Three-Dimensional Coordinate Measurement of Historic Half-Hulled Ship Models | 1996-30

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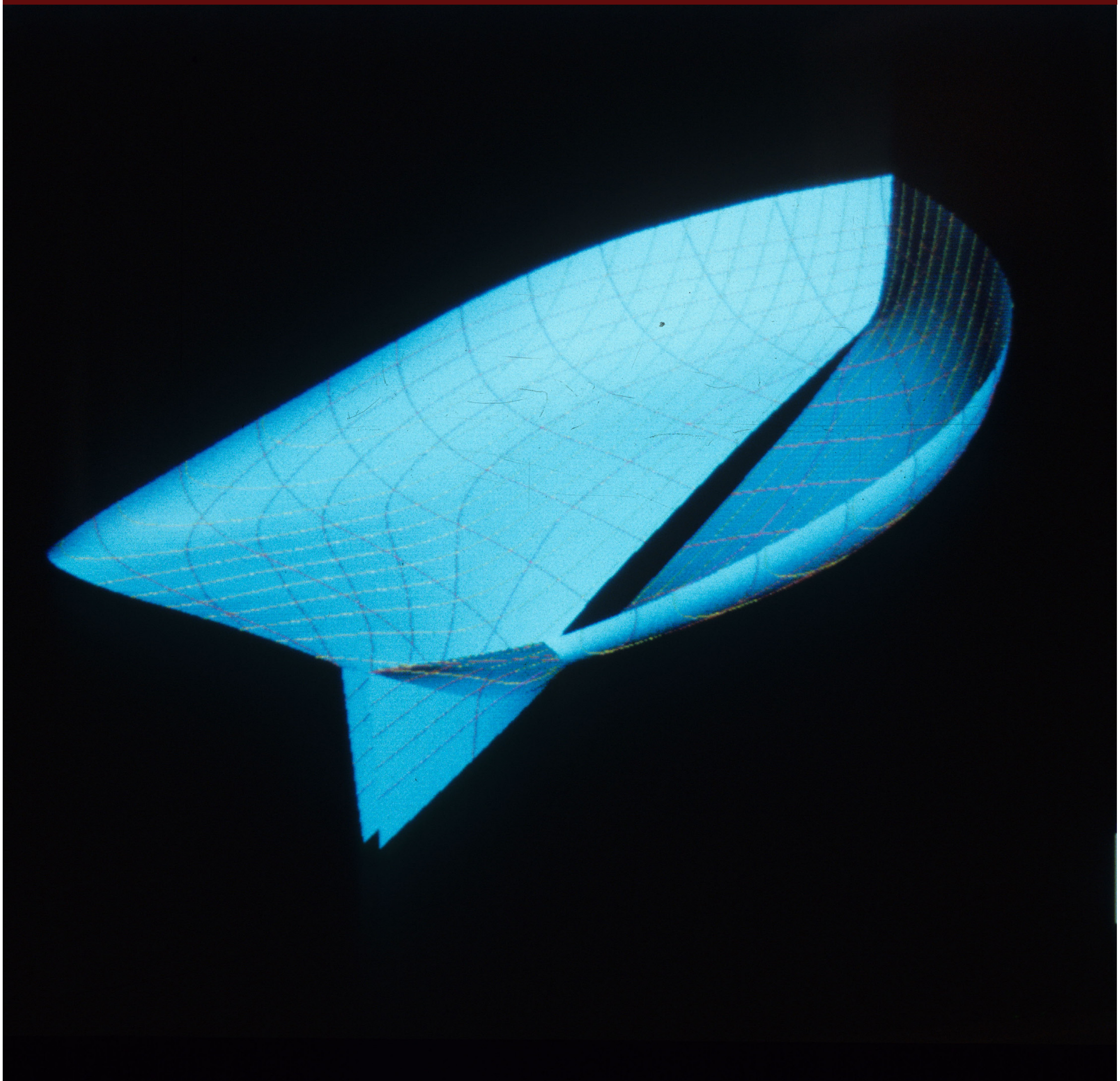

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INTRODUCTION:

This manual is intended to outline the measurement process of complicated three-dimensional curvilinear objects using the Faro Technologies Bronze Series Liberated CMM (Coordinate Measuring Machine) in conjunction with various software packages to produce both two-dimensional and three-dimensional drawings of these objects and their surfaces. It discusses the measurement of half-hull ship models in particular, with the ultimate goal being the generation of traditional lines plans and hydrostatic information for the vessel represented in this wooden form. While the techniques involved in the measurement process are generally the same for any three-dimensional object, the choice of software and output may differ for objects other than half-hull models. The end result is largely driven by the software chosen. If machine parts are to be measured, software that is normally used to generate machine parts may be better suited to the job than software dedicated to the production of ship's lines. Some of the software available is suitable for the production of drawings of almost any object (Autocad, Generic Cadd) while some is designed very specifically for naval architecture (Nautilus, Multisurf, Baseline, GHS Yacht). The Faro CMM is the constant and initial step in the process, and remains independent of the object to be measured. The manual will go into detail on the process of measuring hull forms, but will leave the measurement of other objects largely up to the individual operator's discretion.

The manual is set up in this way: It begins with a brief explanation of the measurement of surfaces in general, before moving on to a complete description of the Faro Arm and its use, from the setup of the machine as it is removed from its case through its calibration and onto the methods used to measure difficult objects. This first section is quite straightforward and easily accomplished. The next part moves into the problem of what to do with the information after it has been gathered. This is the more difficult part of the job: creating a surface from the data that has been gathered. Once the surface has been successfully created with the software, the final production of lines plans and formal drawings, which is once again more routine, is dealt with. Chapter XXX of this manual deals with this task. The last chapter of the manual discusses the measurement of other objects in an attempt to start operators out in the right direction.

