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Abstract

The use of time standards are the basis for the for a high efficiency system in the manufacturing environment. This project will investigate the process followed to design and develop a database used to calculate accurate cable assembly time standards used for scheduling at General Atomics. This project will then justify the use of the Cable Time Estimation Database, through an economic analysis compared to the current methods applied.

Introduction

Every year aerospace companies are designing prototype aircraft, modifying current aircraft, and designing additional components to aid in aircraft functions. The majority of these changes affect every department in a company's supply chain. Issues such as modifying the fuselage of a current aircraft model could affect the structural support, materials used, cable dimensions, servo functions, etc. Every departmental change requires new or updated time standards to forecast the schedule of the product flow.

A leading defense contractor is General Atomics (GA), privately owned and established in 1955. Located in San Diego, California, GA is renowned for setting a benchmark for companies in the High-Technology industry with products such as unmanned aerial vehicles (UAV), nuclear instrumentation, superconducting magnets, mining and processing of uranium, aircraft recovery and launch systems, hazardous material destruction systems, and many more for industry and government use.

General Atomics Aeronautical Systems, an affiliate of GA, manufactures unmanned aeronautical vehicles and related components with product lines consisting of the Predator, Predator B, Skywarrior, variants, and ground control systems. Following is a list of the product features [http://www.ga-asi.com/Company.pdf]:

Predator UAV Series aircraft (Predator, Predator B, Skywarrior, variants)

- Have logged over 700,000 flight hours with over 85 percent in combat

- Remotely piloted or fully autonomous

- Every second of every day, over 40 aircraft are airborne worldwide

- C-130 transportable

- Perform routine LOS and BLOS operations with reachback capability

- Features Lynx SAR/GMTI wide-area surveillance

- Laser designate for another attack aircraft

- Fire precision-guided missiles in combat

- Surpassed a record 14,000 flight hours on a single airframe

Predator aircraft

- Able to remain airborne over 40 hours per flight

- Launched and controlled another UAS

- Transmit imagery to AC-130 gunships

- Controlled from ground vehicles, aircraft, and ships including a submerged

  submarine

- First UAS to launch a weapon in combat

SKY Warrior

- Triple-redundant flight control system

- Heavy-fuel engine

- Fielded two years early

- Controlled by U.S. Army One System GCS

- Carries four Hellfire missiles

Predator B/Variants

- Provide multi-mission capabilities through versatile plug and play

  configurations

- Employ GBU-12, GBU-38 precision-guided bombs and Hellfire missiles

- Operates with a 360° multi-mode maritime radar over a digital satellite data link

- Flew from Southern California to Alaska

- Operated above the Arctic Circle and in Canadian NAS with over-the-horizon

  control

- Monitored forest fires along the Alaska pipeline

- Mapped wild fires across Western U.S. improving firefighting effectiveness

- Provide disaster relief support to federal and state agencies

- Successfully carried a modified F-16 tactical reconnaissance sensor pod

- Received the FAA's first UAS air worthiness certificate, experimental category

- Carried an integrated scientific sensor package up to 45,000 feet altitude for 20

  hours

- Patrols U.S. borders and maritime approaches

- Incorporates a MIL-STD-1760 Stores Management System

Each of these product lines requires thousands of components, specifically cables and

servos, for the final product to function correctly. At GA cable designs change as new

products are introduced to the market, requiring new time standards to accurately

schedule and forecast the production rate to meet demand. Currently, GA roughly

estimates times for the cable building process to schedule work orders. Historically

faulty time standards, due to an insufficient estimation process, lead to bottlenecks and

wasted time. However, advances in utilizing lean techniques and database formulations

could produce accurate time standards in seconds to schedule products through the

system.

Background

The cable time standards database project was addressed at an internship with General Atomics in June 2007. Starting as a project that has never been conducted, the objective was to accurately measure the manufacturing lead times of each cable being produced. This data would then be used to accurately forecast and schedule products through the facility, eliminating wasted time and bottlenecks. It would also serve the purpose of motivating the employees to work faster and better.

The idea for implementing a database presented itself because of the quantity of cable products being produced in the facility. There are currently three commonly ordered aircraft and each one contains over two hundred cables. The goal is to design a database for calculating, storing, and managing cable time standards, while having the ability to quickly locate specific entries with ease.

While discussing the topic with an engineer, it was determined that best way to go about determining the time standards would be to break each cable down into sub-processes that are common throughout every cable. These sub-processes include cutting cables and wires, measuring cables and wires, crimping pins, installing connectors, heat shrinking, bending etc. Each sub-process would be timed multiple times by different operators to ensure data accuracy. After breaking down and timing

each sub-process, the next step would be to interpret the Engineering Drawings and Bill of Materials (BOM) for every cable. From these documents, the exact sub-processes that are required to build these cables can be determined. Based on these processes, the user could calculate manufacturing lead times for every cable.

This method is feasible compared to the alternative of conducting complete time studies of each cable during the build process because some cables can take up to fifty hours to complete. This would extend the completion of the project beyond the allotted timeframe.

Currently, no attempts have been made to determine time standards in the past; instead, build times have been based on previously clocked work orders times. W.O. times are can be inaccurate, due to interruptions on the floor, employees taking breaks while on-the-clock, rework, engineering changes, etc. All these issues inflate W.O. times, making scheduling and forecasting inaccurate. Time standards are also essential because they provide standards to motivate employees to achieve more.

