Silk Screen Operations

The following are details of the setup for a single-sided PC board, a double-sided PC board, letter artwork per stencil, or single side of panel.

	Setup Hour/Job		
	Single-Side PC	Double-Side PC	Letter Artwork
Setup Analysis			
Fabricate negative and positive.	0.5	1.0	0.5
Fabricate silk screen.	0.5	1.0	0.5
Set up silk screen for production	0.3	0.5	0.3
Total	1.3	2.5	1.3
Add per character to draw artwork (LeRoy or similar)			0.01
	Minutes/Unit		
Run time (avg. 6 in. × 6 in. board)			
Clean PC board with cleaner	0.30	0.40	
Silk screen resist board			
Fill plate through holes with resist			
Squeegee one side		0.40	
Squeegee second side		0.40	
Clean two sides with solvent		0.50	
Silk screen board			
Handle board to and from pins	0.20	0.40	
Squeegee ink through screen	0.40	0.80	0.40
Dry in oven (handling only)	0.20	0.40	0.20
Total	1.10	3.30	0.60

Registration

When registration tolerance of double-sided boards is given as ±0.005 in., additional touchup work is required. Generally, a small artist's brush, ink, and a sample board or positive is used. Size of board, complexity of pattern, and registration tolerance all influence touchup time required.

A good method of approximating touchup time is to use the number of holes as the prime variable:

100 holes at 0.01 min = 1.00 min/avg. board.
500 holes at 0.01 min = 5.00 min/avg. board.

Set Up Silk Screen for Production

	Minutes/Job	
	Single-Side PC	Double-Side PC
Receive work order, drawings, blank boards	2.00	2.00
Set up to clean boards	1.00	1.00
Silk screen setup		
Draw screen from storage	0.30	0.30
Clamp to 2 bench hinges	1.00	1.00
Mark tool pin holes on ink board per PC board	0.30	0.30
Drill and pin ink board	2.00	2.00
Position PC board to 2 pins	0.10	0.10
Line up ink board to screen pattern	0.50	0.50
Staple base down	0.30	0.30
Screen first PC board		
Mix ink	1.00	1.00
Squeegee	1.00	1.00
Check registration	3.00	3.00
Put aside PC board for inspection	0.10	0.10
Add time values from "position board to 2 pins" down for double-sided board		6.00
Set up for touchup		
Resist ink, brush, neg., pos., or sample	2.00	2.00
Total	14.60	20.60
Multiplier	0.022	0.022
Setup hours/job	0.32	0.45

Etch Printed Circuit Boards

Equipment

Paddle agitation rack.

Loaded etching maching (using ferric chloride as etching agent).

	Hours
Setup	
Keep etching solution at 105° to 115°F.	
Maintain ferric chloride and distilled water solution.	
Provide lacquer thinner to deresist boards.	0.1
Setup hours/job	0.1

	Minutes/Job	
	Single-Side PC	Double-Side PC
Run time		
Position board on rack.	1.10	2.20
Position rack to etching machine.	0.04	0.08
Turn on.	0.01	0.02
Machine time.	0.60	1.20
Remove rack.	0.02	0.04
Rinse rack.	0.10	0.20
Remove board from rack.	0.05	0.10
Deresist board with thinner and brush.	0.50	1.00
Total	2.42	4.84

NOTE: Add to dresist holes — 0.01 min/hole.

Decals (Made by Silk Screen)

	Hours/Job
Setup	
Fabricate negative and positive (see previous description).	0.5
Fabricate silk screen.	0.5
Set up silk screen for production.	0.3
Total	1.3

	Minutes/Unit
Run time	
Average 3 in. × 3 in. decal.	
Fabricate decal.	
Clear screen (screen clear laquer to base paper).	0.30
Stencilled screen (screen colored lacquer to base paper).	0.30
Clear screen (screen clear lacquer over color pattern).	0.30
Total	0.90
Assemble decal to part of chassis.	
Place decal in water to loosen backing.	0.05
Pick up and peel off backing.	0.15
Position decal to part.	0.10
Wipe smooth.	0.20
Total	0.50

Encapsulating (Vacuum)

Equipment

Vacuum impregnator oven.

Split type mold.

	Minutes/Job
Setup	
Trip to tool crib.	
Set up oven.	
Obtain accessories.	14.0
Total	14.0
Portion out resin.	2.5
Set up mold release.	2.5
Prepare epoxy with catalyst (A and B).	5.0
Portion out amount of mixture required.	1.0
Place in oven (heat time 30 min).	1.0
Place in encapsulator.	2.0
Draw 28 in. vac (approximately 7 min).	
Hold for approximately 15 min.	
Check while in process.	2.0
Remove compound and heat in oven.	2.0
Total	32.00
Multiplier	0.022
Setup hours/job	0.7

	Hours
Add for optional operations	
Shield with silver foil.	
Set per job.	0.1
Total	0.1

	Minutes/Job
Run time	
Clean capsule with solvent.	0.30
Brush cement on capsule.	0.20
Bake 10 min (handle only).	0.20
Cut foil to length.	0.20
Wrap capsule with foil.	0.50
Seal corners with solder.	0.40
Clean resin with solvent.	0.30
Brush lacquer on capsule (dry – 1 h).	0.20
Bake in oven 1 h.	0.20
Total	2.50

	Minutes/Job
Paint capsule	
Clean capsule with solvent.	0.30
Brush paint on 6 sides of capsule.	0.60
Bake 1 h or air dry 6 h (handle only).	0.20
Total	1.10

F. Coil Winding

The standards herein are for flat winding, close winding, space winding, and universal winding. Flat winding means all turns run in the same direction, parallel to each other. Close winding is the same as flat winding with the additional specification that each turn added be against the preceding turn. Space winding is the same as flat winding; however, a controlled space is maintained between each turn. Universal winding is accomplished in such a manner that two succeeding layers of winding will form a cross-hatch pattern.

Coil Winding

	Minutes/Job	
	Hand Wind	Machine Wind
Setup		
Trip to tool crib and supply room.	5.00	5.00
Calculate proper gear ratio (turns/inch).	0	2.50
Calculate cam size (coil width).	0	2.50
Cam disassemble, reassemble.	0	0.20
Nut disassemble, reassemble.	0	0.30
Allen screw — unlock, relock.	0	0.80
Readjust (at halfway point).	0	0.70
Gear disassemble, assemble.	0	0.60
Allen screw disassemble, reassemble.	0	0.90
Line up and adjust.	0	1.00
Spindle assemble arbor base.	0.30	0.30
Winding finger screw, unlock and relock.	0	1.20
Fail stock nut, unlock and relock.	0	0.30
Counter — adjust to stop.	0.40	0.40
Division control adjust.	0	0.20
Tension and spool holder.	0	3.00
Total	5.70	19.90
Multiplier	0.022	0.022
Setup hours/job	0.1	0.4
Add for each additional coil for multiple winding		
Adjust winding finger.	1.20	
Tension and spool holder.	3.00	
Minutes/job	4.20	
Multiplier	0.022	
Setup hours/each added coil	0.1	

	Minutes/Job
Coil winding elements	
Advance arbor.	0.005
Assemble tube or bobbin to arbor	
Random position.	0.04
Chuck arbor.	0.03
Assemble nut.	0.05
Expansion arbor.	0.04
Spring arbor.	0.03