While a high level of computer literacy is not required to operate the Faro Arm, this manual assumes some basic knowledge of the use of a IBM compatible PC running both Windows for Workgroups 3.11 and DOS. If the operator is completely unfamiliar with these operating systems, he or she should read any of the available beginning books on the subject or go through the Window's Tutorial on the laptop, which is found under the **Help Menu** in the **Program Manager.**

As a final word of explanation, I have tried to describe each task in a step-by-step fashion that leaves as little to the imagination as possible. This is not through any doubt of the reader's ability, but rather as an attempt to make the measurement process as fool-proof as possible. For users who wish to go further, the original Faro Arm and software manuals are included with the system. This should provide plenty of room for creativity beyond the measurement process covered here.

The information found in this manual is a distillation of the Faro Arm manual that is included with the machine, and covers only the procedures that are absolutely necessary for this particular measurement project. Since the Faro Arm is primarily intended for use as a machinist's tool, there are many functions that do not pertain to the measurement of museum pieces. Where there is no use in our application, I have only stated the original purpose of the function and moved on, realizing that the operator can always return to the full Faro Arm manual for an explanation. I have also found, however, that the original manual does not describe some of the operations sufficiently, or in some cases does not mirror what occurs in the software package itself. This is at the least disconcerting to the operator and can lead to a certain level of frustration. There is enough to be learned without having to constantly stop and figure out the operation of the arm itself. I hope that my explanations will be a little clearer.

The manual has been set up to proceed through the standard Faro Arm operating screens, from top to bottom as they appear on the computer screen. The Faro Arm comes with two sets of software: a DOS version and a Windows version, and both are installed on the laptop computer. I will only describe the DOS version however, because it is by far more consistent than the Windows version. There are a few nice features in the Windows version, and the operator is encouraged to read the section concerning this in the Faro Arm manual and experiment with the software. I would recommend that this be done only after becoming familiar with the DOS version though, as this will clear up many of the questions that remain unanswered or are obscure in the Windows software.

THE MEASUREMENT OF A MODEL SURFACE

This manual deals primarily with the measurement of historic half-hull ship models. Historic models vary greatly in terms of the original construction quality and the preserved condition. Both of these factors influence the measurement process. Most of the models measured are the original builder's models, as these more closely represent the actual vessel built than do the historic decorative or presentation-quality models that exist. This is not to say, however, that the information gathered can always be taken as gospel. In many cases the models were only a rough start on the final design of the vessel. The vessels were often faired or changed when lofted out at full scale. Unless information is provided with the model to show otherwise, we can only talk about the form that the model represents and let each individual draw his or her own conclusions as to the way in which the form corresponded to the actual vessel built.

There are two separate goals in the measurement of these models, which may lead to two distinct methods of collecting data. The first goal is a curatorial one, relating to the models as objects in a collection, and treating the model simply as an artifact to be recorded and preserved. This process makes information available in a mathematical format rather than a wooden one. In a broad sense, it provides insurance in the way that photographs and written descriptions do, in case of damage or loss of the original model. From a curatorial standpoint, the more information that can be stored outside of the object itself the better, and if the electronic format happens to be efficient, that's better still. The operator may choose to treat the object simply as a complex curvilinear shape, and ignore the historic implications of the vessel that was constructed from the model.

In addition, the measurements taken need to take the future into account. The rapid rise in computing power over the last ten years leads us to expect that we will have more advances in our future, both in terms of computing hardware and the software to handle the data we generate today. Five years ago, surface modeling of complicated objects was done on expensive mainframe computers and graphic workstations. Today, there are many additional options available using relatively inexpensive desktop personal computers to handle the information collected with the CMM. However, we may still need a few more years of software advancement in the desktop line before we are fully satisfied. This means that the operator of the CMM might want to consider future computer developments while measuring the models today.

The Faro CMM is used to collect simple three-dimensional coordinate points from a given surface. The simplicity of this data helps to ensure its future in a changing electronic world. The software that dealt with mathematical descriptions of objects in the past used these coordinate (X,Y,Z) values. The current software and the software of the future uses and will continue to use these values. Therefore, we can be reasonably assured that the measurements we take today will still be useful in the future, and we should be careful to take enough data for software we can only envision now. This approach will also lead to the best description of the surface as it exists at the time of measurement.

The measurement process should attempt to acquire the most information possible. Given that these models are significant historic artifacts, the process should only be performed on each model once. Going back time and time again to a particular model increases the chance of damaging that model. If this is the case, how is this model to be measured? With any complex irregular curvilinear surface the best definition is going to be achieved by obtaining a dense cloud of points over that entire surface. Gathering and recording twenty points over the surface of a half-hull will give a very poor approximation of the surface you are trying to capture. Two thousand points may give you an acceptable representation, while twenty thousand points may be considered overkill. The operator must therefore make a judgment concerning the density of data points necessary to collect for each individual model, which will vary not only in size but also in complexity. A clipper ship model requires more points in its definition than a skiff model does. Given that the Faro CMM can acquire over five hundred coordinate points a minute, it will not be overly time consuming to collect an appropriate amount of data. So the goal of the first measurement method may be to generate a data set both for curatorial records and for the software of the future, which will ideally be able to handle the more irregular cloud point data. The second method of measurement has to do with the model as a design tool of the past. The majority of the models measured fall into the builder's model range. These are models from which the actual ship was lofted out to full scale. The surface they represent is quite different from the curatorial surface already discussed. The surface these models were created for originslly was an "ideal" surface, that is, its small imperfections were going to be lofted out of the equation when the model went to full scale.

