LTA 9

NASA - AMATYC - NSF
Project Coalition

Kennedy Space Center

Work Sampling at the Kennedy Space Center

Mathematics for Engineering Technology

Industrial and Management

Capital Community-Technical College

Photo taken from the top of the 525 foot-tall Vehicle Assembly Building (VAB) shows the Space Shuttle Orbiter Atlantis as it slowly backs out of the Orbiter Processing Facility Bay 3.

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Mathematics for
Industrial and Management Engineering Technology

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Overview of Work Sampling

The primary purpose of this Laboratory Technical Activity (LTA) is to introduce students to "work sampling". Work sampling is one method of determining how employees spend their time at work. The idea is that by looking at what some workers are doing at specified points in time, we can create a statistical estimate of the proportion of time being spent on the various tasks.

The main activities of the LTA are to:
1) work through one complete example of a work sampling study.
2) design and conduct a work sampling study of your choice.

To complete these activities, we will:
- construct pie charts and bar charts,
- calculate sample size,
- generate random numbers,
- collect data,
- make estimates using confidence intervals, and
- analyze results.

Motivation

The simplified work study problem in this LTA is based on work done by Amanda Mitskevich, an Industrial Engineer at the Kennedy Space Center, Cape Canaveral, Florida. She was a consultant on a team that conducted a work sampling study at the Orbiter Processing Facility (OPF). The technicians at the OPF were concerned that they were spending too much time on tasks that could be done by non-technicians. The technicians felt it might be more cost effective if their time were spent on the tasks they were qualified and paid to do. In response to this problem, Ms. Mitskevich and the Overall Shuttle Processing Role Evaluation (OSPREY) team had to design a process (a work study) to determine how the technicians spent their time on the job.

In this case, the technicians requested and supported the study. In other cases, studies like this might be initiated by management. If not explained well, such studies could create unrest and mistrust among the workers being studied.

When Ms. Mitskevich's team presented the study results, the managers were pleased with the design and effectiveness of the work sampling study and excited by the potential for savings and increased productivity. The study worked so well and was so well received by management and non-management alike that the team has conducted additional work sampling studies. These have resulted in significant workplace improvements at the Kennedy Space Center.

Background

The Kennedy Space Center has a multitude of responsibilities, including repair and maintenance of the Space Shuttle Orbiters. The Orbiter, together with the external tank and the Solid Rocket Boosters, make up the Space Shuttle. This LTA concerns the operation of the Orbiter Processing Facility which is responsible for repairing and maintaining the four Orbiters (Atlantis, Columbia, Discovery, Endeavour).

The OPF comprises three buildings where the Orbiters are prepared for future missions. In each building there are access platforms which surround the Orbiter and allow access to its interior. There are shops and equipment for working on the engines, repairing and replacing the tiles, reconfiguring the payload bays, inspecting the wheels and landing gear, and working on other components of the vehicle.

A part of Amanda Mitskevich's job was to analyze the work being done in the OPF. Are tasks completed in a reasonable amount of time? Are workers being used efficiently? These are really important questions since an Orbiter is not that large and access to it is difficult. The access platforms surrounding an Orbiter and the equipment on the floor of the shop restrict the work space, thus limiting the number of technicians who can work on an Orbiter at any one time. As a result, the sequencing and choreographing of tasks is very important.

Industrial engineers are trained in the areas of process analysis, process measurement and process enhancement. They are concerned with studying processes (or the various components of work) in an attempt to improve performance and quality. One of their mottos is “If you don’t measure it, you can’t manage (or improve) it.”

In order to begin her work sampling study of the OPF technicians, Ms. Mitskevich spent time with the technicians to find out what tasks they were performing, the steps needed for each of those tasks, their other job duties such as meetings or training sessions, and the potential causes for delay in their work. She then worked with the team to design a data collection instrument, collect the data, and analyze it. This LTA presents a simplified version of the study she conducted.

Getting Started Activity
How a Typical Worker in the OPF Spends Her Day

A work sampling study was conducted to see how technicians spend their time on the job at one of Kennedy Space Center’s Orbiter Processing Facilities. The information in the table below is hypothetical but will give you an example of the type of data collected.

Technician Activity	Number of Times Observed
Setup	55
Work	215
Delay	27
Cleanup	31
Training/meetings	39
Miscellaneous	23

Your job is to make a pie chart summarizing the above data. You may choose to do it “by hand” using a compass and protractor to measure the angles or with a computer spreadsheet. Make sure that your chart is clearly labeled and easy to read.

Getting Started Homework
Graph It!

For each of the following situations make a pie chart to represent the data in pictorial format. You may use a computer to generate these charts. When you are finished, comment on the "clarity" of the charts. Are there things you could do to make them easier to read? If so, what? Also, make a bar chart for Exercise 2. How does it compare to the pie chart?

1) Faculty at a college were observed at different times to see how they spent their day at work. The following results were obtained from this study:

Faculty Activity	Number of Times Observed
Housekeeping	7
Lecture	41
Student Interaction	20
Facilitate	25
Off Task	9
Test	15
Miscellaneous	13

2) Between 1959 and 1992, 14 groups of astronauts were selected to participate in different NASA projects (including the Mercury, Gemini and Apollo projects). Here is the data about the number of astronauts that were selected in Groups 1-14:

Group Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of Astronauts	7	9	14	6	19	11	7	35	19	17	13	15	23	19

Section 1
Collecting Data

In "Getting Started", you worked with the data from a simplified NASA work study example which is repeated in Table 1 below. How were the entries in this table obtained? To answer this question we will describe a process for collecting and organizing such data. The NASA engineer and the OPF technicians needed to identify the activities to be observed - setup, work, delay, etc. In our simplified example, the activities are listed in the first column of Table 1.

Table 1: Summary Information for Work Study

Technician Activity	Number of Times Observed
Setup	55
Work	215
Delay	27
Cleanup	31
Training/Meetings	39
Miscellaneous	23

Obtaining entries for the second column of Table 1 required a systematic process for observing and recording the technicians' activities at specified times. The work study team had to decide how many technicians would be observed. Ten technicians were selected for observation. The observations were conducted twice a day on twenty different work days. Each observation time with its collected information is defined as a **run**. The forty runs in this work sampling study ($2 \times 20 = 40$) could yield up to 400 observations (10 technicians $\times$ 40 runs). A comprehensive but simple form is needed to record this information. The form is referred to as a **data collection sheet** and is composed of two tables. One table is used to identify the technicians being observed (Roster Table), and the other table is used to record their activities (Activity Table).