Literature Review

Lean Manufacturing

If you need a new process and don't install it, you pay for it without getting it (Stork).

Lean techniques are an important aspect in manufacturing because they eliminate

waste, making the processes more efficient. There are three different types of waste

including muda, mura, and muri. Muri deals with the planning and preparation of the

process by eliminating demanding work from management. These include hazardous

assignments; pushing workers to work faster, harder, and longer; and unnecessary

movement of objects around the facility. The second type of waste is Mura, which

focuses on the implementation of work design and reducing the variation for operations

and scheduling. This makes sure the accurate amount of quality products is

manufactured to satisfy demand. Muda, the final form of waste, comes about after the

manufacturing process has been implemented. This type of waste is seen in activities

that are unproductive or don't add value (Hill).

Originating from the Toyota Production System [TPS], lean manufacturing incorporates

just-in-time [JIT], continuous improvement, and system flexibility. JIT is an inventory

control and production system, used in manufacturing, where units are produced and

materials are purchased only to satisfy demand with as little inventory as necessary. It

relies heavily on maintaining accurate time standards, which provide basic data required for manpower controls, standard cost, production control, machine utilization, manning requirements, budgets, and wage incentives (Hill). Time standards need to be established whenever new products are introduced to eliminate bottlenecks, inventory and scheduling problems. JIT, with the utilization of times standards, lowers inventory costs, but increases lead time due to its build-to-order [BTO] environment. In an ideal situation a company would only order enough materials each day to meet the daily demand.

 The next aspect, introduced by the TPS, is continuous improvement. In manufacturing, continuous improvement is a constant attempt to improve processes and products to make a system more efficient. Companies that concentrate on the external value of the system rather than the internal value, continuous improvement, resulted in wasteful growth, disconnect from employees, and customers finding other companies for business (Vinas).

System flexibility, the last method brought forth by TPS, is important because it allows the system or process to easily adapt to changes of its environment (Cheng). This is idea is crucial with the constant advances in technology affecting production lines without shutting down them down. It saves money and time.

MRP/Inventory Management

Inventory management refers to the process of managing the stocks of finished products, semi-finished products and raw materials by a firm. Inventory management, if done properly, can bring down costs and increase the revenue of a firm (Morris). This process of managing inventories can be separated into four principle stages, consisting of planning, acquisition, stock keeping, and disposition (Plossl). The planning stage is critical to the a company's inventory management because it ensures good customer service, keeping manufacturing costs at a minimum, and satisfying gross production requirements while maintaining the least amount of inventory possible. The acquisition stage, with respect to the system, shows that materials are being acquired and dispersed throughout the manufacturing process from raw materials to final products. Stock keeping, on the other hand, is the company's method of inventory accounting, which could be integrated into the inventory planning functions. The last stage, disposition, is that inventory, ranging from raw materials to finished products, is always delivered to an in-house demand source to satisfy the production schedule (Plossl).

Another important aspect of inventory management and scheduling is material requirements planning, MRP, which is a system of inventory control and production planning intended for managing the manufacturing processes. This technique is expressively designed for dealing with dependent, discontinuous, non-uniform demand, characteristic of most manufacturing environments (Plossl). This method produces an inventory plan based on upcoming gross production requirements, which

can be easily updated for current information. MRP uses Work Breakdown Structures and Bill of Materials, BOM, to determine lead times and quantities of part requirements for each assembly and sub assembly. This method uses the information to plan backwards and show when each operation must be started or ordered to ensure that the gross requirements are achieved.

User Interface Ergonomics

Human Factors Engineering is an applied science that coordinates the design of devices, systems, and physical working conditions with the capacities and requirements of the worker (APA). When applied to software, engineers spend countless hours designing the user interface to make it aesthetically pleasing and easier on the end user. These intuitive designs allow the user to effectively navigate through the software without needing to refer to the user manual, due to its repetitive actions and simplicity.

Efficient software designs also maintain a good contrast ratio between objects and the background, allowing the user to easily read the text and quickly locate objects on the screen such as buttons, text, labels, and pictures. Another aspect of an efficient user interface is effectively locating objects through grouping and recurring elements. Grouping provides quicker access and knowledge of where something might be found. For instance, most programs have a "Minimize," "Maximize," and "Close" buttons grouped together, allowing the user to quickly glance at the group to find what he/she

is looking for. This helps the user navigate through the screen. Locating recurring

objects, such as buttons, in the same place on different screens is also important because

its repeatability. This repeatability shortens the learning curve of learning the software.

An interface is humane if it is responsive to human needs and considerate of human

frailties (Raskin). In industry, faulty user interfaces lead to wasted time, frustration, and

inefficiency in the workplace.

Databases Management Systems

Database management systems are a huge part of effectively maintaining inventory

information throughout a company's supply chain. These databases enable the user to

store, locate, and change information based on the company's needs. Microsoft Access

2007 is a reliable database software application used to maintain excessive amounts of

information. Each database is built up of tables, queries, forms, and reports.