	Minutes/ Job
Align tube to specific lead position	
Chuck arbor.	0.045
Wing nut arbor.	0.04
Assembly nut.	0.05
Expansion arbor.	0.05
Spring arbor.	0.04
Assemble spacer to arbor.	0.02
Close tail stock.	0.03
Press and secure leads of previous winding.	
Unroll tape and position.	0.04
Application per lead.	0.01
Wrap lead to terminal.	0.035
Anchor start lead to wind.	
Thread to hole through coil form and dress	
Coil on arbor	
18 to 22 gage.	0.13
24 to 36 gage	0.11
38 to 40 gage	0.12
Wrap to terminal	
18 to 22 gage	0.07
24 to 28 gage	0.05
30 to 40 gage	0.03
Wrap to tube and tape (wrap lead two turns, unroll tape and apply).	0.08
Double back start lead to reinforce.	0.035
Twist precut and stripped reinforcement lead to coil lead.	0.05
Index wire guide.	0.015
Position wire around guide buttons.	0.03
Set counter.	
Veeder root type — clear to zero.	0.025
Self-braking type — set up to 99 turns	0.045
Per additional digit.	0.015
Hand wind initial turns. 1 turn	0.044
2 turns	0.053
3 turns	0.062
4 turns	0.072

	Minutes/ Job
Cement start of winding	
Handle applicator.	0.025
Apply cement — per lead.	0.015
Wind	
Machine wind using machine lead spacer.	
Start, stop, and brake machine.	0.045
Space wind	
14 - 16 gage 300 rpm.	0.003
18 - 20 gage 500 rpm.	0.002
22 - 24 gage 1000 rpm.	0.001
26 - up gage 1500 rpm.	0.0007
Close or universal	
14 - 16 gage 200 rpm.	0.005
18 - 20 gage 300 rpm.	0.003
22 - 24 gage 500 rpm.	0.002
26 - up gage 1000 rpm.	0.001
Groove wind on threaded core	
16 - 18 gage 200 rpm.	0.005
20 - 22 gage 300 rpm.	0.003
24 - up gage 500 rpm.	0.002
Hand wind	
Hand feed wire to required turns per inch.	
Start, stop, and brake machine.	0.02
Close wind or groove wind	
14 - 16 gage 60 rpm.	0.017
18 - 20 gage 80 rpm.	0.013
22 - up gage 100 rpm.	0.01
Taps and insulation strips.	
Release brake, position arbor.	0.025
Make tap	
Twist tape and knot.	0.13
Twist tape and wrap one turn to terminal.	0.15
Loop tap — anchored with tape	0.19
Anchored with tape and cement.	0.21
Wrap to terminal.	0.18
Add for second tape around tap.	0.07

	Minutes/Job
Cambric type insulation strip	
Insert under lead.	0.07
Spread and position preformed tap.	0.11
Form and position flat tap.	0.12
Hand wind one turn — dress cambric and tap together.	0.06
Kraft paper type insulation strip	
Position to coil.	0.04
Brush with cement (per 1/2 in.).	0.035
Handle brush.	0.03
After wind	
Release brake — position arbor.	0.025
Anchor finish lead to coil with tape, unroll tape and apply.	0.06
Push back guide.	0.015
Cut leads	
Approximate length.	0.005
Exact length.	0.02
Handle scissors.	0.03
Thread finish lead	
One hole through coil form and dress	
18 - 22 gage.	0.07
24 - 22 gage.	0.05
30 - 40 gage.	0.03
Trim leads wrapped to terminal.	0.01
Handle cutters or tweezers.	0.025
Unwrap start leads	
From arbor to tube.	0.015
From terminal.	0.03
Solder start, finish, or splice leads per joint	0.04
Handle iron (solder).	0.045
Disassembly lead of previous winding	
Taped to arbor.	0.02
Taped to tube.	0.03
Unwrap from terminal.	0.03
Open fail stock.	0.03
Disassemble arbor from chuck.	0.04
Disassemble coil from arbor	
Chuck arbor.	0.03
Wind nut arbor.	0.02
Disassembly nut.	0.04
Expansion arbor.	0.035
Spring arbor.	0.02
Disassemble lead from spacer slot.	0.012

G. Wire Preparation and Wiring

This section contains information relative to preparation of wire for the application of various kinds or types of terminals. There is also information for layout and manufacture of wiring harnesses. Both machine type wire preparation and hand type preparation of wiring are addressed.

Machine Preparation of Wire

Operation 14-22 Gauge	No. Ends	Wire Length (in.)					
		2 to 3	3 to 15	15 to 20	20 to 30	30 to 45	45 to 60
Machine cut and strip	1	0.020	0.020	0.040	0.040	0.060	0.080
	2	0.020	0.020	0.040	0.040	0.060	0.080
Twist strands	1	0.035	0.025	0.032	0.032	0.032	0.037
	2	0.060	0.043	0.056	0.056	0.056	0.062
Tin strands	1	0.026	0.017	0.021	0.030	0.030	0.035
	2	0.038	0.024	0.030	0.056	0.056	0.061
Stamp wire — simultaneous	1	00	00	00	00	00	00
with machine cut	2						
Stamp wire — separate	1	0.090	0.130	0.160	0.190	0.230	0.270
operation	2	0.090	0.130	0.160	0.190	0.230	0.270
Total — cut and stamp	1	0.081	0.062	0.093	0.102	0.122	0.152
simultaneously	2	0.118	0.087	0.126	0.152	0.172	0.203
Total — stamp separate	1	0.171	0.192	0.253	0.292	0.352	0.422
	2	0.208	0.217	0.286	0.342	0.402	0.473

NOTE: The Artos machine automatically unreels, cuts to length, and strips solid or stranded wire.

Operation 22-26 Gauge	No. Ends	Wire Length (in.)					
		2 to 3	3 to 15	15 to 20	20 to 30	30 to 45	45 to 60
Machine cut and strip	1	0.0[illegible]	0.020	0.040	0.040	0.060	0.080
	2	0.020	0.020	0.040	0.040	0.060	0.080
Twist strands	1	0.035	0.025	0.032	0.032	0.032	0.037
	2	0.060	0.043	0.056	0.062	0.062	0.068
Tin strands	1	0.030	0.017	0.028	0.030	0.030	0.035
	2	0.042	0.024	0.038	0.056	0.056	0.061
Stamp wire — simultaneous	1	00	00	00	00	00	00
with cut	2						
Stamp wire — separate	1	0.090	0.130	0.160	0.190	0.230	0.270
	2	0.090	0.130	0.160	0.190	0.230	0.270
Total — cut and stamp	1	0.083	0.062	0.097	0.102	0.122	0.152
simultaneously	2	0.122	0.087	0.134	0.158	0.178	0.209
Total — stamp separate	1	0.175	0.192	0.258	0.292	0.352	0.422
	2	0.212	0.217	0.294	0.348	0.408	0.479

Hand Preparation of Insulated Wire

		Minutes 15 in.	Minutes 60 in.
Pull wire from reel			
Grasp wire end.		0.031	0.031
Pull off of reel — 0.001/in.			
Measure			
Line up to marker.		0.028	0.028
Cut with hand pliers			
Tool handling.		0.003	0.003
Identify (temporary)			
Tear tape.	0.030		
Apply to wire.	0.050		
Check drawing for identification.	0.050		
Write identification.	0.050		
Remove after hookup.	0.020	N.R.	0.200
Strip with hand pliers		0.110	0.110
Tool handling.		0.003	0.003
Tin with solder iron		0.120	0.120
Tool handling.		0.004	0.004
Pick up and bundle wires.		0.020	0.080
Total		0.319	0.579

Stake Taper Pin to Wire

	Hours
Setup time	0.4
Total	0.4

AMP type machine — Taper pins are supplied in a continuous chain on a reel. When one staking action is made, the machine automatically cuts the pin free from the chain, stakes it to the wire, and positions the next pin to anvil.