Assume that you are a data collector with responsibility for obtaining information about 10 technicians during 40 runs. This information is to be recorded on a blank form similar to the **Data Collection Sheet for Table 1** that follows. Your first task is to write the names of the 10 technicians on the second line of the Roster Table. Next, you visit the worksite (the OPF) and identify the activity of each technician at the time of your sample run. As you observe the activity of each technician, you make a tally mark in the appropriate row of the Activity Table and then check off the technician's name in the Roster Table. Assume that the actual results of your survey are recorded in the **Data Collection Sheet for Table 1**. This information is summarized and presented in Table 1.

Data Collection Sheet for Table 1

Activity Table

Technician Activity	Description	Run 1 6/23 8:10 AM	Run 2 6/23 10:15 AM	Run 3 6/24 9:30 AM	…	Run 40 7/13 1:35 PM
Setup	Get job instructions, parts, tools and equipment; inventory resources; review instructions.	//	//	///	…	//
Work (Wrench Turning)	Perform the task assigned.	///	/////	//	…	///
Delays	Interrupt work or preparation due to problems with parts, paper, people, tools, equipment, or schedule.	//		/	…	//
Cleanup	Put away job instructions, parts, tools, equipment; clean up work area.	/	//	/	…	/
Training/Meetings	Attend training, meetings.	/	/		…	//
Miscellaneous	Perform tasks that do not fit in the above categories. Note activity.			/	…	

Roster Table

Technicians	1	2	3	4	5	6	7	…	10	Total Number
Name	Joe	Sue	Ty	Ana	…	…	…	…	Bill	
Run 1	√	√			…	…	…	…	√	9
Run 2	√	√	√	√	…	…	…	…	√	10
Run 3	√		√		…	…	…	…	√	8
…	…	…	…	…	…	…	…	…	…	…
Run 40	√	√	√	√	…	…	…	…	√	10

As you can see, the **Data Collection Sheet for Table 1** gives a detailed profile of the types of activities performed by the technicians and the frequency with which they perform them. This completed data collection sheet will be used to determine what proportion of time is spent on essential activities and what proportion of time is spent on activities that might be better done by other employees. Please take a few minutes to study the data collection sheet. Discuss the sheet with members of your group; then complete Activity 1.

Activity 1
Understanding the Data Collection Sheet

Part A Use **Table 1** and the **Data Collection Sheet for Table 1** to answer the following.

1) How many technicians did the data collector study on the 3rd run? ____

2) How many technicians were cleaning up at the time of the 2nd run? ____

3) Was Ty included in every sample run? ____

4) What would be the total number of tally marks in the row marked "Setup?" ____

5) What would be the total number of tally marks in the row marked "Work?" ____

6) What would be the total number of tally marks in the Activity Table? ____;
in the Roster Table?____

7) What was the sample size intended to be at the beginning of the study? ____

8) What was the actual sample size? ____

Part B Congratulations! YOU are the new supervisor at the OPF. Today is your first day. You are given the following data collection sheet that needs to be filled in with information about four technicians in your shop: Marcella, Janet, Cyrus, and Lynnell. Eager to perform your duties, you immediately locate the technicians, observe their activities, and complete the form. In conducting the run, you see that Marcella is picking up parts from the parts "shop", Janet is reviewing instructions for her assigned job, Cyrus is talking to someone who is giving a tour of the facility, and Lynnell is in a meeting. Use this information to make the appropriate tally marks in the sheet provided, and discuss your answers with other members of your group.

Data Collection Sheet for Activity 1, Part B

Activity Table

Technician Activity	Description	One run (today, right now)
Setup	Get job instructions, parts, tools and equipment; inventory resources; review instructions.	
Work (Wrench Turning)	Perform task assigned.	
Delays	Interrupt work or preparation due to problems with parts, paper, people, tools equipment, or schedule.	
Cleanup	Put away job instructions, parts, tools, equipment; clean up work area.	
Training/Meetings	Attend training and meetings.	
Miscellaneous	Perform activities that do not fit in the above categories. Note activity.	

Roster Table

Technicians	1	2	3	4	Total
Name	Marcella	Janet	Cyrus	Lynnell	Number
Only Run					

Part C Months have passed, and you have become well known for your expertise in work sampling. A local video rental store, Laddon's Latest Hits, has hired you to do a work study of their employees Brian, Jerry, and Virginia. The employees say that far too much of their time is spent cleaning up shelves after customers mess them up rather than doing the real work of helping customers, checking in videos, and restocking shelves. You conduct two runs and observe the following activities.

	Brian	Jerry	Virginia
Run 1:	Restock shelves	Talk on phone to a friend	Restock shelves
Run 2:	Check in videos	Clean up shelves	Clean up shelves

Fill in the following data collection sheet for Laddon's Latest Hits. When you are done, compare your answers with those of other students.

Data Collection Sheet for Activity 1, Part C

Activity Table

Employee Activity	Description	Run 1	Run 2
Cleanup	Clean up after customers have shuffled videos.		
Process Videos	Check in videos or restock the videos.		
Help Customers	Help customers by checking out videos, finding videos on shelves, checking inventory on computer, or answering questions.		
Waste Time	Talk to friends or family, walk around without straightening shelves, or do something unproductive.		
Miscellaneous	Perform a job related task not in the above categories. Note activity.		

Roster Table

Employees	1	2	3	Total Number
Name	Brian	Jerry	Virginia	
Run 1				
Run 2				

Homework 1
Introduction

It is extremely important to collect accurate data in order to have a reliable study. To gain some experience collecting data, do Homework 1A or 1B as directed by your instructor and bring your results back to class. Please review the homework assignment today and ask any questions you may have. An attempt has been made to provide you with a realistic experience as a data collector for a small pilot study. We will use these results for the homework in Section 2. Please do a thorough job.

Homework 1A
Work Sampling in the Grocery Store

Your task is to go to your neighborhood grocery store and observe what three checkers are doing at each of the 2 times given. We are asking you to classify their activities at 2 different times during an hour. The times are the 16th minute and the 25th minute. The times that you set for your observations depend upon when you start. For example, if you start at 9:00 PM, you would observe the three checkers at the times 9:16 PM and 9:25 PM. On the other hand, if you begin at 11:04 AM, you would time your two runs at 11:20 AM and 11:29 AM. Be careful to make sure that you record the activities of the same three checkers each time. Record the time of each run in the spaces provided within the column headings for Run 1 and Run 2.

Data Collection Sheet for Homework 1A

Activity Table

Checker Activity	Description	Run 1 16th min Time:	Run 2 25th min Time:	Totals
Housekeeping	Fix cash register, wipe counter.			
Checking	Ring up customer's purchase, receive money, give change.			
Direct Interaction	Ask and respond to customer questions.			
Off Task	Perform activities that are not job related.			
Miscellaneous	Perform job related activities not in the above categories.			