After designing the database, tables are the first thing the designer constructs. A table is

a spreadsheet used to store information and every table is broken down into fields, a

unit of data stored in the database. Some examples of fields include Employee First

Name, Address, City, Number of Children, etc. Once the tables have been designed,

relationships must be established. A relationship corresponds to a correlation between

two or more fields. For example, athletes are assigned to track meets and track meets

have multiple events. The "track meet" field from each table would be related. There

are three types of relationships; one-to-one, one-to-many, and many-to-many. A one-to-one is a relationship where only one occurrence of field A is coupled with only one occurrence of field B, i.e. each school is allotted one mascot and for each mascot there is only one school. The next relationship is a one-to-many where each occurrence of field A is linked with zero, one, or multiple occurrences of field B, i.e. each school has many athletes and each athlete goes to only one school. The third relationship is many-to-many where an occurrence in field A has zero, one, or multiple occurrences of field B and for each occurrence in field B there are zero, one, or multiple occurrences of field A, i.e. athletes can't be assigned to more than three track meet events and each event must have two athletes assigned to it.

The next major aspect of a database is a query, which is the primary mechanism for retrieving data from the database. Queries allow the user to ask the database questions and the database returns to request in data form. This is helpful for finding specific data or information throughout multiple tables, only if the tables are related. For instance, the user could search for which athletes are participating in each event and what school they are attending.

The third major aspect of a database is the form, which is used for data entry and data retrieval. Forms are usually designed for unskilled employees to make data entry

repetitive and easy. These aesthetically pleasing forms take inputted data, from the user, and insert it into the corresponding tables.

Reports, the final major aspect of databases, attractively display information that was recovered from a query or table in an easy to understand manner (Chapple). The user cannot edit the information from the report because it is generated from the data within the database.

Databases are also play a major role in inventory management. In inventory management, databases are used to track orders, provide raw material stock information, and locate current inventory within the facility. In manufacturing plants, they also keep track of lead times and quantities of parts required to build specific products. This information is crucial to ensure the company meets its production requirements.

Design

Problem Definition

In the aerospace industry, cable designs change as new products are produced. As the cable designs change, engineers would roughly estimate the time standards associated with each cable for scheduling purposes. Some cables assemblies, on average, take 2 hours to build while others require up to 40 hours. Faulty time standards, due to this inefficient estimation process, lead to bottlenecks and/or wasted time throughout the manufacturing process. With this in mind, the time standard calculation and the user interface of the database were two major aspects during the design phase to ensure data accuracy and usability. The following sections will breakdown the methods used, design, and statistical requirements involved with the Cable Time Estimation Database.

Time Calculation Design

This section will break down the cable building process into common sub-procedures required for all cables, including crimping a pin to installing heat shrink. These individual times along with the engineer drawing would be used to accurately determine the time standards for any cable in the system or being introduced to the system. The use of these calculated times, applied to scheduling, would eliminate bottlenecks and wasted time in the manufacturing process.

Work Breakdown Structure

From the start it was determined that the calculated time standards needed to be within +/- 7% to ensure accurate scheduling of products through the facility. To achieve this requirement in a timely manner a Work Breakdown Structure (Appendix A: Figure 1) was developed using Engineering Documents (drawings and diagrams). The Work-Breakdown Structure (WBS) is a document used to breakdown and illustrate the top-level processes and their corresponding lower-level processes in an effective and easy-to-view manner. This manufacturing tool helps the understanding of the cable building process and the common sub-processes that are associated with every cable assembly.

Time Studies

After the construction of the WBS, time study sheets were designed to effectively track and record data for the time study process. The Time Study Data Sheet (Appendix A: Figure 2) has fields including; task description, six areas for recorded time trials, operator, date, and a summary table to track the average of all the trials. Multiple time trial sections are required for each employee timed to eliminate the chance of faulty data and outliers. Faulty data and outliers occur when employees have unexpected

interruptions; including restroom breaks, misplacing tooling, interruptions from other employees, and unforeseen difficulties during the timed operation. These times are then disregarded because they're uncommon in the daily routine and would significantly alter the results.

Time studies are the basis for the overall effectiveness of the Cable Time Estimation Database because without accurate process and sub-process times the goal of +/- 7 % could not be achieved. Common difficulties associated with taking time studies occur from the employees being observed. Some employees feel that they are being timed from a performance point-of-view, which raises two possible problematic situations. The first situation is that the employee works at a much faster pace than normal to ensure that his/her performance is at its peak. Employees do this because they feel that their job is on-the-line and the only way to keep it is to out-perform the other workers. This is a major problem because it results in a much faster process time that can't be met on a daily basis without the constant supervision of a superior. The second problematic situation arises when the employee being studied works at a much slower pace than normal because he/she believes that less will be expected out of him/her in the future. This is a major issue when taking time studies because it results in slower process times, in turn, allowing for excess idle time in the daily routine.

These two situations are easily overcome by communicating with the employees and ensuring them that these time studies are not used to rate their individual performance. Instead, they are used to promote the future success of the company and to help improve the individual processes that each employee goes through on a daily routine.

Userform and VBA Coding

In order to calculate the time standards for the cable assemblies, a userform had to be developed in Visual Basic (VBA) utilizing data from the WBS and the Time Study Sheets. The VBA coding (Appendix B) takes the information, inputted by the user via textboxes on the userform (Appendix C: Figure 1), and applies it to the appropriate sub-processes and its corresponding times. The result, the calculated cable time, of the code is then outputted into a textbox for the operator's viewing. All the data and information required for determining the calculated cable time is found on the Engineering Drawing (Appendix F: Figure 1).

Statistical Analysis

Once the userform was completed statistical analysis had to be performed to ensure the calculated cable times were accurate to within +/- 7 %. A sample size of 60 randomly selected cable assemblies were calculated by the userform. These calculated times, with the addition of a 30% allowance, were compared to the corresponding work order (W.O.) times of the same cable assembly. A paired t-test was performed on a 95%

confidence interval, which resulted with a very low P-value. This analysis ensures that the calculated times are accurate to within +/- 5 %, which exceeded the requirements of +/- 7 %.