Although these models were not dented, nicked or scarred when first constructed, it wouldn't have really mattered to the builder in that the model was only going to provide a beginning for the loftsman. Today we have models in all conditions, but from a hull design standpoint (unless the model is heavily damaged) this will not affect this second measurement process, that is, the process aimed at generating the information the model was originally built to provide. After these models were built, they were taken apart and measured at particular intervals, such as station intervals. The hull shape in between the intervals was ignored, except as the "glue" that connected the station information into a seamless whole. The models provided simple coordinate values to describe stations, profiles, edges, waterlines, transoms and other prominent design elements. It is not a surface generation in the way that the curatorial generation is; rather it describes representative curves mathematically in space with only the points required to describe each curve sufficiently.

Of the infinite points available on the original surface, only a few were actually used to describe the ship. In this same way data for our new mathematical description of the surface will contain a smaller amount of points than that of the curatorial description. It reflects the original intent of the wooden form, and meshes with the software available in terms of the way the information is taken and stored. Instead of lofting the ship out full scale with wooden battens in two dimensions, we loft it out mathematically at full scale with electronic battens in three dimensions.

Now that I have described two different ways of measuring surfaces, it is up to the individual operator to decide which type of information to acquire. If the object is not a model, there may be another method of measurement to apply. Usually this method will try to mimic current standard practices for the drawing of that type of object. This may be six orthographic views of an object in two dimensions or a full three-dimensional model of the object. The operator should experiment with all of these forms. A description of the methods used to capture either the curatorial surface or the mathematical surface are described in Chapters xxx and xxx, after the description of the Faro Arm itself.

Description of the Faro Arm or CMM (Coordinate Measuring Machine)

The Faro Bronze series CMM is a six-degree-of-freedom arm with an operating hemispheric envelope of approximately eight feet. Each of the six joints on the arm have a hybrid analog/digital rotary transducer to keep track of the rotation at each joint as the arm is moved through space. The signals from these transducers are sent via serial cable to a serial controller box, and from there to a computer through another serial line. All of the information gathered from the transducers is resolved into coordinate values for the location of the tip of the machine, which contains a probe for measurement of objects.

This probe can be a ball probe or a point probe. Steel tips come as standard equipment with the machine, but I would recommend not using them on wooden artifacts, as they are more likely to damage the object than the custom tip we have machined out of Teflon. While the Teflon tip is less accurate in terms of repeatability, the piece of mind it provides to curators of historic artifacts is well worth it.

We have chosen to use a tip probe rather than a ball probe in order to eliminate the problem of offsets for the radius of the ball. With a ball probe, all measurements are taken at the center of the ball. This means that the radius of the ball and the direction of the offset must be factored into the equation to arrive at the real location of the point desired. Although this can be done automatically with the software provided, it is not as intuitive a process and leaves more room for operator error. The ball probe is a better way to measure in many ways, but its advantages for the type of measurements we are concerned with do not outweigh those of a point probe, which does not need offsets added to the final coordinates. If the individual operator needs the higher tolerances, the probes are available and need only to be calibrated once they are installed.

The Faro Arm itself has a simple two-button setup. The button closest to the probe tip is the data collection button. In single point mode, a single push of the button gathers a single point. In stream mode, pushing down the front button and holding it down gathers streams of points at the resolution previously set. If you wish to have a point taken every quarter inch, the stream resolution would be set to .25".

The back button is the data acceptance button. After collecting a single point or a stream of points, the operator must push the rear button to save the points to a file. If the point or points taken are not acceptable, the operator merely pushes the first button again to replace the first points taken with the new information. To save these new points the operator pushes the rear button.

The Serial Controller Box

The serial controller box has both signal and numerical processors that read and convert the raw data generated by the arm into three-dimensional coordinate points. The box will automatically detect worldwide AC input of 110/220 VAC, 50-60 HZ. The front of the serial controller box has a series of indicator lights: a green power on/off light, a red error light for problems and six red joint lights that show the end-stop status of each of the individual joints on the arm. Since each of the joints have less than 180 degrees of freedom of movement, a tone sounds when a particular joint reaches its end-stop and that particular joint's red light goes on to warn the operator not to take any data while this condition occurs. This prevents torque from being applied to the delicate mechanisms within the joints of the arms and prevents any damage the torque may cause. The serial controller box connection ports are clearly labeled to match the labels on the ends of the cables from both the arm and the computer.

Temperature Considerations for the Faro Arm

The Faro Arm has built into it a semiconductor temperature sensor to monitor fluctuations in the room temperature. The optimum operating temperature is around 71° Fahrenheit. The machine should be operated in a room that does not fluctuate in temperature more than ±5°. If these conditions are not met, the Faro serial controller box will beep and not allow measurements to be taken until the temperature has stabilized for at least five minutes. During normal operation, the serial controller box constantly makes corrections to allow for the expansion and contraction of materials throughout the arm, ensuring greater accuracy during the measurement process.

Maintenance of the Faro Arm

The Faro Arm is a delicate measuring instrument, and should be treated as such during its use, storage and shipping. There are also a number of recommended steps that should be taken to prevent problems from cropping up. These are:

1) Cover both the arm and the serial controller box with their respective dust covers when not in use. Do not run the serial controller box with the dust cover or anything else blocking the air flow through the unit.
2) Clean the Faro Arm with a dry dust cloth. **Do not use any cleaning liquids on the arm or serial controller box** as this may damage the equipment. **Do not use any lubricants on the Arm or its related equipment.**
3) Make sure the cooling fan runs when the power is turned on to the serial controller box. If the fan does not come on with the power, turn off the machine immediately and contact Mystic Seaport for help.

4) Make sure the cables and their connections from the Faro Arm to the serial controller box and between the serial controller box and the computer are not damaged. Do not bend or kink any of the related serial cables, as this may damage them.
5) If anything appears to be wrong with the equipment, shut it off and notify **Mark Starr** at Mystic Seaport Museum (phone # **860-572-0711, extn. 5092**)

Care of the Laptop Computer

The Toshiba laptop computer that goes with the Faro Arm is also a delicate machine and should be treated as such. Please follow these suggestions to ensure a long and useful life for the computer.