Roster Table

Checkers	1	2	3	Total Number
Name or ID No.				
Run 1 (16th min)				
Run 2 (25th min)				
Totals				

Homework 1B
Work Sampling in Your Classes

Your task is to observe the activities of two of your instructors at selected times during their classes. We are asking you to classify the instructors' activities at 3 different times during the first hour of their classes. The times are: 02, 31, and 42. What this means in terms of your observation time depends upon when your next class starts. For example, if it starts at 9:00 AM, you would place tally marks in the appropriate columns on the data collection sheet at the times 9:02 AM, 9:31 AM and 9:42 AM. On the other hand, if your class begins at 11:10 AM, the times you would make your tally marks would be 11:12 AM, 11:41 AM and 11:52 AM.

Data Collection Sheet for Homework 1B

Activity Table

Instructor Activity	Description	Run 1 (2nd minute) Obs. time for Instr. 1:_____ Obs. time for Instr. 2:_____	Run 2 (31st minute) Obs. time for Instr. 1:_____ Obs. time for Instr. 2:_____	Run 3 (42nd minute) Obs. time for Instr. 1:_____ Obs. time for Instr. 2:_____	Totals
Housekeeping	Take roll, collect or distribute papers and materials.				
Lecture	Talk about the day's topics.				
Direct Interaction	Ask questions and respond to student questions				
Resource Person	Work with student groups and facilitate.				
Off Task	Perform tasks that are not job related.				
Proctor	Give a test or show a video.				
Miscellaneous	Perform job related activities not described above. Note activity.				

Roster Table

Instructors	1	2	Total Number
Instructor Name or Course Title			
Run 1 (2nd min)			
Run 2 (31st minute)			
Run 3 (42nd minute)			

Section 2
Determining Sample Size

Recall that the purpose of the work study is to find a good estimate of the proportion of time that the technicians spend on a key activity. This proportion is denoted by the letter **p**. The value of **p** cannot be known exactly, since this would require continuous observations of all technicians, but it can be estimated from a corresponding proportion calculated from a sample. One of the elements that affects the goodness of an estimate is the size of the sample. All other things being equal, the larger the sample, the more confident we can be that our estimate is close to the actual value of **p**.

In the NASA example, a sample of 390 observations was collected over a period of 20 days. How was this number determined? Was this sample large enough to provide a good estimate of **p**? Could a smaller number of observations have been taken, thus saving time and resources? To answer these questions, we need to know how the sample size is related to the level of confidence and the desired accuracy of our estimate. This relationship is expressed by a formula that involves **p**. However, since we cannot know the exact value of **p**, we replace it with an estimate denoted by $\hat{\mathbf{p}}$. This yields the following formula for the sample size.

$$\mathbf{n} = \left(\frac{\mathbf{z}}{\mathbf{s}}\right)^2 \frac{\left(1-\hat{\mathbf{p}}\right)}{\hat{\mathbf{p}}} \qquad (1)$$

where,

$\hat{\mathbf{p}}$: the sample proportion of time the technicians spend on the key activity (often written as a percent).

s: relative accuracy desired (the tolerable error for the estimate of the population proportion **p**, expressed as a percentage).

z: number of standard deviations (determined from the standard normal distribution and the given confidence level).

n: sample size required to achieve the desired accuracy with a given confidence level. To obtain **n**, the value calculated from the formula is rounded up to the nearest whole number.

We will now consider how the values for the variables in formula (1) are obtained.

a) Identify the "key activity" and calculate a preliminary value of $\hat{\mathbf{p}}$.
The preliminary estimate of **p**, the value of $\hat{\mathbf{p}}$, is typically obtained from a pilot study or its value is assigned by an expert who is familiar with the tasks. If the initial value of $\hat{\mathbf{p}}$ is obtained from a pilot study (an initial small scale study designed to provide guidance for the subsequent full scale work study), its value is determined by the formula, $\hat{\mathbf{p}} = \frac{\mathbf{x}}{\mathbf{n}}$, where **x** is the number of times the key activity was observed and **n** is the total number of observations (sample size). In the pilot study, it is important to pick an activity with a sample proportion, $\hat{\mathbf{p}}$, that is not too close to zero. For our NASA example, we select "Work" or "Wrench Turning" as the key activity for the pilot study, and we will use 0.50 or 50% as the preliminary value of $\hat{\mathbf{p}}$.

b) Choose a value for **s**.
The value for **s** will generally be given by the project manager. The usual value for **s** is 10%. This means that you can "live with" an estimate of the proportion for your key activity that is in error no more than 10%.

c) Determine the value for **z**.
The value used for **z** is the same **z** score as traditionally used in a statistics class. The value represents distance from the mean as a number of standard deviations and is linked to the confidence level used in the construction of confidence intervals (Section 3). Ms. Mitskevich, the NASA Engineer working with us, used **z** = 1.96 (the **z** value associated with the 95% confidence level).

In the NASA example, $\hat{\mathbf{p}}$ = 50%, **z** = 1.96 and **s** = 10%. Thus, $\mathbf{n} = \left(\frac{1.96}{0.10}\right)^2 \frac{(1-0.50)}{0.50} = 385.$

The value of 385 for **n** is the minimum number of observations that have to be made for the study. The NASA example was set up to collect a possible 400 observations. Due to worker illness or errors in the data collection phase of the project, the actual number of observations was 390. Since 390 is greater than the minimum sample size of 385, the NASA engineers were satisfied that the study was based on a sufficient number of observations.

It is worth noting that the sample size is defined to be the total number of observations, not the number of technicians observed in the study. As long as the study had 385 or more observations, the results would be within the 10% relative accuracy with a 95% level of confidence.

Activity 2
How Many Observations Do We Need?

1) The managers at the Marcella Utility Company want to find out what their workers are really doing. They are most interested in the activity of light bulb installation. Assume that our relative accuracy **s** is 10%, the confidence level is 95% and a preliminary estimate of the proportion of time spent on light bulb installation is 22%. What **size sample** is needed for their work sampling study?

2) The managers at the Tarjan Tar Removal Company think that too many of their employees are on a coffee break at any given time in the day. From a pilot study, they feel it is reasonable to estimate that the proportion of time spent on a coffee break is 15%. They will use a relative accuracy of 10% and a **z** value of 2. **How many observations** will they need to schedule?

   If 15 employees are to be observed, and there are 20 days available for observations, how many runs a day will need to be scheduled? (Assume the same number of runs each day.) How many extra observations above the minimum number does this give?

Homework 2
How Many Observations Will Be Enough?

For this homework you will need the class results from Homework 1A or 1B. Use these results to decide how large a sample you need to conduct a work sampling study. Define your key activity as the one that occurred most frequently in the compiled results. Use 10% for the relative accuracy level and 1.96 for your **z** value.