Software Design

The database to be designed had to be created in Microsoft Office because GA already had access to this software. After talking with Scot Bilinsky, the shop engineer/manager, to decide on the requirements the first step was to determine the software to be used and interface design of the layout. This proposed two alternatives, a userform in MS Excel that outputs the calculated times into a spreadsheet and a userform in MS Access to store the calculated times in a database. This first alternative was rejected because it would be extremely difficult for the user to look-up specific cable assemblies in the spreadsheet. It was obvious that the second alternative was superior choice because it would allow the user to easily locate cables on an individual or on a plane basis and it also leaves GA with the ability to expand on the database in the future. More details of this comparison can be seen in the 'Access/Excel Comparison' section of this article.

Database Design

The database was designed to allow the user to input information from the Engineering Drawing document (Appendix F: Figure 1) into the 'Cable Calculation' form (Appendix C: Figure 2), which then determines and stores the calculated build time of the cable

assembly along with the processes required to build the cable assembly. The form also

allows the user to look-up and edit existing cable assemblies in the database, delete old

cable assembly records, and to bring up a calculator to aide in the calculation process.

This form is also linked to a 'Help' form, which walks the user through setting up the

calculator if it's not working correctly. It also guides the user through editing the VBA

code in order to alter sub-process build times that have changed due to new building

methods.

The database also is has a 'Cable Look-Up' form (Appendix C: Figures 3 & 4) so the

user can easily view all the cable build times by a specific plane or on an individual

basis by inputting the cable's part number. This method populates a list of cables

assembly build times which can be easily viewed for scheduling purposes. All database

screenshots can be viewed in Appendix C.

Access/Excel Comparison

The approach of using MS Access compared to MS Excel was based on the features

associated with each software package. The main pro of using Excel is that a higher

percentage of GA's employees know how to operate the software more than Access, but

Excel lacks the ability to store and link multiple tables of data. Access, on-the-other-

hand, uses relationships between specific fields to link tables together and to update

data universally. For example, the Cable Estimation Database has a table that contains

plane assemblies and another that contains cable assemblies. A single plane assembly

may have multiple cable assemblies, making this a one-to-many relationship. The idea

of storing and relating data across tables is a key aspect of the Cable Estimation

Database, which could not be mirrored in Excel. A more detailed comparison of Access

and Excel can be seen in Table 2.

Table 2: Access/Excel Comparison

	Access	**Excel**
Relational database	X	
Ability to use queries as an universal editing capability	X	
Reliable way of retrieving data	X	

Microsoft Office product	X	X
Reliable way of storing data	X	X
Lower "Learning Curve"		X
Easy table editing		X
Ability to produce reports	X	
Ability to use forms	X	X
Powerful computations	X	X
A scheduling application	X	X
Help files	X	X
Integration with other MS Office products	X	X
Portability	X	X
Future Expansion	X	

Future Expansion

Access has the unique ability to be expanded to help GA become a more efficient

manufacturing organization. Future expansion of the database includes the addition of

an integrated scheduling feature, comparing W.O. times to the standard, tracking

W.O.'s through the facility, and reports showing overdue products.

The scheduling feature is an important aspect of future expansion because it would take

the current employees and populate a monthly schedule for GA to meet demand. The

addition of this feature would eliminate the use of operating multiple software

packages, which is time consuming and inefficient. It results in lower costs and a more

efficient process.

Another addition to the database would include a way of tracking W.O. times and

comparing them to the calculated standard build times. This approach would allow

management to accurately track the efficiency and performance of employees on an

individual basis. The higher performing employees would then be scheduled to highest

difficulty cable assemblies, while the lower performing employees would be scheduled

to the lowest difficulty of cable assemblies.

Tracking W.O.'s through the facility is a feature that would significantly improve the current system because it would show the location of each cable assembly. This would eliminate lost W.O.'s on the manufacturing floor and save time searching for ones that need to be recalled.

The final feature that can be added to the database would be a report showing overdue cables. The database would search through the start and estimated finished dates for each cable assemble and populate a list of assemblies that are overdue. Overdue products can be caused from the W.O. being lost in the facility, unexpected problems in the building process, and many other reasons.

Results

The database that was designed to calculate and maintain cable assembly time standards improves the current model of scheduling products through the facility by providing the scheduling software with accurate build times. The higher accuracy of scheduling helps GA to accurately forecast orders to meet demand by eliminating bottlenecks and idle time in the manufacturing process.

Table 1: Economic Analysis

Current System		
	Value	**Units**
Avg. time to take cable assembly time standard	26.30	hours
Avg. engineer's annual rate	$ 70,000.00	
Avg. Engineer's hourly rate	$ 35.00	
Avg. total cost per new cable per time std.	$ 920.50	
Avg. time lost in day-to-day job to determine time standard	26.30	per cable
Cost for time lost	$ 920.50	
Avg. Total Cost to Determine new Cable Time Std.	$ 1,841.00	per cable