	Minutes/ Unit
Run time — machine	
Separate wire from group.	0.005
Grasp.	0.002
Position to taper pin on anvil.	0.022
Press foot pedal and machine cycle.	0.010
Remove wire from anvil and aside.	0.005
Total — one end	0.044
Add for second end	0.044
Total — two ends	0.088
Run time — hand	
Pick up, position pin to pliers.	0.045
Pick up, position wire to pin.	0.040
Squeeze.	0.015
Release pliers, aside wire.	0.010
Total — one end	0.11
Add for second end.	0.11
Total — two ends	0.22
Add for tool handline (pliers).	0.03

Table of Values — Wiring

Operation	Setup (h)	Run Time Values (min) Machine Preparation Length (in.) 15	Machine Preparation Length (in.) 60	Hand Preparation Length (in.) 15	Hand Preparation Length (in.) 60
Insulated wire — prepare and install 2 ends					
Crimp and solder					
Point to point	0.10	0.65	1.00	0.95	1.15
Lay in U channel	0.10	0.70	1.15	1.00	1.35
Lace harness	0.10	0.95	1.60	1.25	1.80
Taper pin (solderless)					
Point to point	0.10	0.50	0.85	0.95	1.15
Lay in U channel	0.10	0.55	1.00	1.00	1.35
Lace harness	0.10	0.80	1.45	1.25	1.80
Pneumatic wrap (solderless)					
Point to point	0.10	0.30	0.60	0.55	0.75
Lay in U channel	0.10	0.35	0.75	0.60	0.95
Lace harness	0.10	0.60	1.20	0.85	1.40
Bus — wire — cut crimp solder 2 ends	*	0.40		0.45	
Resistor — 2 ends					
Crimp and solder to terminals	0.01	0.45		0.50	
Crimp to PC board and dip solder	0.01	0.30		0.35	
Transistor, 3 lead component					
Crimp and solder to terminals	0.01	0.65		0.70	
Crimp to PC board and dip solder	0.01	0.40	0.45		

Operation	Setup (h)	Run Time Values (min) — Machine Preparation Length (in.) 15	Machine Preparation Length (in.) 60	Hand Preparation Length (in.) 15	Hand Preparation Length (in.) 60
Sleeving — cut to length — thread to lead	*	0.05		0.10	
Shielded cable — prepare and install 2 ends					
Single conductor				3.95	4.35
Double conductor				5.00	5.40
Coax cable — prepare and install 2 ends					
Ground lead termination	0.10			4.15	4.55
Connector termination	0.10	8.50		9.20	
Connect first end, ground lead second end	0.10			6.30	6.85
Connector-mechanical assembly to harness					
Small — 5 to 10 pin				2.70	
Medium — 10 to 25 pin				4.25	
Large — 25 to 40 pin				6.15	
Pull tubing over cable					
1 to 2 ft/ft				0.70	
3 to 5 ft/ft				0.80	
6 to 15 ft/ft				0.90	
Twist cable wire per foot				0.06	
Spot tie harness per foot				0.90	
Seam solder per inch				0.10	
Develop wire list from schematic per wire	0.10				
Fabricate harness nail board — basic	3.50				
Add for each wire	0.06				
Set up components at work station	0.02				
Buzz wire to identify				0.20	

*Negligible

H. Soldering

Soldering covered herein is concerned with soft solder, an alloy of 63 percent tin and 37 percent lead. Silver solder or brazing is not generally applicable to soldering electronic wiring connections.

Time values shown herein are based on the use of 63 percent tin — 37 percent lead solder, 0.062 in. diameter with resin core.

Solder Wire to Terminal Values

Wire Gage	No. Wires on Terminal	Solid Terminal	Hole Terminal	Hollow Term		Solder to Chassis	
				Prefill	Heat and Insert Lead	Heat to Cool	Without Cooling Time
18 to 24	1	0.047	0.400	0.070	0.080	0.135	0.080
	2	0.057	0.045				
	3	0.061	0.055				
16	1	0.060	0.053	0.080	0.090	0.148	0.093
	2	0.071	0.059				
	3	0.077	0.071				
14	1	0.073	0.066	0.090	0.100	0.161	0.106
Spot							
Solder	0						0.070
Braid							
Pigtail	1					0.165	0.100

Dip Soldering of Etched Circuit Boards

Equipment — semiautomatic machine

Automatic machine lowers board into solder bath, removes, and positions for manual unloading. Pot size is approximately 16 in. × 16 in. by appropriate depth.

	Hours
Setup	
Obtain solder stock.	
Adjust dwell time of mechanism.	
Turn on heat.	
Cut and try out sample board.	0.4
Total	0.4

	Minutes		
	4 in. × 4 in.	4 in. × 6 in.	4 in. × 12 in.
Run time			
Mask board with tape.	0.18	0.42	0.63
Dip solder.			
Brush flux on board.	0.10	0.20	0.30
Assemble board on holding fix.	0.08	0.10	0.13
Actuate machine switch.	0.02	0.02	0.02
Machine cycle.	0.35	0.35	0.35
Remove board from fix.	0.05	0.07	0.10
Wash off flux residue.	0.30	0.50	0.70
Blow dry.	0.15	0.25	0.35
Subtotal	1.23	1.91	2.58
Touch up with handiron (a.g.).	0.30	0.60	0.90
Total/board	1.53	2.51	3.48

Seam Solder

	Minutes
Equipment — 150 watt electric solder iron	
Run time	
Handiron — pick up and lay aside	0.045
First inch.	0.120
Each additional inch.	0.080

I. Etched Circuit and Terminal Boards

Etched circuit and terminal boards require the use of sheet metal, machine shop, and other process operations. The most common of these operations are combined into tables which can be used to estimate various types of circuit boards. Etched circuit board standards are based on using epoxy laminate 0.062 in. thick, 1 oz. copper clad, Spec. EG751 or EG758T. Standards for terminal boards are based on using phenolic laminate sheet stock 0.125 in. thick.

Setup time shown in the table "Terminal Board Operations" includes silk screening which includes making a negative, a positive, and a silk screen stencil, as well as setting up the screen jig for production.