1) Are you using class data from Homework 1A or 1B?
2) What activity did you select as the key activity? Calculate the value of $\hat{\mathbf{p}}$.
3) What is the total number of observations you must make for your survey?
4) If you have 15 people selected for observation, and you can spend no more than 20 days collecting data, how many times a day will you need to observe them in the workplace?
5) If, instead, you have 10 days in which to gather the data, and a maximum of 5 opportunities each day to observe the people, how many people (grocery store clerks or instructors depending on the Homework) will you need to observe to have a sufficiently large sample?

Section 3
Constructing Confidence Intervals

Remember that the primary purpose of conducting the work sampling study is to estimate the population proportion of time that the OPF technicians spend on various key activities. We cannot determine the true population proportions, since this would require that all the technicians be observed at all times with no interruptions. Nonetheless, we can estimate the proportions by selecting a sample of what the technicians are doing at various times and use it to find confidence intervals for the proportions of time spent on key activities. In this section, we shall use confidence intervals to estimate the population proportions.

In Section 2, we used 0.50 as a preliminary estimate of the proportion of time spent on the key activity, wrench turning, so that we could calculate the sample size. We determined that the required sample size was 385. The next step involved conducting runs of a full scale survey that yielded 390 observations. The summary information for that work study is in Table 1 of Section 1. This data can be used to revise our value for $\hat{\mathbf{p}}$ and then to construct a confidence interval estimate of **p**. As part of the calculation, we will update the value of **s**, the relative accuracy, and from this determine the value of the "absolute accuracy" **a**. The steps involved are shown below.

a) Calculate the revised proportion estimate from the sample data.

We can calculate our revised proportion estimate $\hat{\mathbf{p}}$ using the fraction $\frac{\mathbf{x}}{\mathbf{n}}$, the number of times an activity is observed **x** divided by the total number of observations **n**. For our sample data, this gives the fraction 215 (the number of times wrench turning was observed) divided by 390 (the total number of observations). The result is $\hat{\mathbf{p}} = 0.55$.

b) Determine the relative accuracy.

Solve for **s** in the formula for the sample size, $\mathbf{n} = \left(\frac{\mathbf{z}}{\mathbf{s}}\right)^2 \frac{(1-\hat{\mathbf{p}})}{\hat{\mathbf{p}}}$, to obtain:

$$\mathbf{s} = \mathbf{z}\sqrt{\frac{(1-\hat{\mathbf{p}})}{\mathbf{n}\hat{\mathbf{p}}}}.$$

Using **z** = 1.96 (for a 95% confidence level), **n** = 390, and $\hat{\mathbf{p}} = 0.55$, we find that

$$\mathbf{s} = 1.96\sqrt{\frac{(1-0.55)}{(390)(0.55)}} = 0.09 = 9\%.$$

Since NASA had set the relative accuracy level to be no more than 0.10, this is indeed an acceptable relative accuracy. If the calculated value for **s** was greater than 10%, then NASA may have decided to conduct another work sampling study using a larger sample size. This would have the effect of decreasing the value of **s**. In fact, the value of **s** can also be calculated and monitored throughout the study. A value of **s** less than 10% is a signal that the observation phase of the work study can be stopped.

c) Calculate the absolute accuracy.

The absolute accuracy represents the margin of error, a term that will be used in the confidence interval. It can be calculated by the following formula.

margin of error = absolute accuracy = $\mathbf{a} = \mathbf{s}\hat{\mathbf{p}}$

Determine the value for **a**, the absolute accuracy achieved by our study, by substituting **s** = 0.09 and $\hat{\mathbf{p}}$ = 0.55.

absolute accuracy = $\mathbf{a = s\hat{p}}$ = (0.09)(0.55) = 0.0495 ≈ 5%.

d) Construct the confidence interval.
We are 95% confident that **p** and $\hat{\mathbf{p}}$ differ by less than the absolute accuracy, **a**. This means that in repeated sampling, the probability is 95% that **p** and $\hat{\mathbf{p}}$ will be within **a** units of each other. Thus, we are 95% confident that **p** is between $\hat{\mathbf{p}} - \mathbf{a}$ **and** $\hat{\mathbf{p}} + \mathbf{a}$. On the basis of the OPF data, the 95% confidence interval for **p** is:

$$\hat{\mathbf{p}} - \mathbf{a} < \mathbf{p} < \hat{\mathbf{p}} + \mathbf{a}$$
$$0.55 - 0.05 < \mathbf{p} < 0.55 + 0.05$$
$$0.50 < \mathbf{p} < 0.60$$

Finding a confidence interval is one way of estimating **p**. In this case, we are 95% confident that the true population proportion of the time that the technicians do work (wrench turning) is between 50% and 60%. In Activity 3 below, you will determine accuracy levels and confidence intervals for some other choices of the key activity in the OPF example.

Activity 3
Confidence Interval for Technicians Activities

Technician Activity	Number of Times Observed
Setup	55
Work	215
Delay	27
Cleanup	31
Training/Meetings	39
Miscellaneous	23

1) Define "Setup" as the key activity. Using the data given in the NASA OPF technician study above, calculate the relative accuracy **s** and absolute accuracy **a**. What is the 95% confidence interval for the true proportion of time spent in "Setup"? Write a sentence to describe your results.

2) Define "Cleanup" as the key activity. Using the data given in the NASA OPF technician study above, calculate the relative accuracy and absolute accuracy. What is the 95% confidence interval for the true proportion of time spent in "Cleanup"? Write a sentence to describe your results.

Homework 3
Constructing Confidence Intervals

You will need the class results from either **Homework 1A: Work Sampling in the Grocery Store** or **Homework 1B: Work Sampling in Your Classes**. Your instructor can provide this for you if you did not combine the data as a whole class. Using these totals, pick a key activity to analyze. Calculate the relative accuracy, the absolute accuracy, the 95% confidence interval, and write a sentence describing the results. Pick one of the other activities as the key activity, and repeat the calculations. What differences do you notice?

Section 4
Developing Activities for a Data Collection Sheet

Examine the OSPREY Technician Sampling Worksheet (Appendix A) in your groups. This data collection sheet is more complicated than those we have used in class. At NASA, data collectors examined 10 technicians on each of 40 sample runs. On each run, the data collector classified the technician's observed activity by making a tally mark in one of 21 possible activity categories. The data collection sheets we discussed in earlier sections were much smaller in scope.

The OSPREY Worksheet is also more complicated than those we have used previously because there is a column labeled "LOGIC". This column is important for distinguishing between two activities that initially may seem to be identical. For example, if a technician is working with a part, actually "turning the wrench", and the tool breaks, the technician's work is interrupted in order to locate and retrieve a new tool. In this case, the act of "getting a tool" would be a "Delay" rather than "Wrench Turning." So, the data collector must understand the reason why a technician needs to locate and retrieve a tool. If getting a tool is expected and appropriate, the task is identified as "Activity 9". If locating and retrieving a tool is an interruption of wrench turning, then no tally mark is placed in Activity 9. The task observed is instead recorded as a tally mark in the category "Activity 13: tools/equipment delay".