Proposed System		
Initial Cost		
Time to develop Database while employed at GA	240	hours
Inter wage	$ 19.00	per hour
Total cost to build database	$ 4,560.00	
Recurring Cost/Cable		
Avg. time to take cable assembly time standard	0.05	hours
Avg. engineer's annual rate	$ 70,000.00	
Avg. Engineer's hourly rate	$ 35.00	
Avg. total cost per new cable per time std.	$ 1.75	
Avg. time lost in day-to-day job to determine time standard	0.05	hours
Cost for time lost	$ 1.75	
Avg. Total Cost to Determine new Cable Time Std.	$ 3.50	per cable

Breakeven Point	2.48	Cables

Taxes, inflation, and interest are not taken into account

The key metric measured was the time it takes to determine a time standard of a new

cable assembly introduced into the system. Currently, to determine the time standard

the engineer would have to take a time study of the entire building process for the cable

assembly being introduced into the system. Assuming that the engineer would take

only one overall time study of the cable because of the time required it would cost the

company on average 26.3 hours to time the entire process and another 26.3 hours that

were lost from the day-to-day job. This results in an average cost of $1,840 per cable

assembly. Since this process isn't practical GA's engineers roughly estimate the build

times for incoming cables, which affects the entire scheduling process. This problematic

solution causes bottlenecks, idle time, and demands that can't be met. The proposed

solution has an initial cost of $4,560, but reduces the time to determine time standards

to an average of 2 minutes. This compared to the current system of timing the entire

build process has a payback period of 2.5 cables. See Table 1 for the details of the

calculations. Additional value is the ability to locate the time standards easily in the

matter of moments and the ability to expand on the database. These weren't factored

into the economic analysis because there is nothing to compare these values too.

Conclusion

The proposed software system is more efficient and economical tool than the current one in many areas. Its ability to calculate cable time standards in the matter of minutes allows engineers to effectively schedule products through the facility while maintaining their day-to-day routine. The database's ability for expansion is another huge aspect for GA. The database could be developed into a scheduling tool, which would keep track of the time standards while scheduling the monthly demand to the employees in the facility. This would eliminate the current method of scheduling while integrating it into one software package. Until then this database software should be immediately introduced into the system to eliminate scheduling errors due to inaccurate times. These recommendations will help GA become a more efficient company while meeting demand and reducing costs.

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Appendix

Appendix A: Database Design Tools

WBS					
P.N.	Level				Description
	0	1	2	3	
B101	x				Cutting cables/wires
A		x			Prep. For cutting cables/wires
B		x			Pull and cut the cables/wires
C		x			Make and Label the kit
D		x			Post Paperwork & W.O.
B102	x				First Prep
E		x			Prep cable/wire ends
1			x		Srtip the jacket
2			x		Trim shield
3			x		Shirnk sleeve cable/wire end
F		x			Splice w/ Busswire wrap
G		x			(2x1; 1x2) Splice
H		x			(1x1) Splice
I		x			Crimp Wire
4			x		Srtip wire end
5			x		Trim wire
6			x		Crimp end
J		x			Heat Shrink
7			x		Install heat shrink
8			x		Shrink sleeve
K		x			Install shielding
L		x			Insatall Connectors
9			x		Install overbraid, sleeve, label
10			x		Busswire wrap overbraid
11			x		Trim overbraid & file band
12			x		Heat shrink sleeve & label
13			x		Tighten backshell to connector
B103	x				Second Prep.
M		x			Bending Cable
N		x			Measuring cable
14			x		Layout cable
15			x		Measure cable length

Figure 1: Work Breakdown Structure

Time Calculation Sheet

Operation:	Date:
Observer:	Study Start Time:
Operator:	Study End Time:

Task Description		Cycle # Time						Summary Data		Units
		1	2	3	4	5	6	SUM	AVG	
1										
2										
3										
4										
5										
6										
7										
8										

Figure 2: Time Study Data Sheet

Backbone

ID #		Desc.	Qty
B101		Cutting cables/wires	
A		Prep. For cutting cables/wires	
B		Pull and cut the cables/wires	
C		Make and Label the kit	
D		Post Paperwork & W.O.	
B102		First Prep	
E		Prep cable/wire ends	
	1	Srtip the jacket	
	2	Trim shield	
	3	Shirnk sleeve cable/wire end	
F		Splice w/ Busswire wrap	
G		(2x1; 1x2) Splice	
H		(1x1) Splice	
I		Crimp Wire	
	4	Srtip wire end	
	5	Trim wire	
	6	Crimp end	
J		Protecting Cable	
	7	Heat Shrink	
aa		Install heat shrink	
bb		Shrink sleeve	
	8	Install shielding	
K		Insatall Connectors	
	9	Install overbraid, sleeve, label	
	10	Busswire wrap overbraid	
	11	Trim overbraid & file band	
	12	Heat shrink sleeve & label	
	13	Tighten backshell to connector	
B103		Second Prep.	
L		Bending Cable	
M		Measuring cable	
	14	Layout cable	
	15	Measure cable length	

Cables

ID #	Cable #
A	UHK1000
B	UHK1000
C	UHK1000
D	UHK1000
E	UHK1000
F	UHK1000
G	UHK1000
H	UHK1000
I	UHK1000
J	UHK1000
K	UHK1000
L	UHK1000
M	UHK1000
N	UHK1000
A	UHK1001
B	UHK1001
C	UHK1001
D	UHK1001
E	UHK1001
F	UHK1001
I	UHK1001
J	UHK1001
K	UHK1001
L	UHK1001
M	UHK1001
N	UHK1001
A	UHK1002
B	UHK1002
C	UHK1002
D	UHK1002
E	UHK1002
F	UHK1002
I	UHK1002
J	UHK1002
K	UHK1002
L	UHK1002
N	UHK1002