C-2

Table of Values — Fabrication of Etched Circuit Board

Operation [One Side (4 in. × 4 in.)]	Setup (h)	Run Time: Operation Time (min)	Run Time: No. of Operations	Run Time: Total (min)
Stamp blank with tool holes — punch press.	0.4	0.20		
Shear blank.	0.2	0.10	1	0.10
Drill 2 tooling holes.	0.3	0.50	1	0.50
Drill circuit holes				
Per circuit pattern.	0.3	0.08		
Per drill jig				
1/stack.	0.3	0.07		
2/stack.	0.3	0.05		
3/stack.	0.3	0.04	1	0.04
4/stack.	0.3	0.035		
Deburr holes with vibrator — per board.	0.1	0.50	1	0.50
Silk screen resist				
1 side.	1.3	1.10	1	1.10
2 sides.	2.5	3.30		
Add per hole for ±0.005 tolerance.		0.01		
Etch and deresist				
1 side.	0.1	1.40	1	1.40
2 sides.	0.1	2.85		
Add to deresist plate through holes.		0.01		
Rout blank to size (1/16 in.) per inch.	0.3	0.04	16	0.64
Deburr edges — per inch.		0.02	16	0.32
Clean and plate.				
Copper through holes ($in.^2$).	0.6	0.07		
Nickel-rhodium tab ($in.^2$).	0.4	0.10	16	1.60
Gold flash circuit ($in.^2$).	0.4	0.09		
Connector tab and key slot				
Punch press both.	0.4	0.20		
Shear tab.	0.2	0.10	1	0.10
Saw and bevel slot.	0.1	0.40	1	0.40
Connector tab — chamber 3 in. tab	0.1	0.20	1	0.20
Eyelet — handle board		0.10		
Install eyelet — automatic feed.	0.4	0.04		
Solder both sides — handiron.		0.10		
Epoxy coat after assembly — per side		0.35		
Total constant time/board	3.4	—	—	6.86
Total variable time/board/hole				0.04

Table of Values — Fabrication of Etched Circuit Board

Operation [Two Side (4 in. × 4 in.)]	Setup (h)	Run Time		
		Operation Time (min)	No. of Operations	Total (min)
Stamp blank with tool holes — punch press.	0.4	0.20		
Shear blank.	0.2	0.10	1	0.10
Drill 2 tooling holes.	0.3	0.50	1	0.50
Drill circuit holes.				
Per circuit pattern.	0.3	0.08		
Per drill jib				
1/ stack.	0.3	0.07		
2/ stack.	0.3	0.05		
3/ stack.	0.3	0.04	1	0.04
4/ stack.	0.3	0.035		
Deburr holes — per board.	0.1	0.50	1	0.50
Silk screen resist				
1 side.	1.3	1.10		
2 sides.	2.5	3.30	1	3.30
Add to deresist plate through holes.		0.01	1	0.01
Etch and deresist				
1 side.	0.1	1.40		
2 sides.	0.1	2.85	1	2.85
Rout blank to size (1/16 in.) per inch.	0.3	0.04	16	0.64
Clean and plate				
Copper through holes ($in.^2$).	0.6	0.07	16	1.12
Nickel-rhodium tab ($in.^2$).	0.4	0.10	16	1.60
Gold flash circuit ($in.^2$).	0.4	0.09		
Connector tab and key slot				
Punch press both.	0.4	0.20		
Shear tab.	0.2	0.10	1	0.10
Saw and bevel slot.	0.1	0.40	1	0.40
Connector tab — chamber 3 in. tab.	0.1	0.20	1	0.20
Eyelet — handle board		0.10		
Install eyelet — automatic feed.	0.4	0.04		
Solder both sides — handiron.		0.10		
Epoxy coat after assembly — per side.		0.35		
Deburr edges — per inch.		0.02	16	0.32
Total constant time/board	5.2	—	—	11.68

Circuit Boards
(Composite Jig Handling and Drilling Time)

No. of 1/16 in. Boards in Stack	Jig Handling Time	Proration at 100 Holes per Board	Move from Hole to Hole	Drill Time at 0.32 min/in.	Total per Board in Jig	Total per Hole per Board
1*	0	0	0.060	0.020	0.080	0.080
1	0.20	0.002	0.047	0.020	0.069	0.069
2	1.20	0.012	0.047	0.040	0.099	0.050
3	1.30	0.013	0.047	0.060	0.120	0.040
4	1.40	0.014	0.047	0.080	0.141	0.035
5	1.50	0.015	0.047	0.100	0.162	0.033

*No drill plate. Align and position drill per circuit pattern.

Terminal Board Operations

Operation [4 in. × 4 in. Board (Example)]	Setup (h)	Run Time: Operation Time (min)	Run Time: No. of Operations	Run Time: Total (min)
Cut blank to size				
Handle board				
1 in. × 2 in.		0.03		
4 in. × 4 in.		0.04	1	0.04
4 in. × 12 in.		0.08		
Diamond saw — 2 sides (1/8 in.) per inch.	0.1	0.02	8	0.16
Deburr 4 edges — per inch.		0.02	16	0.32
Drill terminal holes				
Per drawing dimension.	0.3	0.08		
Per drill jig				
1/ stack.	0.3	0.07	1	0.07
2/ stack.	0.3	0.05		
3/ stack.	0.3	0.04		
Deburr holes with vibrator				
1 in. × 2 in. board.	0.1	0.20		
4 in. × 4 in. board.	0.1	0.40	1	0.40
Silk screen identification data to board				
1 in. × 2 in. board.	1.3	0.25		
4 in. × 4 in. board.	1.3	0.40	1	0.40
4 in. × 12 in. board.	1.3	0.60		
Stake terminal — handle				
1 in. × 2 in. board.		0.03		
4 in. × 4 in. board.		0.04		
4 in. × 12 in. board.		0.08		
Pick up and stake terminal	0.4	0.06	1	0.06
Epoxy coat after assembly — per side		0.35		
Total constant time/ board	2.2	—	—	1.45
Total variable time/ board/ hole				0.13

IV. FACTORS

Incorporated in this section is an assemblage of factors which have been gathered from many areas. Some have been taken from formal writings by professionals in fields such as electronics, mechanics, refrigeration, etc. Others have been extracted from proposals for procurements for which the Cost Analysis Office has prepared government estimates. These latter factors are mostly derived averages of all proposals for the given procurement. These factors are not meant to be absolutes in the sense that they can be used categorically. They are intended for the rational establishment of parameters when the estimator is trying to get a "handle" on areas with which he may not be fully conversant. For instance, factors are included from "Program Management." These factors are based on averages taken from such Shuttle procurements as External Tank, Integrated Electronics Assembly, and others. A review of the percentages of Program Management man-hours proposed to total man-hours proposed reveals that among contractors there is a fairly broad range of percentages. However, if all percentages are taken into consideration on an individual procurement basis, it appears that if the average was used as an estimate of the Program Management man-hours, it would be a conservative estimate.

A. Individual Cost Element as a Percent of Total Cost

In this section, various elements of cost have been related to the total cost as proposed for various programs by various contractors. So that any sensitivity relative to divulging contractor information is obviated, we have removed names and used numbers for identification. These percentages may or may not be useful in establishing an estimate from scratch, but they could be used as validation checkpoints after an estimate is tentatively formulated.