In both the simplified data collection sheets that we have used and the more complicated form in Appendix A, the activities have been carefully defined so that there is no overlap or confusion about them. Furthermore, every possible task can be assigned to an activity on the form. As much as possible, similar tasks have been grouped together to reduce the number of activities.

Activity 4
Activities and Tasks

Part A Look at the copy of your OSPREY Technician Sampling Worksheet (Appendix A). Suppose that you've been asked to observe (collect data on) 5 technicians on each of 3 runs. The five technicians are Alicia, Betty, Colleen, David, and Euler. The following chart describes what the technicians are doing during each of the three runs you make as a data collector. In each cell there is a space provided to write the number of the OSPREY activity that corresponds to your observation. Do your best to choose the right activity. Then discuss your answers in your group.

Technicians	Run 1 Observation	Run 2 Observation	Run 3 Observation
Alicia	Work in a different area than usual Activity: _____	Eat lunch Activity: _____	Attend training session Activity: _____
Betty	Clean up the shop, not at the beginning of the shift Activity: _____	Clean up mess from a spill that could be dangerous Activity: _____	Work on assigned task Activity: _____
Colleen	Get a new tool because one broke Activity: _____	Eat lunch Activity: _____	Locate paperwork for tasks Activity: _____
David	Clean up before beginning task for safety Activity: _____	Check parts to make sure that everything needed is there Activity: _____	Get a new tool when the old one stops working Activity: _____
Euler	Attend a training meeting Activity: _____	Replace a tile Activity: _____	Call for quality inspector Activity: _____

Part B We've been using data collection sheets with activities already defined. Now, we'd like to have you help decide what definition of activities might be good. Each of the following jobs has three sets of activities from which to choose. Select the Set (I, II, or III) that you think is most descriptive, and provide two reasons why you think it is better than the other two sets. Also, give a specific reason why you did not choose each of the other sets.

Job: Waitress/Waiter

Set of Activities I	Set of Activities II	Set of Activities III
Talk to customer	Take orders	Take orders/explain menu
Work the cash register	Fill orders	Get food
Get food from kitchen	Take care of bill	Check on progress at table
Get drinks		Refill food
Clean the table		Refill drinks
Take orders		Bus dishes during meal
Take a break		Do side jobs:
		Fill ice
		Fill condiment containers
		Wipe trays
		Break, lunch, bathroom

Reasons that Set ___ is better than the others: 1. _____

2. _____

Reason I didn't choose Set ___:

Reason I didn't choose Set ___:

Job: Trainer at a Fitness Gym

Set of Activities I	Set of Activities II	Set of Activities III
Schedule appointments	Get equipment out	Explain program
Check area, safety	Put equipment away	Get weights
Enforce rules	Teach customer	Answer phone
Put away weights	Breaks	Breaks
Conduct group training		Take new customers on tour
Conduct individual training		
Visit with people (not training)		
Staff meetings		
Break		

Reasons that Set ___ is better than the others: 1. _____

2. _____

Reason I didn't choose Set ___:

Reason I didn't choose Set ___:

Now, consider four criteria that any list of activities should satisfy.

1) The activities should be **well defined**. Well defined means that the data collector should understand the meaning of the activity description. For example, "talk to customer" is probably not as well defined as either "take food order" or "check on progress of table during meal." A data collector might be confused as to whether explaining a menu counts as "talk to a customer" or "take orders"!

2) Are the activities **mutually exclusive**? The idea of "mutually exclusive" is that there is no possible overlap of activities. If two choices are "talk to customer" and "take orders," for example, you might be confused when collecting data because taking orders looks, sounds, and feels like talking to a customer. Where would you put a mark if it is possible to put a mark in two different places? If it is possible to have one task count in two different activities, then the activities would not be mutually exclusive.

3) The list of activities should be **exhaustive**. This means that there will be some activity in the list that describes whatever a worker may do on the job. To accomplish this, someone who truly understands the job should help define the activities. Otherwise, a common activity may be omitted completely. For example, someone who has not worked as a waitress may not have thought of filling the condiments as part of the job. Great care should be taken to anticipate all possible activities so that a data collector is able to quickly find an appropriate one for any observed task. Sometimes, the category of "miscellaneous: a task that is none of the above" is added to ensure that every task fits somewhere.

4) The activities should be **meaningful divisions** of how workers spend their time on the job. In a work sampling study of waitressing, it would make sense to separate the time spent on refilling drinks from that spent on refilling food. The reason to separate them is that if too much time is spent refilling drinks, the task "refill drinks" may be assigned to the bus boy. However, the task "refill food" would not be. One would have to do a study to determine if "refilling drinks" takes enough time on its own so that reassignment would be helpful. In the NASA example, getting parts was identified as a separate activity because NASA managers were trying to decide which tasks really were "time wasters" for technicians and should be reassigned to other, perhaps new employees, such as technician assistants. Also, to distinguish between retrieving parts and reviewing paperwork, the tasks had to appear as separate entries in the activity list.

Summary
The activities should be well-defined and meaningful divisions of how workers spend their time on the job. They should be mutually exclusive. As a group, they should be exhaustive.

Review your earlier decisions
Now, return to your answers about the waitress/waiter and trainer jobs. Do you still think you made the right choice about which set is best? Can you justify your current point of view (whether or not it is the same as before) by using the concepts of well defined, mutually exclusive, exhaustive, and meaningful?

Part C

- Work in groups.
- Identify jobs each person in the group has performed.
- Spend 5 minutes discussing them.
- Choose ONE job to work with as a group.
- Make a list of 6 or 7 different activities and describe each one with at least two tasks which might be associated with the chosen job.
- Evaluate whether your defined activities meet the four criteria listed in this section.

Homework 4
Design the Activity and Description Columns for a Data Collection Sheet

- Choose a job performed by someone you know that is different from the ones you did in class or for homework.
- Contact the person doing the job you've chosen and ask what they do as part of their job every day. Be careful. You will want to identify regular job activities and tasks not just unusual ones.
- Make a list of 6 or 7 different activities associated with the chosen job. Describe each with at least two tasks.
- Evaluate whether your defined activities meet the four criteria listed in this section.
- Turn in the completed list of activities and tasks as they might appear on a data collection sheet.

Section 5
The Capstone Project

How can you use what you have learned so far to do your own work study? What would you do first, second, etc.? Even though you carried out each step of the simplified NASA work study, you may not have seen it as a whole. As a prelude to the capstone project, we will now consider each step of the NASA OPF work study project.