Cable Sub Processes

Sub #	ID #
1	E
2	E
3	E
4	I
5	I
6	I
7	J
8	J
9	L
10	L
11	L
12	L
13	L
14	N
15	N

Plane

Cable #	Plane #
UA1000	Predator
UA1001	Predator
UA1002	Predator
UA1003	Predator
UA1004	Predator
UA1005	Predator
UA1006	Predator
UA1007	Predator
UA1008	Predator
UA1009	Predator
UB1000	Predator B
UB1001	Predator B
UB1002	Predator B
UB1003	Predator B
UB1004	Predator B
UB1005	Predator B
UB1006	Predator B
UB1007	Predator B
UB1008	Predator B
UB1009	Predator B
UB1010	Predator B
UB1011	Predator B
UB1012	Predator B
UHK1000	Sky Warrior
UHK1001	Sky Warrior
UHK1002	Sky Warrior
UHK1003	Sky Warrior
UHK1004	Sky Warrior
UHK1005	Sky Warrior
UHK1006	Sky Warrior
UHK1007	Sky Warrior
UHK1008	Sky Warrior
UHK1009	Sky

	Warrior
UHK1010	Sky Warrior
UHK1011	Sky Warrior
UHK1012	Sky Warrior
UHK1013	Sky Warrior

Figure 3: Database Relationship Table

Appendix B: Visual Basic Time Standard Calculation Code

*The following VBA code is used to calculate the time standards of the cable assemblies

```
Private Sub Calculate_Button_Click()

On Error GoTo MyError

Dim pap, d, y, g, yu, yo, ut, q, zm, JLO, ui, dp, rw, jt, t, w, e, b,
r, z, x, s, zk, zx, m, p, poi, u, l, o, i, h, qa, ou, ly, lu, k, f,
uv, fu, rt, yt, yr, ye, qs, gy, j As Integer

    pap = 20

    d = Me.Textbox2.Value

    e = Me.TextBox3.Value

    uv = e * 0.011

    'Prep for cutting wire

    fu = 0.99

    'Paperwork and Work Order after cutting the wire

    k = 0.9

    'Make the Label
```

```
    f = d * 0.48
```

'**********Start First Prep.***************'

```
    x = Me.TextBox4.Value
```

'Multiply the number of wires by the average time to strip the jacket.

```
    y = x * 1.03 * 2
```

'Trim Shield

```
    h = x * 1.11 * 2
```

'.5 in rubber sleeving on shield end and where it meets the jacket

```
    qs = x * 0.46 * 4

    z = Me.TextBox5.Value
```

'Multiply the number of splices requiring a busswire wrap by the average time for a busswire wrap splice

```
    r = z * 6.69

    s = Me.TextBox6.Value
```

'Multiply the number of splices without a busswire wrap by the average time for a splice

```
    g = s * 3.71

    b = Me.TextBox7.Value
```

'Multiply the number of splices without a busswire wrap by the average time for a splice

```
    qa = b * 1.66

    w = Me.TextBox8.Value
```

'Multiply the average time to strip and trim each wire by the amount of wires requiring stripping and trimming

```
    m = w * 0.3
```

If CheckBox3.Value = True Then

```
    yu = Me.TextBox9.Value
```

'Shrink sleeve entire cable

```
    yt = yu * 0.1
```

'Put on shrink sleeve

```
    yr = yu * 0.1
```

Else

```
    yt = 0
```

```
    yr = 0
```

End If

If CheckBox2.Value = True Then

```
    yu = Me.TextBox9.Value
```

'Put shielding on entire cable

```
    ye = yu * 0.16
```

Else

```
    ye = 0
```

End If

```
    t = Me.TextBox10.Value
```

'multiply the number of connectors by the time to busswire wrap overbraid

```
    u = t * 5.42
```

'Time to heat gun the label and sleeving

```
    l = t * 4.48
```

'Time to put the the overbraid, sleeving, and label on the cable

```
    o = t * 1.25
```

'Time to trim the overbraid and file the band

```
    i = t * 2.65
```

'Tighten the backshell on the connector

```
    ou = t * 2.11
```

```
    jt = Me.TextBox11.Value
```

```
    ly = jt * 0.82

    lu = jt * 0.49

'*******Second Prep. Start***********

'Laying out the cable for measuring

    rw = Me.TextBox12.Value

    zk = rw * 0.01

    dp = rw / 5.5

    zm = dp + 1

    zx = zm * 0.64

'number of bends

   ui = Me.TextBox16.Value

   gy = ui * 5.42

'Additional Task Time

   poi = Me.TextBox17.Value

'Add all the times together to get the time for a cable

   j = y + r + g + zk + zx + m + p + pap + poi + u + l + o + i + h +
qa + ou + ly + lu + k + f + uv + fu + rt + yt + yr + ye + qs + gy

   k = Me.TextBox13.Value

'Fudge Factor w/ 10% QA Time Factored in

    JLO = k * 2 + 10

    q = (j * (JLO / 100) + j)

    yo = q / 60

    ut = uv + fu + k + f

    Me.TextBox14.SetFocus

    Me.TextBox14.Value = q

    Me.TextBox15.SetFocus

    Me.TextBox15.Value = yo
```

```vba
If q >= 30 Then

    Me.TextBox14.SetFocus

    Me.TextBox14.Value = Round(q, 2)

    Me.TextBox15.SetFocus

    Me.TextBox15.Value = Round(yo, 2)

End If

If q < 30 Then

    Me.TextBox14.SetFocus

    Me.TextBox14.Value = 0

    Me.TextBox15.SetFocus

    Me.TextBox15.Value = 0

End If

Exit Sub

MyError:

   MsgBox ("Error 13: Check Form and Enter a Numeric Value into Each
Textbox.")

   MsgBox Err.Number & " " & Err.Description

End Sub
```