1) Keep the computer in a reasonably controlled environment in terms of temperature, moisture, and dust.
2) Be careful to avoid shocks while moving the computer.
3) Allow plenty of air circulation around the computer to prevent overheating. Do not place anything on top of the computer at any time.
4) Do not use an A/C outlet that is subjected to fluctuations in voltage.
5) Only use the cables and adapters supplied with the computer.
6) Do not push on the LCD screen or expose it to direct sunlight. Do not hold the computer by its screen, or push the screen beyond its full open position.
7) If there is any indication of problems with overheating turn off the machine at once and contact **Mark Starr** at Mystic Seaport Museum (phone # **860-572-0711**, exten **5092**)

Setup of the Faro Arm

The Faro Arm is shipped in a substantial, padded plastic case. Although it is somewhat inconvenient, the arm should always be transported in this case and stored in it when not in use for long periods of time. This will help prevent damage to the instrument. The setup of the arm is straight forward.

The first requirement for the Faro Arm is a solid work surface to attach the arm itself to. The heavy C-clamp should be securely fastened to the surface of the table first. There are two wooden pads in the transportation case to help prevent damage to the work surface, but the operator should note that the machine should not be clamped to a valuable table top, as the clamp exerts considerable pressure. After tightening down the clamp, the post that will hold the Faro Arm is threaded onto the base clamp. The post has a 3.5" threaded ring that fits over the clamp base. This should only be tightened by hand. Once this has been installed, the Faro Arm itself can be slid down over the post shaft and locked into position with the large hand screw. The arm should be positioned so that the serial cable that threads into the bottom of the arm clears the table top.

Once this hardware has been securely fastened, the serial controller box (the blue metal box that provides the power to the arm itself) can be set in a convenient location, as well as the Toshiba laptop computer. The next step is to connect the Faro Arm to the controller box. The heavy, long, gray cable plugs into the bottom of the Faro Arm by aligning the round connection (labeled #4). It will only fit into the bottom of the arm in one position. Once it is rotated into this position and pressed in, the outer screw lock can be rotated and turned to lock the cable to the arm. The other end of the serial cable (labeled #3) plugs into #3 on the back of the blue serial box. The light putty colored serial cable also plugs into the serial controller box and connects it to the laptop computer. The end labeled #2 plugs into #2 on the back of the serial box, and the other end of the plug (#1) plugs into the serial port on the back of the computer. The computer is labeled on the bottom of the unit to show what the various ports are for. The rear of the serial controller box also has an A/C power in outlet on the bottom left corner on the back of the box. The short black power cord plugs in here, and then into a regular **110V grounded** outlet. It is generally best to plug the laptop into this same type of outlet rather than to rely on the computer's battery power for the duration of the measurement process. This is all that is required to set up the machine and begin operation. Power up the serial controller box by flipping the toggle switch directly above the A/C in socket. (This is the black switch, not the red button above it. The red button is a reset button.) Power up the Toshiba laptop by pushing in the ON button on the left side of the computer at the back corner until the power on light comes on and you hear the disk drive start to wind up.

Calip3d - Operating System Software

Calip3d is the operating software provided with the Faro Arm. The software has a DOS and a Windows version. Both are installed on the laptop computer. While each version does *most* of the same things, there are some differences between them. Depending upon the project measurement needs, the operator may choose one over the other. I will describe the operation of the DOS version, as it is the most consistent and more highly developed version. After becoming familiar with the DOS version, the operator should take a look at the Windows software, which largely operates in the same fashion, but is more graphically oriented.

Once the laptop is turned on, it automatically goes to Windows for Workgroups 3.11. The operator needs to leave the Window's environment and return to DOS by clicking on FILE, located at the top left of the Program Manager, and then clicking on the EXIT WINDOWS option at the bottom of the-drop down menu. After answering **OK** to the prompt the operator will be sent to the **C:** prompt in the DOS environment.

Before entering the Calip3d software program, the operator should make sure that all of the proper connections between the Faro Arm and the serial controller box and the serial controller box and the laptop computer have been made, and that the serial controller box has been turned on and has cycled through its startup procedure. The operator is then ready to load Calip3d.

Enter the Calip3d software package (which has been pre-installed on the Toshiba laptop) by typing **calip3d** at the DOS prompt and then pressing **ENTER↵** This will start the Calip3d software program and bring you to the first screen. The first screen looks like this and provides some general information:

Caliper 3D
V 2.09
Connected with Arm 308-02-94-00676
Last Calibrated 12-12-94
Version 2.04
Connected: Com 1 9600 n 8 1
Hit any Key to Start Program

If the proper connections between the serial controller box, the arm and the computer have not been made, or if the serial controller box has not been turned on and cycled through its setup procedures, the software will perform a scan sequence to try and find the connection. In this case, the initial screen will look like this:

Caliper 3D
V 2.09
Attempting Com 1 9600 E 7 1
<R>econfigure Com <E>xit to DOS

Pressing the **R** key will allow the operator to tell Calip3d where the connection is made, and pressing the **E** key will bring the operator back out to DOS. Since the laptop has already been configured to run with the Faro Arm, the operator should not go to the **Reconfigure** option by pushing the **R** key, but should instead press the **E** key and return to DOS, where the connections can be made and the serial controller box turned on. After this has been done, the software can be relaunched by typing **calip3d** at the DOS prompt and pressing **ENTER↵**. To move to the second screen merely press **ENTER↵** again. This is the Default Settings screen, which gives an overview of the defaults that have been previously set. This is only used as a review screen: no defaults can be changed from here. The screen looks like this:

```
                 Default Settings
                      V 2.09
        Connected with Arm  308-02-94-00676
                Calibrated 12-12-94

Current Tip----------------------->Point Tip
Tip's X--------------------------> +000.4425"
Tip's Y--------------------------> -001.3453"
Tip's Z--------------------------> +004.9328"
Tip Calibration-------------------> ≅ 0.0066"
Probe Compensation----------------> Off
Communications-------------------->1   9600   N   8   1
Snd: Main/alrm/Box/Stop----------->on/on/on/on
Freq1/Freq2---------- ----------->100/200
Save File Format------------------>xyz
Aux Switch------------------------>Off
Options Port---------------------->Off
Units----------------------------->Inches
Stream Resolution----------------->0.25"
Arm Temperature------------------->+24.13 (deg C)
Arm Controlled Scroll------------->Off

Hit any Key or Button to Continue
```

After reviewing the default settings, press **ENTER↵** to advance to the next screen.