First, the background information. At the beginning of the day, each technician in the OPF checks in at a certain location in order to receive a notebook binder describing his or her job assignment. The technician reads through the assignment. Next, the technician goes to another location (sometimes another building) to get the materials (tools and parts) needed for the assignment. Then the technician begins to work on the job assignment.

Step 1: Define the problem.

For a variety of reasons, the number of tasks technicians were asked to do increased rapidly over a short period of time. For example, they were expected to check their own work before moving on to a new job rather than having a different person inspect their work. Technicians also went through regular training sessions. The technicians began to feel that they were expected to do too many unnecessary tasks and that there were too many interruptions in their work. They wanted more time during their work day to "turn the wrenches" or actually perform the work they were trained and hired to do. The OPF technicians asked management for a study to be conducted to see if some of their activities could be delegated to other workers. In summary, the problem was to determine what proportion of the technician's time was spent "wrench turning."

Step 2: Define each activity to be observed.

There were many elements measured in the actual study of technicians in the OPF at KSC (Appendix A). When the study was finally approved, the technicians participated in the creation of the data collection instrument. That is, they helped define and organize "wrench turning" and "non-essential" activities for the data collection instrument. For the simplified version of the study, activities were classified under the following categories:

- Job Setup: get job instructions, parts, tools and equipment; inventory the resources; review the instructions.
- Wrench Turning: perform the assigned task.
- Delay: interrupt the work or preparation due to problems with parts, paper, people, tools, equipment, or schedule.
- Training/Meetings: attend training, meetings.
- Job Cleanup: put away job instructions, parts, tools, equipment; clean up the work area.
- Miscellaneous: perform tasks that do not fit in the above categories.

Step 3: Make sure that the people to be observed are notified.

Meetings were held with the shop employees so that they understood the purpose of the study and the future use of the data.

Step 4: Set the desired accuracy and confidence level.

The industrial engineers at NASA used 10% relative accuracy and a 95% confidence level since these are well accepted in industry. Therefore, $\mathbf{s} = 10\%$ and $\mathbf{z} = 1.96$.

Step 5: Make a preliminary estimate of the proportion of time spent on a key activity.

The key activity is defined as "work" or "wrench turning." Normally you either get a preliminary estimate of **p** from qualified experts or from the results of a pilot study. This estimate will be revised to a more accurate one based on the data that is collected.

Step 6: Develop the observation process.

- Determine the number of observations required, the number of people to be observed, and the number of runs.

  The minimum number of observations must be determined. Recall that the minimum value of **n** was calculated to be 385 (Section 2). The number of runs was determined using this value. There were 10 technicians in the shop, 385 observations were to be made, so approximately 40 sample runs were needed. This would provide up to 400 observations. Note that while 385 was the minimum sample size according to the computations, no effort was made to take exactly 385 observations. (Why not? The number 385 divided by 10 is not a natural number.)

- Determine the number of days/shifts.

  Notice that a "shift" in this shop is 7:00 AM to 3:30 PM. To get a good representation of all of the types of work being done, it was decided to run the study over 20 days, so they decided to take 2 sample runs per day.

- Determine randomly the times for each run.

  Random times were generated for each day of data collection. (Section 6)

- Determine who will be the observer(s).

  The data collectors must be identified. That is, who will make the observations? Possibilities include the shop supervisor, an industrial engineer, or another employee. In the NASA example, it was members of the OSPREY team who did the observing and reporting. This was significant because they were the people who were very familiar with the work being done, and who were, in most cases, technicians out of the shops. This allowed the people being observed to be more comfortable with the process and also increased the "buy-in" from the technicians.

- Design the data collection sheet.

  An example was presented in **Data Collection Sheet for Table 1**. The observations could also have been tallied on a form such as Table 2 on the following page. The major difference between the two data collection sheets is that the rows and columns have been interchanged. The number and definitions of runs and activities may make one style more desirable than the other. The features on the computer software provide another consideration. It is possible to design and use different data collection sheets in the same study if desired.

Table 2

Sample Run	Date	Time	Setup	Work	Cleanup	Delays	Training/ Meetings	Misc.	Totals
1	6/23	8:10 AM							
2		10:25 AM							
3	6/24	9:30 AM							
....	....	....							
40	7/13	1:35 PM							

Step 7: Take the observations and record the data.

At NASA, members of the OSPREY team collected the data. Each data collector had a copy of the data collection sheet. At the end of the study, information from all the sheets was compiled. Here are the totals from the simplified version of the actual study. Please note that the data provided in this simplified version are not exact results from the actual NASA work sampling study of technicians but have been simplified for this example.

Technician activity	Number of times observed
Setup	55
Work	215
Delay	27
Cleanup	31
Training/Meetings	39
Miscellaneous	23

Step 8: Analyze the data.

Notice that the total above is 390. Because 390 was more than the needed 385, they could stop the study as planned. Had the errors in data collection and/or technician illnesses led to a total of fewer than 385 observations, the study would have been extended for additional days. After the data was collected, some calculations were made to check the relative accuracy level and the absolute accuracy level (Section 3). The relative accuracy was **s** = 9%, which is below the 10% standard set by NASA, so the study achieved an acceptable relative accuracy . The absolute accuracy achieved by the study, **a** = 0.05, was used to construct the 95% confidence interval. Thus, the proportion of time that the technicians spent wrench turning was estimated to be between 50% and 60% at the 95% confidence level. The industrial engineers could also calculate confidence intervals and accuracy levels for some of the other activities if they desired to do so.

Step 9: Prepare findings and recommendations.

In the actual study done at NASA, another run of data with even more samples was taken and analyzed for the purpose of looking for patterns of high activity and/or idle time throughout the work day. Based on the analysis, a pilot program using split work shifts was implemented to decrease gaps of time when technicians were not doing their specialized work. The daily scheduling meeting was moved from 9:00 AM to 8:00 AM, so that work could be defined earlier in the day. It was decided that any time a technician spent not working on an assigned job was time that could be reallocated. Since a lot of time was spent in setup activities, it was recommended that this activity be investigated further and that workers other than technicians be assigned to perform these duties. The team also recommended that the category of "delays" be further investigated to see what changes might decrease time spent on these activities. Finally, it was decided to look closely at activities that involved meetings to ensure that they were "value added." Work sampling was again conducted, and preliminary analysis indicated larger **p** values for wrench turning and thus more productivity from the technicians. The application of work sampling at NASA resulted in significant changes and improvement in how business is done in the Orbiter Processing Facility.

The nine steps for carrying out a work sampling study are summarized in Table 3 below.

Table 3

Pilot Work Study
Step 1: Define the problem.
Step 2: Define each activity to be observed.
Step 3: Make sure that the people to be observed are notified.
Step 4: Set the desired accuracy and confidence level.
Step 5: Make a preliminary estimate of the proportion of time spent on a key activity.
Full Scale Work Study
Step 6: Develop the observation process. • Determine number of observations, people to be observed, and runs. • Determine the number of days/shifts. • Determine randomly the times for each run. • Determine who will be the observer(s). • Design the data collection form.
Step 7: Take the observations and record the data, make appropriate diagrams.
Step 8: Analyze the data.
Step 9: Prepare findings and recommendations.