Appendix C: Database Screen Shots

Figure 1: Main Form

Cable BOM

<div>Home</div> <div>Help</div>

CablePart#:	C1	Length of Sleeve/Overbraid (in):	12
Plane#:	P1	# of Connectors:	12
# of Cables/Wires to be Cut:	12	# of Contacts in all Connectors:	12
Overall Length of Cables/Wires to be Cut (in):	12	Measuring Length of the Cable (in):	12
# of Shielded Cables:	12	Additional Task Times (min):	12
# of Splices with a Busswire Wrap:	12	Fudge Factor (%):	12
# of Splices (2 x 1):	12	TotalTime_min:	716.9
# of Splices (1 x1):	12		
# of Wire Ends to be Stripped, Trimmed, and Crimped:	12	TotalTime_hr:	11.95
# of Bends:	12		
Shrink Sleeve:	☐		
Overbraid Cable:	☐		

Calculate   New Cable   Locate Cable   Delete Cable   Open Calculator

Figure 2: Cable Calculation Form

Cable Build Time

Look up build times by plane

Plane #   P2

Cable #	Build Time (min)	Build Time (hr)
C3	2302.18	38.37
C4	723.6	12.06
C8	1093.5	18.23

Add New Cable

Look up by cable

Cable Part #:

Plane #:

Build Time (min):

Build Time (hr):

Figure 3: Cable Lookup Form Using the "By Plane" Combo Box

Cable Build Time

Figure 4: Cable Lookup Form Using the "By Cable" Textbox

Help Center

Back   Home

☐ Edit VBA Code

☐ Calculator Not Appearing

Go to the Start Menu and select 'Search'. Click 'Search all files and folders' and type in 'calc.exe'. Right Click the calc.exe and select properties. Copy the location path and open VBA to edit. Find 'Private Sub CommandButton5_Click()' and scroll down until you find the loaction path that is specified. Erase and paste in the new location with '\calc.exe' at the end of it.
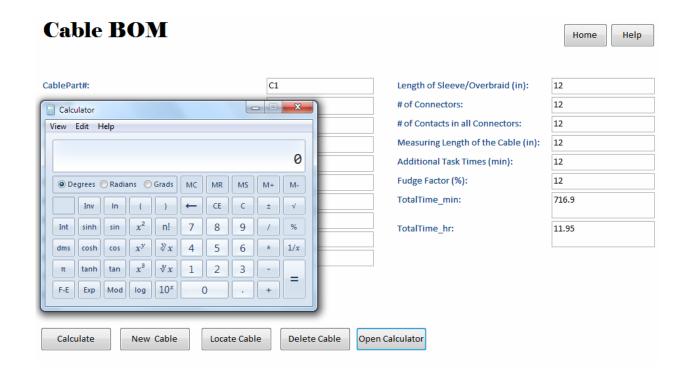
Figure 5: Help Form

Cable BOM

Home   Help

CablePart#:   C1

Length of Sleeve/Overbraid (in):   12

# of Connectors: 12

# of Contacts in all Connectors: 12

Measuring Length of the Cable (in):   12

Additional Task Times (min):   12

Fudge Factor (%):   12

TotalTime_min: 716.9

TotalTime_hr: 11.95

Calculator

View   Edit   Help

0

○ Degrees ○ Radians ○ Grads   MC   MR   MS   M+   M-

Inv   ln   (   )   ←   CE   C   ±   √

Int   sinh   sin x^2 n!   7   8   9   /   %

dms   cosh   cos x^y $\sqrt[y]{x}$ 4   5   6   *   1/x

π   tanh   tan x^3 $\sqrt[3]{x}$ 1   2   3   -   =

F-E   Exp   Mod   log 10^x 0   .   +

Calculate   New Cable   Locate Cable   Delete Cable   Open Calculator

Figure 6: Cable Entry Form Using the "Open Calculator" Button

Appendix D: Economic Cost Analysis

Table 1: Economic Analysis

Current System		
	Value	**Units**
Avg. time to take cable assembly time standard	26.30	hours
Avg. engineer's annual rate	$ 70,000.00	
Avg. Engineer's hourly rate	$ 35.00	
Avg. total cost per new cable per time std.	$ 920.50	
Avg. time lost in day-to-day job to determine time standard	26.30	per cable
Cost for time lost	$ 920.50	
Avg. Total Cost to Determine new Cable Time Std.	$ 1,841.00	per cable

Proposed System		
Initial Cost		
Time to develop Database while employed at GA	240	hours
Inter wage	$ 19.00	per hour
Total cost to build database	$ 4,560.00	
Recurring Cost/Cable		
Avg. time to take cable assembly time standard	0.05	hours
Avg. engineer's annual rate	$ 70,000.00	
Avg. Engineer's hourly rate	$ 35.00	
Avg. total cost per new cable per time std.	$ 1.75	
Avg. time lost in day-to-day job to determine time standard	0.05	hours
Cost for time lost	$ 1.75	
Avg. Total Cost to Determine new Cable Time Std.	$ 3.50	per cable