The next screen is the Utilities Menu and is the first working screen. It lists the nine possible choices for the operation of the Faro Arm. The screen looks like this:

Utilities Menu
Point Tip

0)---<Exit Program>
1)---<Setup object coordinate system>
2)---<Setup leap frog coordinate system>
3)---<Collect 3d points>
4)---<Collect 3d point streams>
5)---<End effector tips>
6)---<Certification>
7)---<Change default settings>
8)---<Build Mode>
9)---<Diagnostic>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The options in the menu are selected through the use of the **up** and **down** arrow keys and by pushing the **ENTER** ↵ key. It should also be noted that the two buttons on the Faro Arm itself can be used to move up or down through the program and make selections. However, their performance is somewhat erratic and occasionally can lead to unexpected results (including loss of data). It is recommended that the arrow keys be used until familiarity is increased with the operation of the program and the buttons on the arm. In many cases, the buttons in the Windows version of Calip3D do not work as a selection tool. The way in which the buttons are *supposed* to perform is listed at the bottom of each screen and looks like this:

ENTER Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

I will now progress through the Utilities Menu program one menu choice at a time.

Setting The Object Coordinate System

(0)---<Exit program>

To leave the program and return to DOS use this first option. After highlighting this menu choice by arrowing up or down to it, press **ENTER ↵.** This leads to a screen asking if the operator really wants to leave the program and gives a **yes** or **no** choice. Once again, arrow up or down to the required action and press **ENTER↵.** Answering **no** returns you to the previous screen. Answering **yes** takes you immediately to the DOS **C:/>** prompt. The next choice on the menu is:

1)---<Setup object coordinate system>

This item sends the operator to the Object Alignment screen, which has eight choices of its own and looks like this:

Object Alignment
Point Tip

0)---<Cancel>
1)---<Three points>
2)---<Three spheres>
3)---<Key-in>
4)---<Three datum points>
5)---<Plane/line/datum/offset>
6)---<Three datum planes/offset>
7)---<Clear Alignment>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The Object Alignment screen is where the coordinate system to be used during the measurement process is initially set up. The machine will use the center of the one inch steel sphere located at the base of the arm itself as the origin point for all of the data collected; that is to say its value is (0,0,0). All data taken from the object is referenced from the steel sphere. While this is perfectly acceptable, it is often not as convenient as one would like. The Object Alignment screen therefore allows the operator to set up the origin at any location desired, usually a prominent feature on the object itself. The coordinate system is a regular Cartesian coordinate system and is defined by points, lines and planes. The choices on this screen offer six ways in which to set up the object coordinate system, either on the object itself or in some other meaningful way. Any of the other choices may be accessed by arrowing up or down to highlight the choice and pressing **ENTER↵**. The first choice is:

0)---<Cancel>

This returns the operator to the previous Utilities Menu screen. The next menu choice is:

1)---<Three points>

This option allows the operator to define the coordinate system using three points. When this option is picked, a Coordinate System screen appears, which looks like this:

Setup Object Coordinate System
Point At Object Origin

x: -0006.9334" y: +0010.7010" z: +0002.8132"	
Capt XYZ	

	CNT: 00000	

Digitize Point #1 on Position #1

Hit < Front Button> to digitize point

Hit < Back Button> twice to quit

This screen asks the operator to digitize in a first point at the desired location of the origin (0,0,0). As you will notice, the third line up from the bottom of this screen is asking for point #1 on position #1. The reason for this is that the operator can take multiple points at the origin and have the machine average those "hits" to get a more accurate origin. This is intended more for high-precision measurement of machine parts, where you may have a machined hole to use as the origin with the ball probe installed as the end effector. However, in working with a point probe, the ability to reference the same exact point is somewhat lost. The operator measuring half-hull models will only need to take one "hit" at the origin unless he or she does not like the spot recorded when the actual point was acquired. While multiple points may be taken and averaged, for the purposes of this project the operator will generally take only one "hit" at each required location.

To take the first point for the Three Point Mode the operator moves the arm to the point desired on the object and, after placing the tip on the exact place, pushes the front button. A beep sounds to acknowledge that a point has been taken. If the point is the desired one, the operator then presses the rear button to accept the data. If it was not quite where he or she intended to take the point, the operator simply moves the arm to the new location and presses the front button again. This clears the first attempt and replaces the old data with the new point information. Pushing the rear button records the new location permanently. After pushing the front button, the screen looks like this:

Setup Object Coordinate System
Point At Object Origin

x: −0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

x: −0000.0070"
y: +0000.0300"
z: +0000.0420"

CNT: 00000

Digitize Point #1 on Position #1

Hit < Front Button> to redigitize point
Hit < Back Button> to store point

The operator can see the location of the point picked for the origin. As the bottom two rows of commands show, the operator pushes the rear button if happy with the point chosen, or redigitizes the point by selecting a new origin.