Homework 5
Design a Work Sampling Study

Your assignment is to design and implement a work sampling study following the nine steps in Table 3. Select an area of work in which you are interested in the way workers spend their time. It will be easier if you choose an area with which you are familiar. The following steps will guide you through the project.

Step 1: Define the problem
- The objective of the study will be to determine an estimate of the proportion of time spent on various activities so that an accurate profile of the work day can be generated.
- Select a work area or job type that your will observe.

Step 2: Clearly define each element to be measured
Identify all of the activities and their descriptions.

Step 3: If appropriate, make sure that the people to be studied are notified.

Step 4: Set the desired accuracy and confidence levels.
Use 10% relative accuracy (**s** = 10%) with a 95% confidence level (**z** = 1.96).

Step 5: Make a preliminary estimate of the proportion of time spent on a key activity.
- Identify one activity to be the key activity.
- Carry out a pilot study by randomly selecting 12 observation times over the course of 4 days (3 times per work day) and collecting data at those 12 times.
- Use the results to make a preliminary estimate for **p**.

Step 6: Develop the observation process.
- Determine the number of observations required, the number of people to be observed, and the number of runs (Section 2).
  Use the provided worksheet to calculate the minimum sample size to achieve the desired relative accuracy and confidence level. Record your result and include it in your final report. For the purposes of completing the study for the class project, use the calculated sample size if it is between 100 and 200. If your calculated sample size is either less than 100 or greater than 200, use 150 as your desired sample size.
- Determine the number of days/shifts.
  Determine how many days you have to collect data and from this how many observations you will need to make on each of those days to get the total number of observations to be between 100 and 200.
- Determine randomly the times for each run (Section 6).
  Use a calculator, computer or tables to generate the random times that you will need for your observations. Include the list of these dates and times in your report or on your data collection form.
- You will be the observer.
- Design the data collection form (Section 4).
  Make sure your data collection form includes all activities defined in Step 2 and shows all dates and times for your observations.

Step 7: Take the observations, record the data, and make appropriate diagrams.
- Make any changes needed to the design of your data collection sheet. Collect your data.
- Collate and summarize your results. Create a table and pie chart to summarize your results.

Step 8: Analyze the data.
- Select a key activity (this may be the same one from Step 5).
- Compute the new $\hat{\mathbf{p}}$, **s**, and **a** from the formulas (Sections 2 and 3). Analyze your results. If your value of **s** is too large (over 10%), calculate what sample size **n** you need so that **s** is 10%. Be sure to calculate the confidence interval for the population proportion (Section 3) and to write a sentence describing you results.
- Select another activity as the key activity and perform the same calculations and analysis ($\hat{\mathbf{p}}$, **s**, **a**, **n** and the 95% confidence interval for the proportion.)

Step 9: Develop findings and recommendations.
Make recommendations based on your results for future action (Section 6).

What Your Work Sampling Report Needs

You will be writing a paper to present your results. This paper needs an introduction, a body and a conclusion, written in clear English. Even though this paper is about statistics, sentences still begin with capital letters, end with periods, and include nouns and verbs.

In the **introduction** you need to explain what your topic is and to describe the type of work you are studying. Detail the activities you have divided the work into, and give your rationale for selecting those activities. How did you collect your data? Where was the data collected? What might be some sources of bias or inconsistency in your survey?

In the **body** of the paper, record all data and your analysis of the data. Be sure to include a copy of your completed data collection sheet. Show the steps of your work clearly. Be sure to do the analysis for two different key activities. For each, what is the relative accuracy? Are you satisfied with it? If not, what sample size would you need for the study to achieve the desired relative accuracy and confidence level for both of the selected activities?

In the **conclusion** of your paper, you need to describe in words non-statisticians can understand, what conclusions can be drawn from this study. Do you have any recommendations for improving the quality of the workday for the individuals that you studied? Be sure to indicate the limitations of your study and any qualifications that you may have regarding your conclusions. Include any further studies that could be conducted if your study was inconclusive or if your study has created additional questions. Your personal opinions should also be included in this section.

As part of a work sampling study you need to generate random times for your runs. Section 6 provides instructions to generate random numbers using calculators made by Texas Instruments, but random numbers can be easily generated with a variety of graphing calculators.

A Worksheet for the Sample Size of Your Work Sampling Study

The formula we are using is $\mathbf{n} = \left(\frac{\mathbf{z}}{\mathbf{s}}\right)^2 \frac{(1-\hat{\mathbf{p}})}{\hat{\mathbf{p}}}$, where the variables are defined below.

p: the population proportion of time the technicians spend on the key activity (often written as a percent)

$\hat{\mathbf{p}}$: the sample proportion of time the technicians spend on the key activity (often written as a percent)

s: relative accuracy desired (the tolerable error for the population proportion **p**)

z: number of standard deviations (for constructing a confidence interval for **p**)

n: sample size required to achieve the desired accuracy level for a given confidence level. For now, we'll use **s** = 0.10 and **z** = 1.96 (the value for a 95% confidence interval).

What is your key activity? _____

What preliminary value will you use for $\hat{\mathbf{p}}$? _____

What value of **n** does the formula yield? _____
(You may use a value of **n** between 100 and 200 if the above value is too large.)

Now let's figure out how many observations you'll need each day:

Your value of **n**:_____

Number of workers you will be observing: _____

Number of days you will be collecting data: _____

What dates will you be observing on? _____

Calculate how many observations you will need **each** of those dates.

Use the calculators to generate the random times of your observations on each day. Do not use the same random times each day.

The dates and times are: _____

Use a spreadsheet to create your data collection form.

Section 6
Using Technology to Generate Random Numbers

Generating Random Numbers with Texas Instruments Calculators:

TI-81™, TI-82™, and TI-83™ calculators:
By selecting **rand** (found in the **Prb** portion of the **MATH** menu) and pressing the **ENTER** key, you will obtain a random decimal number between 0 and 1. Each time you press **ENTER**, you will obtain another random number. If you multiply **rand** by 17, you can generate a list of random numbers between 0 and 17 with 8 or 9 decimal places. You can generate random integers by using the **iPart** command found in the **NUM** portion of the **MATH** menu.

- **7*rand** generates random decimal numbers between 0 and 7.
- **7*rand+5** generates random decimal numbers between 5 and 12.
- **iPart(7*rand + 5)** generates integers from 5 through 11.