Breakeven Point	2.48	Cables

Table 2: Access/Excel Comparison

	Access	Excel
Relational database	X	
Ability to use queries as an universal editing capability	X	
Reliable way of retrieving data	X	
Microsoft Office product	X	X
Reliable way of storing data	X	X
Lower "Learning Curve"		X
Easy table editing		X
Ability to produce reports	X	
Ability to use forms	X	X
Powerful computations	X	X
A scheduling application	X	X
Help files	X	X
Integration with other MS Office products	X	X

Portability	X	X
Future Expansion	X	

Appendix E: Project Management Tools

Table 1: Project Schedule

Task Name	Duration	Start Date	Finish Date	Predecessor
Senior Project	100 days	1/4/2010 8:00	5/21/2010 17:00	
Final Report	100 days	1/4/2010 8:00	5/21/2010 17:00	
IME 481	48 days	1/4/2010 8:00	3/10/2010 17:00	
Technical Advisor	5 days	1/4/2010 8:00	1/8/2010 17:00	
Find a Technical Advisor	5 days	1/4/2010 8:00	1/8/2010 17:00	
Problem Statement	11 days	1/11/2010 8:00	1/25/2010 17:00	4
Find Problem to Fix	7 days	1/11/2010 8:00	1/19/2010 17:00	
Write Problem Statement	2 days	1/20/2010 8:00	1/21/2010 17:00	7
Review with Technical Advisor	2 days	1/22/2010 8:00	1/25/2010 17:00	8
Literature Review	17 days	1/26/2010 8:00	2/17/2010 17:00	6
Decide on Topics	3 days	1/26/2010 8:00	1/28/2010 17:00	
Research Topics	4 days	1/29/2010 8:00	2/3/2010 17:00	11
Rough Draft	7 days	2/4/2010 8:00	2/12/2010 17:00	12
Final Draft	3 days	2/15/2010 8:00	2/17/2010 17:00	13
Introduction	7 days	2/18/2010 8:00	2/26/2010 17:00	10
Brainstorm	3 days	2/18/2010 8:00	2/22/2010 17:00	
Write Introduction	4 days	2/23/2010 8:00	2/26/2010 17:00	16
Background	7 days	2/18/2010 8:00	2/26/2010 17:00	10
Research Company & Project	3 days	2/18/2010 8:00	2/22/2010 17:00	
Write Background	4 days	2/23/2010 8:00	2/26/2010 17:00	19
Status Report of Project	8 days	3/1/2010 8:00	3/10/2010 17:00	18,15

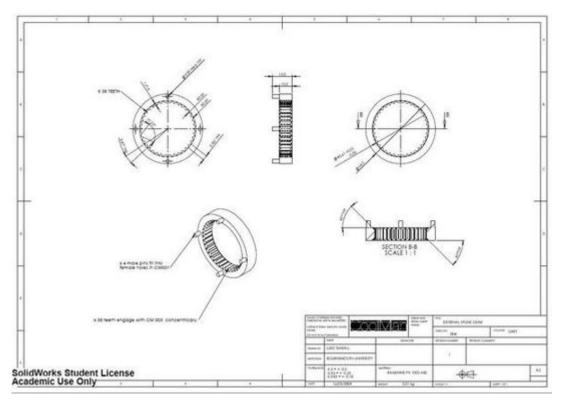|				
IME 482	40 days	3/29/2010 8:00	5/21/2010 17:00	3
Database	30 days	3/29/2010 8:00	5/7/2010 17:00	
Tables	13 days	3/29/2010 8:00	4/14/2010 17:00	
Work Breakdown Structure of Products	7 days	3/29/2010 8:00	4/6/2010 17:00	
Desgin Tables	4 days	4/7/2010 8:00	4/12/2010 17:00	25
Define Table Relationships	2 days	4/13/2010 8:00	4/14/2010 17:00	26
Queries	7 days	4/15/2010 8:00	4/23/2010 17:00	24
Define Function	7 days	4/15/2010 8:00	4/23/2010 17:00	
Build Queries	5 days	4/15/2010 8:00	4/21/2010 17:00	
Forms	10 days	4/15/2010 8:00	4/28/2010 17:00	24
Define Function	3 days	4/15/2010 8:00	4/19/2010 17:00	
Design Layout	5 days	4/15/2010 8:00	4/21/2010 17:00	
VBA Coding	10 days	4/15/2010 8:00	4/28/2010 17:00	
Use time studies to build calculation formula	10 days	4/15/2010 8:00	4/28/2010 17:00	
Reports	7 days	4/29/2010 8:00	5/7/2010 17:00	28,31
Define Layout	7 days	4/29/2010 8:00	5/7/2010 17:00	
Data Collection	10 days	3/29/2010 8:00	4/9/2010 17:00	
Data Analysis	10 days	4/12/2010 8:00	4/23/2010 17:00	38
Statistical Analysis	10 days	4/12/2010 8:00	4/23/2010 17:00	
Recommendations	6 days	4/26/2010 8:00	5/3/2010 17:00	39
Bibliography	1 mon	4/6/2010 8:00	5/3/2010 17:00	10SS,41FF
Appendix	10 days	3/29/2010 8:00	4/9/2010 17:00	10SS
Presentation	14 days	5/4/2010 8:00	5/21/2010 17:00	41

Figure 1: Gantt Chart

Appendix F: Engineering Documents

Figure 1: Sample Engineering Drawing