When the rear button is pushed, the screen changes to this:

Setup Object Coordinate System
Point At Object Origin

x: −0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

CNT: 00001

Digitize Point #2 on Position #1

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

We now see that one point has been recorded and that the system is ready to take another "hit" at the origin for averaging if desired (Digitize Point #2 on Position #1). In general, however, the operator will not be doing this, and instead will advance to point number two by pushing the rear button twice more. (The two pushes of the rear button are in addition to the first push of the rear button, which stored the first point. Also note that the button can not be pushed too rapidly in succession. Although the serial controller box will beep twice, sometimes it does not actually record the two beeps. Simply push the rear button one more time if the software does not advance. The screen updates to reflect the operator's desire to move on and looks like this:

Setup Object Coordinate System
Get Pt on +X axis >11" from Pt 1

x: -0006.9334" y: +0010.7010" z: +0002.8132"	
Capt XYZ	
CNT: 00000	

Digitize Point #1 on Position #2

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

This screen tells the operator to Digitize Point #1 on Position #2 and that this point should be more than 11" from the first point and in the direction the operator wants to be the positive X axis: Get Pt on +X axis >11" from Pt 1. The operator then moves the arm to this point and takes a first "hit" to record it. After pushing the front button, the screen looks like this:

Setup Object Coordinate System
Get Pt on +X axis >11" from Pt 1

x: −0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

x: +0023.3214"
y: +0000.0810"
z: +0000.0660"

CNT: 00000

Digitize Point #1 on Position #2

Hit < Front Button> to redigitize
Hit < Back Button> to store point

By pushing the back button this first "hit" on the second point is recorded and the operator is given a chance to take more "hits" if desired. Generally though, the operator pushes the rear button two more times to advance to the third screen and gather the third and final point. This next screen looks like this:

Setup Object Coordinate System
Get Pt on +XY Pln >11" from Pts 1&2

x: -0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

CNT: 00000

Digitize Point #1 on Position #3

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

The operator is now asked to get a third point to finish the definition of the **XY** plane by picking a triangular point more than 11" from both of the first two points. (The greater the spread in the points taken the more accurate the geometry will be. Eleven inches is the minimum distance allowed by the software). This screen command looks like this: Get Pt on +XY Pln >11" from Pts 1&2.

Once the third point has been taken and recorded, the operator pushes the rear button twice again to finish the Three Point object alignment phase. The **XY** axis and the **XZ** axis are then resolved by the software and set square to the **XY** plane defined by the three points digitized by the operator. The coordinate system to be used during the measurement process has been completely established, and all new measurements taken will be relative to the new (0,0,0) origin. The screen then automatically returns to the previous screen:

Object Alignment
Point Tip

0)---<Cancel>
1)---<Three points>
2)---<Three spheres>
3)---<Key-in>
4)---<Three datum points>
5)---<Plane/line/datum/offset>
6)---<Three datum planes/offset>
7)---<Clear Alignment>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

From here the operator, if happy with the new coordinate system, can exit by picking 0)---<Cancel>, or can start the whole process over by choosing any of the other options. This brings us to the next choice on the Object Alignment Screen:

2)---<Three spheres>

This menu choice requires the use of three high-precision steel spheres to be located with the Faro Arm to create the object coordinate system and will not be used in this particular project. It is designed for precise machined parts measurement and does not make sense in terms of the point probe that we are using. A full discussion of this method is available in the Faro manual.

The next choice on the Object Alignment screen is:

3)---<Key-in>

This menu choice also will not be used in this particular project. It is intended for use with multiple Faro Arms whose coordinate systems are tied together with lasers. A full discussion of this method is available in the Faro Manual.

This brings us to the next choice on the Object Alignment screen:

4)---<Three datum points>

Once again, this menu choice will not be used in this particular project. It, like the Key-In screen, gives the operator the ability to directly type in the coordinates for an origin that is unreachable with the Faro Arm. It is intended for an object that already has an established origin. While this is of some use in special cases where the operator wants to return later to an object and gather new data, the object needs to have a set of three points that are permanently affixed and redigitizable. A full discussion of this method is available in the Faro manual.

This brings us to the next choice under the Object Alignment screen.

5)---<Plane/line/datum/offset>

This option, along with the Three Point method, is the easiest way to establish the coordinate system desired for projects such as this. This method first defines a plane, then an axis line, and then a point that defines the origin to create the coordinate system. After selecting this menu option, the operator goes to the first of several screens:

Select Plane
Point Tip

(0)---<Cancel>
(1)---<XY>
(2)---<XZ>
(3)---<YZ>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

Now the operator decides which plane, the **XY**, the **XZ** or the **YZ** plane to define. Typically this is an easily defined plane, such as the backboard that the model is mounted to. After arrowing down to the desired plane, the operator pushes the **ENTER** ↵ key and is shown this screen:

Plane
Digitize Points on XY Plane

x: −0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

CNT: 00000

Digitize PNT On X Axis on XY PLN

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

The next step is to begin to define the plane by digitizing in three points. The first point is picked by placing the probe and pushing the front button. This brings up this screen:

Plane
Digitize Points on XY Plane

x: −0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

x: +0016.3495"
y: +0004.9325"
z: +0012.9411"

CNT: 00000

Digitize PNT On X Axis on XY PLN

Hit < Front Button> to redigitize
Hit < Back Button> to store point

By pushing the rear button, the point is stored and the machine is ready to receive the second point of the triangle. After the rear button is pushed, the screen changes to this:

Plane

Digitize Points on XY Plane

x: −0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

CNT: 00001

Digitize PNT Along +X Axis on XY PLN

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

At this stage, the operator takes the second point on the plane in the direction that he or she wants the positive **X** axis to go: (Digitize PNT Along +X Axis on XY PLN), at least 11" away from the first point taken. After taking and storing the second point, the screen changes to look like this:

Plane
Digitize Points on XY Plane

x: −0006.9334" y: +0010.7010" z: +0002.8132"	
Capt XYZ	
CNT: 00002	

Digitize PNT In +XY Quadrant on XY PLN

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

The operator takes the third and final defining point for the plane at least 11" from each of the other points in an approximate equilateral triangle. After taking and storing the third point, the screen advances to a Select Axis screen which looks like this:

Select Axis
Point Tip

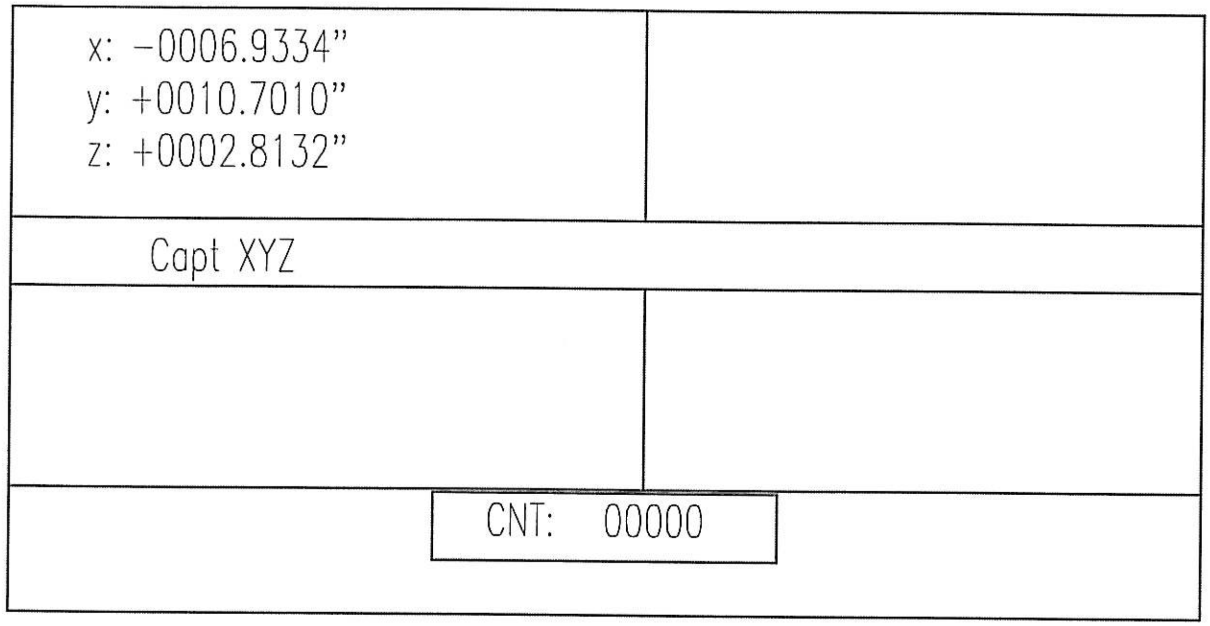
(0)---<Cancel>
(1)---<X>
(2)---<Y>

Enter Choice: 0

<FRONT BUTTON> or ↑↓ to Navigate
<BACK BUTTON> or ↵ to Select

This screen requires the operator to pick the axis line to be defined, either the **X** axis or the **Y** axis. After choosing the desired axis, the screen changes to the typical point acquisition screen:

Line
Digitize X Axis



Digitize Start Point

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

This first point selection is any point on the **X** or **Y** axis Digitize Start Point (depending on which axis was chosen in the previous screen). The operator should keep in mind, however, that the next point asked for will be in the positive direction, so this first point should be at the negative end of the axis. After picking the first point and saving it, the screen moves ahead to:

Line
Digitize X Axis

x: −0006.9334" y: +0010.7010" z: +0002.8132"	
Capt XYZ	
CNT: 00001	

Digitize End Point

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

The computer is now looking for the end point of the **X** axis. After digitizing the second point along the axis, the screen changes to:

Point
Digitize Datum Origin

x: −0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

CNT: 00000

Digitize Point #: 1

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

The point to be digitized now is the point that the operator wishes to be the origin, or (0,0,0). After picking this point with the front button and saving it with the rear button, the screen changes to this:

Enter Offsets To Datum Point

Enter Offset X:

Hit <ENTER> or <FRONT BUTTON> for 0.0

The purpose of this screen is to allow the operator to enter offsets if the pointer can not reach the desired location. This is generally used when the ball probe is on the machine and the radius of the ball needs to be factored in. As the point probe will generally be able to reach the point required without offset corrections, the operator can Hit <ENTER> or <FRONT BUTTON> for 0.0 to enter +000.000 as the offset desired. Hitting **ENTER↵** three times enters 0.0 as the corrections to be applied in the X,Y, and Z directions. If offsets are required, the operator types in the decimal value for each variable. After the offsets have been entered, the machine returns the operator to the initial Object Alignment screen:

Object Alignment
Point Tip

0)---<Cancel>
1)---<Three points>
2)---<Three spheres>
3)---<Key-in>
4)---<Three datum points>
5)---<Plane/line/datum/offset>
6)---<Three datum planes/offset>
7)---<Clear Alignment>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The coordinate system has now been set using the Plane/line/datum/offset mode. The next menu choice is the:

6)---<Three datum planes/offset> mode.