SRB — Integrated Electronics Assembly
[Element of Cost Comparison (%)]

Cost Elements	Government Estimate	I	II	III	IV	V	VI	VII	Contractor Average
Direct Labor	29.6%	30.8%	29.5%	33.5%	28.8%	32.8%	25.3%	28.2%	29.5%
Total Indirect	49.6%	52.2%	45.4%	47.1%	51.4%	46.2%	56.3%	54.0%	50.8%
Material and Subcontract	17.9%	14.6%	23.2%	18.6%	18.1%	20.7%	17.6%	14.9%	18.0%
Other Direct	2.9%	2.4%	1.9%	0.8%	1.7%	0.3%	0.8%	2.9%	1.7%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

External Tank
[Element of Cost Comparison (%)]

Cost Elements	Government Estimate	I	II	III	IV	Contractor Average
Direct Labor	35.5%	30.7%	28.2%	26.7%	26.2%	28.0%
Total Indirect	43.7%	34.3%	30.4%	32.0%	20.3%	29.3%
Material and Subcontract	19.1%	25.2%	37.7%	40.7%	50.6%	38.5%
Other Direct	1.7%	9.8%	3.7%	0.6%	2.9%	4.2%
Total	100%	100%	100%	100%	100%	100%

SRB — Booster Separation Motors
[Element of Cost Comparison (%)]

Cost Elements	Government Estimate	I	II	III	Contractor Average
Direct Labor	28.5%	29.2%	27.9%	31.2%	29.4%
Total Indirect	55.6%	58.2%	57.7%	52.2%	56.0%
Material and Subcontract	13.1%	11.0%	12.4%	12.5%	12.0%
Other Direct	2.8%	1.6%	2.0%	4.1%	2.6%
Total	100%	100%	100%	100%	100%

SRB Structures
[Element of Cost Comparison (%)]

Cost Elements	Government Estimate	I	II	III	IV	Contractor Average
Direct Labor	31.6%	26.7%	29.3%	20.2%	22.9%	24.8%
Total Indirect	55.6%	35.0%	52.6%	47.6%	46.3%	45.4%
Material and Subcontract	12.3%	36.8%	17.8%	31.5%	24.2%	27.6%
Other Direct	0.5%	1.5%	0.3%	0.7%	6.6%	2.2%
Total	100%	100%	100%	100%	100%	100%

SRB Decelerator Subsystem
[Element of Cost Comparison (%)]

Cost Elements	Government Estimate	I	II
Direct Labor	30.1%	22.2%	28.0%
Total Indirect	52.8%	53.2%	48.2%
Material and Subcontract	14.7%	20.5%	14.6%
Other Direct	2.4%	4.1%	9.2%
Total	100%	100%	100%

B. Major WBS Element Cost as a Percentage of Total Cost

In this section, major WBS elements of cost are related to the total cost. It is recognized that seldom, if ever, will a project to be estimated be exactly the same as the ones included herein; however, review of these tabulations of percentages may give the estimator an idea of what relationship some areas of program cost should have to other areas and to the total. Again, it is not suggested that any percentage would be used as an absolute in formulating an estimate, but they can be used for increasing the estimator's confidence in figures he may otherwise have derived.

Integrated Electronics Assembly
[Costs Relationships by Major and Subsystem WBS's (%)]

	WBS	Government Estimate	I	II	III	IV	V	VI	VII	Contractor Average
IEA Management	1.4.1.4.2.1	15.3%	12.1%	11.1%	27.5%	8.6%	12.6%	10.5%	21.2%	14.8%
Proj Engr & Integ	1.4.1.4.2.2	20.8%	15.5%	16.8%	18.1%	18.9%	23.1%	12.7%	19.5%	17.5%
Sp Req Anal & Integ	1.4.1.4.2.2.1	10.9%	12.8%	12.3%	8.9%	14.6%	13.1%	10.7%	2.4%	10.7%
Safety Rel & QA	1.4.1.4.2.2.2	9.0%	2.2%	4.0%	7.8%	3.5%	7.5%	1.4%	14.6%	5.8%
Maintainability	1.4.1.1.2.2.3	0.9%	0.5%	0.5%	1.4%	0.8%	2.5%	0.6%	0.5%	1.0%
IEA Dev & Del Hdwe	1.4.1.4.2.3	52.2%	55.2%	59.2%	45.5%	65.5%	53.7%	69.9%	49.9%	57.0%
Mech Housing	1.4.1.4.2.3.1	5.5%	4.7%	7.7%	6.4%	7.8%	11.6%	16.5%	8.2%	9.0%
Distributor	1.4.1.4.2.3.2	25.8%	25.7%	35.2%	23.1%	30.3%	17.3%	13.1%	16.0%	23.0%
Multiplexer	1.4.1.4.2.3.3	0.6%	0.2%	1.9%	0.7%	-0-	-0-	1.3%	0.2%	0.5%
Signal Conditioning	1.4.1.4.2.3.4	6.3%	8.3%	5.8%	6.8%	12.1%	9.2%	10.5%	7.2%	8.5%
Dev Testing	1.4.1.4.2.3.5	1.5%	8.0%	1.8%	2.1%	3.1%	2.7%	5.4%	1.8%	3.6%
Assembly & Inspection	1.4.1.4.2.3.6	1.6%	3.1%	1.2%	1.3%	2.6%	3.6%	12.0%	4.2%	4.0%
Acceptance Test	1.4.1.4.2.3.7	3.4%	2.9%	2.2%	1.0%	2.1%	4.0%	3.8%	3.6%	2.8%
Maint & Refurb	1.4.1.4.2.3.8	7.3%	2.3%	4.3%	4.1%	7.5%	5.3%	7.3%	8.7%	5.6%
Support Equip & Tooling	1.4.1.4.2.5	11.7%	17.2%	12.9%	8.9%	6.8%	10.6%	6.9%	11.4%	10.7%
IEA Test Set	1.4.1.4.2.5.1	8.2%	12.7%	9.3%	5.0%	3.8%	8.3%	6.2%	8.0%	7.8%
Special Test Equip	1.4.1.4.2.5.2	3.5%	4.5%	3.6%	2.9%	3.0%	2.3%	0.7%	3.4%	2.9%
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%

NOTE: The above excludes GFE of the following items:

Multiplexer
Signal conditioner
MIA's
PIC's
Data bus couplers.

However, the contractor will integrate all of the above.

SRB — Booster Separation Motors
[Cost by Major WBS (%)]

	WBS	Government Estimate	I	II	III	Contractor Average
Management	1.4.1.7.1	15.2%	25.1%	23.8%	11.5%	20.1%
Safety Rel & QA	1.4.1.7.2	3.0%	9.0%	5.2%	9.2%	7.8%
BSM Design & Dev	1.4.1.7.3	29.1%	27.5%	24.7%	25.9%	26.1%
Support Equip & Tooling	1.4.1.7.4	9.1%	5.5%	3.0%	9.0%	5.8%
Deliverable Hdwe	1.4.1.7.5	23.4%	14.4%	13.0%	19.0%	15.5%
Fld Opns & Flt Supp	1.4.1.7.6	11.4%	6.9%	16.8%	12.7%	12.1%
Special Analysis	1.4.1.7.7	8.8%	11.6%	13.5%	12.7%	12.6%
Total		100%	100%	100%	100%	100%

External Tank
[Cost by Major WBS (%)]

	WBS	Government Estimate	I	II	III	IV	Contractor Average
Project Management	1.6.1	10.2%	5.3%	9.8%	11.3%	11.9%	9.6%
Proj Engr & Integ	1.6.2	9.6%	14.6%	13.0%	13.9%	7.6%	12.2%
External Tank Stage	1.6.3	64.2%	58.7%	63.6%	68.4%	66.1%	64.2%
External Tank Support	1.6.4	16.0%	21.4%	13.6%	6.4%	14.4%	14.0%
Total		100%	100%	100%	100%	100%	100%

SRB Structures
[Cost by Major WBS (%)]