The TI-83™ calculator:
In addition to the procedure outlined above, you can also generate random numbers using the **randInt** command on the TI-83™ calculator. For example, **randInt (2,35)** will generate integers between 2 and 35.

The TI-92™ calculator:
If you use a TI-92™ calculator, **rand( )** generates decimal numbers between 0 and 1. Thus **7*rand( )** generates decimal numbers between 0 and 7.

Generating Random Times:

As part of our work sampling study, we need to generate random times for making our observations. One way to do this is to use the 24-hour system for measuring time. In the 24-hour system 839 is 8:39 AM and 1737 is 5:37 PM. You can use a calculator to generate a list of random integers between 0 and 2400 and select times from the list. One would have to ignore numbers like 1177 (there is no time 11:77 AM), but 2243 would be fine (since 10:43 PM is a valid time).

Usually though, the observations would be made during a working day. Therefore, it is important to generate random times within a fixed time period. For example, the instruction **100*iPart(4*rand+8) + iPart(60*rand)** generates times between 8:00 AM and 12:00 noon. For the TI-92™, use the instruction **100*iPart(4*rand( )+8) + iPart(60*rand( ))**. This instruction was developed as follows. We selected a four-hour period, **4*rand**, started it at 8:00 AM, "+8", multiplied by 100 to place the hour ahead of the minutes and then inserted the minutes in the last two places.

If a four-hour shift started at 10:00 AM and ended at 2:00 PM, we would use **100*iPart(4*rand+10) + iPart(60*rand)**. For the TI-92™, use the instruction **100*iPart(4*rand( )+10) + iPart(60*rand( ))**. The hours would show up as 1000, 1100, 1200, and 1300 as with a 24-hour clock.

Activity 6
How Random Are You?

For this activity, you and your partner need to have a calculator that will generate random numbers.

1) Use your calculator to generate a list of 8 random decimal numbers between 0 and 45.

2) Use your calculator to generate a list of 8 random integers between 0 and 45.

3) Use your calculator to generate a list of 10 random integers between 1 and 100.

4) Use your calculator to generate a list of 10 random integers between 40 and 75.

5) Use your calculator to generate a list of 10 random decimal numbers between 2.00 and 3.50.

6) How would you generate a list of random numbers to select 5 days in the month of March on which to observe the workers in a laboratory? Do it and write down the dates you found.

7) This time, you and your partner need to generate a list of 28 times between 8:00 AM and 4:00 PM. You will be visiting a factory on 7 days: August 1, 2, 3, 6, 7, 8, 9, and you will make 4 observations on each of those days. Use the list you found to write the times when you will be observing on each day.

Homework 6
Determining Random Times

1) Generate a list of 10 random times between 8:00 AM and 5:00 PM.

2) Generate a list of 10 random times between 3:00 PM and 11:00 PM.

3) Generate a list of 10 random times between 12:30 PM and 5:30 PM.

4) Suppose that there are 172 technicians working at the OPF. You are going to do a work sampling study in which 6 of these 172 technicians will be observed. Using your calculator, describe how you would select the random sample of 6 technicians. Now do it, and write down the numbers of the technicians you selected.

5) You have been hired as a consultant to select at random 10 working days (Mon-Fri) in the month of November. Furthermore, you are to randomly select 5 times on each of those days when you will be observing the 25 people working in a factory. Using your random number generator, make a list of the 50 times (days and clock times) you will be visiting the factory.

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Bay 1 and Bay 2 (two cubical buildings) of the Orbiter Processing Facilities can be seen to the left of the Vehicle Assembly Building (VAB)

Appendix A

OSPREY TECHNICIAN SAMPLING WORKSHEET

Name: _____ Area Sampled: _____ Date_____Alternate Time:_____

Activity Table

				time	time	time
	ACTIVITIES	**DEFINITION**	**LOGIC (D= mark against Delay)**	**Sample Run 1**	**Sample Run 2**	**Sample Run 3**
1	Preshift briefing	Work responsibilities assigned; ends when tech begins work.				
2	Debris/other walkdowns	Check work areas at beginning of shift for debris; dispose of properly. Ensure safety of the area.				
3	Hazardous waste control	Move waste material to appropriate locations. Fill out and complete paper work; insure proper labeling.				
4	Continual Improvement	Attend Continual Improvement meetings; work on action items	if 4 then 4 if 13 then 4			
5	Training/Certification Classes	Includes travel time to and from class, and class attendance.	if 5 then 5 if 13 then 5			
6	Get/Return task paper	Locate and retrieve paper, or return paper at completion of task. Includes time to locate/return paper.	if 6 then 6 if 13 then 13D			
		paper delay				
7	Review task paper	Read through task paperwork.	if 7 then 7 if 13then 13D			
		engineering delay				
8	Get/Return parts	Get parts from logistics. Return parts after job complete.	if 8 then 8 if 13 then 13D			
		parts delay				
9	Get/Return tools & equipment	Obtain tools, shop aids, equipment from logistics or other locations. Includes checking out items to the shop. Return all tools and equipment to original location and check back in.	if 9 then 9 if 13 then 13D			
		tool equipment delay				
10	Inventory kitted parts, tools, equipment	Verify everything required to perform task is correct	if 10 then 10 if 13 then 13D			
		parts delay				
		tool equipment delay				
11	Obtain Quality and safety support	Sign up for Quality inspector; call for safety	if 11 then 11 if 13 then 13D			
		quality/safety delay				
12	Attend Task Team Briefings	Briefing prior to performing the task. Includes time to go to and from meeting.				

Continued on next page

Activity Table Continued

				time	time	time
	ACTIVITIES	**DEFINITION**	**LOGIC (D= mark against Delay)**	**Sample Run 1**	**Sample Run 2**	**Sample Run 3**
13	Real work on WAD	"Wrench turning." Includes stand-by for Quality inspection or start of job. (This is the intent of the assigned task.)				
		paper delay				
		engineering delay				
		quality/safety delay				
		parts delay				
		tools/equipment delay				
		scheduling delay				
		unplanned hardware problem delay				
		other delay				
14	Write problem reports	Obtain form; request initiation of report; fill out form; attach form to part and route to proper location.	if 14 then 14 if 13 then 13D			
15	Tie-in	Job status communications. May occur at any time of the day.	if 15 then 15			
16	Shop Work	Work not requiring a task number. May include shop clean up.				
17	Not Assigned	Awaiting supervisor direction on work assignment(s), or previously assigned job completed.				
18	Loaned out	Technicians on loan to another area.				
19	Other	Does not fit into any other category or unable to find tech after 5 minutes. Activity must be described below				
20	Scheduled down time	Lunch, breaks				
21	Leave	Sick, vacation				

Roster Table

Technicians	1	2	3	4	5	6	7	8	9	10
Name, Initials, or I.D.										
Sample Run 1										
Sample Run 2										
Sample Run 3										