	WBS	Government Estimate	I	II	III	IV	Contractor Average
Management	1.4.1.3.1	21.2%	8.3%	7.1%	6.7%	24.9%	11.8%
Special Analysis	1.4.1.3.2	2.6%	3.8%	2.7%	5.2%	1.7%	3.2%
Deliverable Hardware	1.4.1.3.3	35.0%	53.0%	55.7%	55.1%	44.4%	52.1%
Tooling	1.4.1.3.4	24.9%	25.0%	21.9%	24.6%	22.5%	23.5%
Multielement Support	1.4.1.3.5	5.5%	2.3%	2.2%	1.5%	1.0%	1.7%
MSE	1.4.1.3.10	10.8%	7.6%	10.4%	6.7%	5.5%	7.7%
Total		100%	100%	100%	100%	100%	100%

Decelerator Subsystem
[Cost by Major WBS (%)]

	WBS	Government Estimate	I	II
Management	1.4.1.6.1.1	14.2%	9.5%	16.6%
Development	1.4.1.6.1.2	39.8%	55.8%	53.9%
Manufacturing	1.4.1.6.1.3	46.0%	34.7%	29.5%
Total	1.4.1.6.1	100%	100%	100%

C. Rates Comparison

This section gives various contractor labor, overhead, G&A, and composite rates for numerous procurements which have been made in the relatively recent past. They serve only to show differences among contractors. They could be used for pricing out current estimates for other things that are similar; however, more current and more detailed rates can be obtained on an individual basis.

External Tank
(Comparison of Rates)

	Government Estimate	I	II	III	IV	Contractor Average
Direct Labor Rate	$ 7.26	$ 8.09	$ 7.43	$ 6.36	$ 6.18	$ 7.[illegible]
Overhead Rate	6.61 (91%)	7.93 (98%)	5.28 (71%)	6.81 (107%)	3.58 (58%)	5.90 (84%)
Subtotal	$ 13.87	$ 16.02	$ 12.71	$ 13.17	$ 9.76	$ 12.92
G& A Rate	1.53 (11%)	0.67 (4.2%)	1.47 (11.6%)	-	0.54 (5.5%)	0.67
Composite	$ 15.40	$ 16.69	$ 14.18	$ 13.17	$ 10.30	$ 13.59

SRB Structures
(Rate Comparison)

	Government Estimate	I	II	III	IV	Contractor Average
Direct Labor Rate	$ 7.60	$ 7.92	$ 7.82	$ 6.53	$ 8.56	$ 7.71
Overhead Rate	10.11 (133%)	10.61 (134%)	11.42 (146%)	7.18 (110%)	12.50 (146%)	10.33 (134%)
Subtotal	$ 17.71	$ 18.53	$ 19.24	$ 13.71	$ 21.06	$ 18.04
G& A Rate	2.48 (14%)	2.89 (15.6%)	2.10 (10.9%)	0.33 (2.4%)	7.71 *(36.6%)	2.96 (16.4%)
Total	$ 20.19	$ 21.42	$ 21.34	$ 14.04	*$ 28.77	$ 21.00
Fee	1.62					1.68
	$ 21.81					$ 22.68

*If G& A on cost input is $ 25.70

Booster Separation Motors
(Rate Comparison)

	Government Estimate	I	II	III	Contractor Average
Direct Labor	$ 8.67	$ 10.09	$ 8.31	$ 10.41	$ 9.59
Labor Overhead	11.04 (127.3%)	10.45 (103.6%)	10.73 (129.1%)	14.63 (140.5%)	11.92 (124.3%)
Subtotal	$ 19.71	$ 20.54	$ 19.04	$ 25.04	$ 21.51
G& A Expense	4.73 (24%)	5.07 (24.7%)	5.27 (27.7%)	4.81 (19.2%)	5.12 (23.8%)
Subtotal	$ 24.44	$ 25.61	$ 24.31	$ 29.85	$ 26.63
Profit	2.44 (10%)	2.84 (11.1%)	2.07 (8.5%)	2.69 (9%)	2.53 (9.5%)
Total (composite rate/ hour)	$ 26.88	$ 28.45	$ 26.38	$ 32.54	$ 29.16

SRB Integrated Electronics Assembly
(Rate Comparison)

	Government Estimate	I	II	III	IV	V	VI	VII	Contractor Average
Direct Labor	$ 8.66	$ 10.47	$ 8.90	$ 8.36	$ 7.19	$ 9.10	$ 7.73	$ 6.67	$ 8.35
Overhead									
Amount	10.05	10.55	10.66	11.44	10.47	11.68	7.22	7.40	9.97
Rate	116.0%	100.7%	119.8%	136.8%	145.6%	128.4%	93.4%	110.9%	119.4%
Subtotal	$ 18.71	$ 21.02	$ 19.56	$ 19.80	$ 17.66	$ 20.78	$ 14.95	$ 14.07	$ 18.32
G&A									
Amount	$ 2.99	$ 3.03	$ 3.98	$ 2.66	$ 4.31	$ 4.51	$ 2.44	$ 1.55	$ 3.19
Rate	16%	14.4%	20.4%	13.4%	24.4%	21.7%	16.3%	11%	17.4%
Total	$ 21.70	$ 24.05	$ 23.54	$ 22.46	$ 21.97	$ 25.29	$ 17.39	$ 15.62	$ 21.51
Fee	1.74								1.72
	$ 23.44								$ 23.23

Decelerator Subsystem
(Rate Comparison)

	Government Estimate	I	II
Average Labor Rate	$ 8.65	$ 8.56	$ 8.52
Composite Overhead			
Amount/hour	10.60	14.49	9.59
Rate	(122.5%)	(169.3%)	(112.5%)
Subtotal	$ 19.25	$ 23.05	$ 18.11
G & A Expense			
Amount/hour	$ 3.46	$ 3.30	$ 3.77
Rate	(18%)	(14.3%)	(20.8%)
Total Composite Rate (before prime fee)	$ 22.71	$ 26.35	$ 21.88

D. Inspection

In this section are some observations and information relative to inspection. Inspection may or may not be estimated as a direct labor cost depending on a given contractor's accounting practices. Inspection labor may be estimated by using overall percentage ratios or by detailed time standards. The percentage technique appears to be most practical for the types and quantities of production generally contemplated in space programs. In general, inspection appears to be directly relatable to other fabrication and assembly labor.

A commonly used method of estimating inspection labor is to use a percentage of productive labor hours. The following are some typical percentages which may be used in estimating inspection costs. It is noted that these percentages are not stated in hard terms, but allow the estimator to use judgment in determining the relative difficulty of inspection and the stringency of quality and/or reliability requirements. It is recommended between average and maximum (as shown following) unless the estimate is being made for production which contemplates absolutely no MIL specs or NASA specs. If the production involves traceability requirements, a high maximum should be used. It is worth noting that experience over the past two years has confirmed the following percentages:

	Percentage of Production Labor		
Type Inspection	Min	Avg	Max
Receiving Source Inspection	2%	5%	7%
Production Inspection	5%	10%	15%
Total Inspection	7%	15%	22%

Definitions applicable in determining the previously mentioned percentages follow:

1. Production labor — The total of all direct labor hours used in fabrication and assembly, e.g., machining, processing, welding, wiring, soldering, etc.

2. Receiving and source inspection — The inspection of all material purchased from vendors when it arrives in plant or inspection of materials at a vendor's plant. Generally, source inspection is most widespread when military specifications or NASA specifications are applicable.

3. Production inspection — The inspection of all parts fabricated, subassemblies, assemblies, units, and subsystems during the production process and at the completion of the process.

E. Direct/Indirect Cost

1. Direct Cost. A direct cost is any cost which is identified specifically with a particular final cost objective. No final cost objective shall have allocated to it as a direct cost any cost, if other costs are incurred for the same purpose, in like circumstances, or have been included in any indirect cost pool to be allocated to that or any other final cost objective. (Direct cost elements are typically direct labor, materials, subcontracts, travel, computer, and other direct items and services.)

2. Indirect Cost. An indirect cost is one which, because of its incurrence for common or joint objectives, is not readily subject to treatment as a direct cost. After direct costs have been determined and consistently charged directly to the contract, or other work as appropriate, indirect costs are those remaining to be allocated to the several cost objectives.

Indirect costs are accumulated by logical cost grouping with due consideration of the reasons for incurring the costs. Each grouping should be determined so as to permit distribution of the grouping on the basis of accruing benefits.

Commonly, examples of distinct pools are engineering overhead, manufacturing overhead, material overhead, and G&A overhead; however, there is no standard industry grouping. Some companies may have only one plant-wide overhead rate, whereas, others may have separate section or departmental rates which can be numerous.

Random experience sampling of common aerospace firms reflects a trend as shown in the following typical contractor data.

Manufacturing overhead is generally higher than engineering because of expensive equipment and facilities, utility consumption, and indirect materials, supplies, and maintenance.

The types of expense items included in the various overhead pools are summarized as follows:

a. Engineering/manufacturing overhead —

- Indirect salaries and wages (managerial, foreman, supervi... clerical, administrative, control, maintenance, and janitor...
- Employee fringe benefits and payroll taxes (vacation, sick leave, holiday, insurance, retirement, and payroll taxes).
- Depreciation and occupancy (building, machines, equipment, and rentals).
- Utilities (water, lights, and telephone).
- Supplies and material (normally expendable or small value common consumption items).
- Indirect travel.
- Property taxes (state and local) and insurance.
- Plant rearrangement.
- Training.
- Perishable tools, major tooling depreciation (special tooling normally charged direct).
- Miscellaneous support services.
- Personnel hiring.
- Publications.

b. Material overhead —

- Procurement expense allocation (personnel and related).
- Shipping and receiving (personnel and equipment).
- Occupancy and storage.
- Material handlers (personnel and related).

c. G&A — This type expense is common to the overall operation of the business. Key expense elements are:

- Corporate allocation.
- Top executives and office expense.
- Financial and accounting.
- Personnel/ security.
- Marketing/ contract administration.
- Bid and proposal expense.
- Independent research and development.

Typical Contractor Overhead Rates

	Contractor					
	A	B	C	D	E	F
Engineering Overhead (Normally applied to engineering and management)	121%	96%	76%	127%	98%	75%
Manufacturing Overhead (Normally applied to manufacturing, test, qual, and tooling)	148%	171%	140%	202%	165%	147%
Material Overhead	None	None	None	None	None	None
Off-Site Overhead	38.3%	66%		34.5%		55%
G& A Expense Rate	36.4% Applied to labor, overhead and overtime premium only (would be more like 23% of cost input).	22.7% For major subsystems $ 3M or over 3.5% applied.	25.4% Applied to total estimated cost.	24.1% Applied to total estimated cost.	15.7% Applied to total estimated cost.	13.5% Applied to total estimated cost.

Typical Contractor Overhead Rates

	Contractor					
	G	H	I	J	K	L
Engineering Overhead	93%	99%	96%	73%	98%	105%
Manufacturing Overhead	142%	165%	153%	134%	141%	166%
Material Overhead	5%		10%	9%	5.6%	
Off-Site Overhead						
G& A Expense Rate	10.4% Applied to cost input.	12.9% Applied to total estimated cost.	16% Applied to total estimated cost.	14.5% Applied to total estimated cost.	18.4% Applied to total estimated cost.	20.1% Applied to total estimated cost.

Typical Contractor Overhead Rates

	Contractor		
	M	N	Trend
Engineering Overhead	106%	110%	98%
Manufacturing Overhead	150%	169%	157%
Material Overhead	-	7%	7%
Off-Site Overhead			46%
G& A Expense Rate	18%	6.6%	17%

Fringe Benefits
As a Percentage of DL Cost

	*Chamber of Commerce Data Industry Average	Contractor A	Contractor B	Contractor C
Pension, Saving, Retirement	6.9%	10.2%	14.1%	3.3%
Group Insurance, Health, Life	5.5%	4.9%	8.1%	3.8%
Paid Absence	10.1%	11.9%	13.7%	10.2%
Payroll Taxes (FICA, Workmens Compensation, Unemployment)	8.0%	6.7%	6.1%	7.2%
Other	0.7%	0.1%		
Total	31.2%	33.8%	42.0%	24.5%

*1975 Data

F. Test

Test ratios and standards presented are for receiving and production testing. Environmental or life tests are not included. A technique for estimating total unit test labor is to use a percentage of the total production labor hours. Experience has shown, generally, test labor varies directly with the amount of fabrication and assembly labor. As circuits, components, wires, parts, and subassemblies increase, assembly labor must increase. By the same token more components, more harnesses, larger chassis, more circuit boards, more plumbing assemblies, etc., mean more fabrication labor. These things mean that a greater amount of checkout time is required. The following table provides factors for estimating test time based on total production labor and based on assembly labor only.

Test Estimating Ratios

	Percent of Direct Labor		
	Simple	Average	Complex
Fabrication and assembly labor base			
Receiving test	1	2	4
Production test	9	18	36
Total	10	20	40
Assembly labor base			
Receiving test	2	3	7
Production test	15	32	63
Total	17	35	70

NOTE: Receiving test — Tests performed on purchased components, parts, and/or subassemblies prior to acceptance by the receiving department.

Production test — Tests of subassemblies, units, subsystems, and systems during and after assembly.

Simple, average, complex — Complexity of an end item subsystem or system will vary the ratio of test labor to other production labor. These categories are an attempt to recognize the variableness of production labor, as well as test labor, according to complexity of the task concerned.

G. Special Tooling and Test Equipment

Special purpose tooling and special purpose test equipment are important items of cost because they are used only for a particular job; therefore, that job must bear the full cost of the tool or test fixture. Contrasted to the special items, general purpose tooling or test equipment is purchased as capital equipment and costs are spread over many jobs. Estimates for tooling and test equipment are made by specialists in these areas; however, included herein is information which may be useful in making these estimates.

Costs of major manufacturing programs can be divided into start-up (nonrecurring) costs and recurring costs. The following table shows typical ratios of start-up costs to recurring costs.

Manufacturing Start-Up Ratios

Cost Element	Degree of Implementation	Percent of Recurring Manufacturing Costs			
		Lot Quantity			
		10	100	1000	10K
Production Planning	High Medium Low	20 10 5	6 3 1.5	1.7 0.8 0.4	0.5 0.25 0.12
Special Tooling	High Medium Low	10 5 3	6 3 1.5	3.5 2 1	2 1
Special Test Equipment	High Medium Low	10 6 3	6 3 1.5	3.5 2 1	2 1 0.5
Composite Total	High Medium Low	40 21 11	18 9 4.5	8.7 4.8 2.4	4.5 2.25 1.12

NOTE: High — Ultrahigh precision electromechanical instrumentation type systems, or highly tooled and planned programs for maximum monthly delivery dates.

Medium — Moderately complex circuits or other black boxes or subsystems with not overly sophisticated design, and moderate delivery schedules.

Low — Simple circuitry or very straight forward design, low delivery requirements, or high proportion of subcontracted parts or subsystems.

The following is a table showing values for design and drafting time relative to test equipment.

Test Equipment Design and Draft

Type Design	Hours/ Sq. ft	Standard Drawing Size	Sq. ft/ Drawing	Hours/ Drawing
Original Concept	15	C	2.5	38
		D	5.0	75
		H	9.0	135
		J	11.0	165
Layout	10	B	1.0	10
		C	2.5	25
		D	5.0	50
		H	9.0	90
		J	11.0	110
Detail or Copy	3	A	0.7	2.1
		B	1.0	3.0
		C	2.5	7.5
		D	5.0	15.0
		H	9.0	27.0
		J	11.0	33.0

H. Manufacturing Engineering

Manufacturing engineering as described and used herein is preproduction planning and operations analysis. This differs from the general type of production engineering wherein overall manufacturing techniques, facilities, and processes are developed. Excluded from this categorization is the design time of production engineers who redesign a prototype unit to conform to manufacturing or consumer requirements, as well as time for designing special tooling and special test equipment. A listing of some typical functions of manufacturing engineering follows:

1. Fabrication planning —

   - Operations sheets for each part.
   - Operational sequence for materials, machines, functions.
   - Recommend standard and special tooling.
   - Make up tool order for design and construction of special tooling.
   - Develop standard time data for operations sheets.
   - Liaison with production and design engineers.

2. Assembly planning —

   - Develop operations sheet for each part.
   - Build first sample unit.
   - Itemize assembly sequence and location of parts.
   - Order design and construction of special jigs and fixtures.
   - Develop exact component dimensions.
   - Build any special manufacturing aids, such as wiring harness jig boards.
   - Apply standard time data to operations sheet.

- Balance time cycles of final assembly line work stations.
- Effect liaison with production and design engineers.
- Set up material and layout of each work station in accordance with operations sheet.
- Instruct mechanics/operations in construction of the first unit.

3. Test planning —

- Determine overall test method to meet performance and acceptance specs.
- Break total test effort into positions by function and desired time cycle.
- Prepare test equipment list and schematic for each position.
- Prepare test equipment design order for design and construction of special purpose test fixtures.
- Prepare a step-by-step procedure for each position.
- Effect liaison with production and design engineers.
- Set up test positions and checkout.
- Instruct test operator on first unit.

4. Sustaining manufacturing engineering —

- Debug, as required, engineering design data.
- Debug, as required, manufacturing methods/processes.
- Recommend more efficient manufacturing methods throughout the life of production.

The following formula may be helpful in deriving manufacturing engineering man-hour estimates:

1. Total fabrication and assembly man-hours, divided by the number of units to be produced, multiplied by 21.4 gives manufacturing engineering startup costs.

2. For sustaining manufacturing engineering, take the unit fabrication and assembly man-hours, multiply by 0.07.

These factors are suggested for quantities up to 100 units.

I. Standards, Allowances, and Multipliers

After time standards for production are estimated, other applications and allowances must be made. Generally, a standard is predicated on select time, that is to say, working time utilizing good effort and skill, from personnel who have reached maximum efficiency through the learning process. This, then, indicates some adjustment to standards when they are used in estimating. Such things as time out for personal comfort, for the effects of fatigue, and for unavoidable delays must be considered. Included in this section are some rule-of-thumb factors which should be considered when making production estimates.

Typical Adjusted Estimate

Select Time		45.40 min	
+ personal, fatigue, delay (PFD)	15%		
+ tool and equipment maintenance allowance	10%	(0.022 Multiplier)	
= standard hour or		1.00	
× learning factor of 2.2			
= realized hours (performance goal)		2.2	
+ variance from measured labor	10%		
+ normal rework and repair	10%		
+ other if required	0%		20%
Total Estimated Hours			2.64

Allowances

	Minimum	Average	Maximum
PFD			
Personnel — coffee break, rest room, etc.	3%	5%	5%
Fatigue — inability of worker to work at the same pace all day.	3%	5%	10%
Delays — unavoidable delays caused by supervisory instructions, equipment breakdown, etc.	4%	5%	5%
Total PFD	10%	15%	20%
Tooling and Equipment Maintenance (typical)			
Machine shop — adjust and sharpen tools.			
Periodically clean and oil machines.			
Electroplate and process operations maintain solutions, compounds handling racks, and fixtures.			
Total	5%	10%	12%
Assembly Cycle			
Operator efficiency decreases as the job cycle time increases. Even after the learning period is complete, the longer the period of time involved in a repetitive cycle, the less efficient the operation.			
Job cycle in basic select time.			
0 - 9 min	0%		
10 - 19 min		5%	
20 - up min			10%

Multipliers

Mulitpliers are used as arithmetic short cuts. A multiplier converts minutes to hours and adds PFD allowances which make up a standard hour. The following is a table with the makeup of some multipliers:

Type Operation	1 ÷ 60 Converts Minutes to Hours	×	Allowance as Percentage of Work Day	=	Multiplier
Fabricate and Process 15% PFD 10% tool maintenance	1/60 = 0.0167	×	$\frac{100}{100 - (15 + 10)}$	=	0.022
Assembly — 0-9 min	1/60 = 0.0167	×	$\frac{100}{100 - (15)}$	=	0.020
Assembly — 10-19 min	1/60 = 0.0167	×	$\frac{100}{100 - (15 + 5)}$	=	0.021
Assembly — 20 -+ min	1/60 = 0.0167	×	$\frac{100}{100 - (15 + 10)}$	=	0.022

Contingency Allowance

Standard hours plus learning allowances are measured standards of performance for a shop or activity. That is to say, it is what is to be expected when the prescribed tooling, materials, manpower, and facilities are available. This does not include rework caused by inspection rejects, engineering changes, temporary tooling, etc. These reworks may or may not be performed in the initial work flow pattern; however, time must be included for these functions. Instead of contingency allowance, these are frequently labeled "variance from standard." There follows listings of various things that create or are roots of variances from standards.

	Minimum	Average	Maximum
Variance from Measured Labor			
Variation from standard time.			
Variation from standard method.			
Faulty tools, fixtures, machine.			
Material shortages.			
Reset.			
Total	5%	10%	20%

	Minimum	Average	Maximum
Normal Rework and Repair			
Rework purchased material.			
Rework inspection rejects.			
Rework test rejects.			
Rework minor engineering changes.			
Repair units damaged in handling.			
Total	10%	15%	20%
Engineering Change Allowance			
This allowance is for projects where design stability is poor, as when production in initiated prior to final design release on a crash basis and field testing is concurrent with production.			
Total	0%	8%	15%
Design Growth Allowance			
Similar to the above where estimates are based on concepts or early breadboard. Experience has shown that as design matures and passes through various stages, the degree of sophistication, and consequent time, will increase.			
Total	0%	15%	30%
Engineering Prototype Allowance			
Construction labor to build an engineering prototype is more than that required to build the first production model. Reworks are more frequent so work is done from sketches rather than production drawings. The increase over first unit production labor is shown.			
Total	15%	20%	25%

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APPROVAL

HANDBOOK OF ESTIMATING DATA, FACTORS, AND PROCEDURES

By Leonard M. Freeman

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

for T. P. Isbell
H. E. THOMASON
Director, Systems Analysis and Integration Laboratory

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