This selection allows the operator to set up a coordinate system by defining three planes (XY, XZ & YZ) with the origin at the intersection of the three planes. After choosing this particular method, the operator is brought to this screen:

Select Plane
Point Tip

(0)---<Cancel>
(1)---<XY>
(2)---<XZ>
(3)---<YZ>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The operator begins once again by choosing the first plane he or she would like to define. After picking, the operator is brought to a data capture screen:

Point
Digitize Points on XY Plane

x: −0006.9334" y: +0010.7010" z: +0002.8132"	
Capt XYZ	
CNT: 00000	

Digitize Point On X Axis on XY Pln

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

The operator is asked to (Digitize Point On X Axis on XY Pln). This begins the definition of the **XY** plane along the **X** axis. After picking a point along this plane and recording it with the rear button, the operator is asked to (Digitize PNT Along +X Axis On XY PLN). After picking this point, the operator is asked for the last point of the first plane- (Digitize PNT in +XY Quadrant On XY PLN). As before, this third point should be in an approximate equilateral triangle from the first two points and at least 11" away from both of the other two if possible. After gathering and recording this point, the screen changes to:

Select Axis
Point Tip

(0)---<Cancel>
(1)---<XZ>
(2)---<YZ>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

Here the operator can choose which of the two remaining axes he or she wants to digitize next. After making this choice, the operator returns to the digitizing screen:

Line
Digitize +X Axis On XZ Plane

x: −0006.9334" y: +0010.7010" z: +0002.8132"	
Capt XYZ	
CNT: 00000	

Digitize Start Point

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

The operator will begin to digitize the positive **X** axis on the **XZ** plane by digitizing the start point (which will define the starting point of the axis), and then the end point for the **Z** axis (which defines the positive direction of that axis). After defining this axis and plane, the screen changes to:

Point
Digitize Point On YZ Plane

x: -0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

CNT: 00000

Digitize Point #1

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

Here the operator will digitize a point to define the third plane, which will be mutually perpendicular to the first two planes. After choosing and recording this last point, the operator can specify offsets for each plane (if the ball probe is on the machine or the origin cannot be reached directly). The screen commands look like this:

Enter Offsets To Datum Planes

Offset for YZ plane, X=

Hit <ENTER> or<FRONT BUTTON> for 0.0

Pressing **ENTER↵** three times in succession enters a value of 0.0 for each offset for each plane. Of course the operator can choose a value other than zero for the offset if required. Once the offsets have been entered, the coordinate system is complete and the operator is returned to the Object Alignment Screen.
The last menu choice on this screen is:

7)---<Clear alignment>

If this menu choice is made, the defined coordinate system is cleared and reset to the machine coordinate system located at the center of the one inch sphere on the machine. The operator also may choose to redefine the coordinate system by picking any of the other choices and beginning anew.

SETUP OF THE LEAP FROG COORDINATE SYSTEM

The third choice on the Utilities Menu screen (see page xxx) is the:

(2)---<Setup leap frog coordinate system>.

The "Leap Frog" coordinate system allows the Faro Arm to measure objects larger than the eight-foot hemispherical envelope it is capable of reaching from one position. In order to do this, the operator moves the machine down the length of the object to reach other points while maintaining the same object coordinate system. (It is also possible to move the object past the machine and still maintain the same object coordinate system as long as one condition is met). In order to perform this "leap frog" jump down the length of the object, the operator digitizes three repeatable points (1, 2 &3), moves the arm (or moves the object, along with the three points attached to the object) and redigitizes the leap frog points (1, 2 &3) in the same order they were previously digitized. The software will then do the geometry needed to locate itself in the same coordinate system that had been previously set on the object. From here the operator can continue to digitize points on the object and have them all tied to the initial set of points from the first location.

Supplied in the Faro Arm case are three 2"x2" aluminum plates with a dimple stamped into the surface and an aluminum triangle with three dimples. These are the "leap frog" jigs. The operator can use the triangle to provide the three points needed to "leap frog" the machine, or if preferred, use the individual square plates, set up as a triangle, as the reference points. The dimples on the plates are marked 1, 2 and 3. The three plates or the triangle should be securely taped down to either the table on which the model is being measured or on the backboard of the model itself (this should be done only if absolutely necessary and only if no possible damage will occur to the backboard by the tape). In either case, all three points of the plates or the triangle must be reachable both before and after the Faro Arm or the model itself is moved. The important thing is that the three dimples always maintain the same spatial relationship to the model both before and after the move. After these conditions are met, the operator begins the Leap Frog move.

In order to begin this process, the operator picks (2)---<Setup leap frog coordinate system> from the Utilities Menu and hits **ENTER↵** This brings up:

Leap Frog
Point Tip

(0)---<Cancel>
(1)---<With points>
(2)---<With spheres>
(3)---<Recover temporary system>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The first choice cancels this screen and returns the operator to the previous Utilities Menu screen.

The next choice allows the operator to define three points (1, 2 &3) to be used as reference points during the move. If this choice is selected, the digitizing screen appears:

Setup Leap Frog Coordinate System

Fix Leap Frog Jig

x: −0006.9334" y: +0010.7010" z: +0002.8132"		
Capt XYZ		
	CNT: 00000	

Digitize Point #1 on Position #1

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

As before, the operator begins to Digitize Point #1 on Position #1. ***Unlike before the operator must take multiple "hits" on the leap frog jig, even with the point probe, before making the move***. The jig has been set up to allow the point probe to do this with reasonable accuracy, and multiple "hits" on each point will give greater accuracy to the move by averaging all of the "hits." The operator can take anywhere from five to fifty points at each of the three plates: the more points taken, the better the accuracy after the move. Since this is a very simple process, it is recommended that at least ten "hits" be taken at each point. It should be noted again that the three points should be at least 11" apart from each other. If the points are not this far apart, a warning will come up to let the operator know that this is not recommended, though it will allow the operator to continue.

The operator then takes the first five (at the minimum) "hits" at dimple #1. The counter on the screen records the number of "hits" taken as they are stored for the operator. When the operator is satisfied with the collection of points at the first dimple, he or she pushes the rear button twice after recording the last point to move to collect data at the second dimple. Once again, the operator takes and records multiple "hits" at this point until satisfied that there are enough to average, then pushes the rear button twice to move to the third dimple. After digitizing the third dimple, the screen jumps to this:

Setup Leap Frog Coordinate System
Reposition Arm and Redigitize

x: −0006.9334" y: +0010.7010" z: +0002.8132"	
Capt XYZ	

	CNT: 00000	

Digitize Point #1 on Position #1

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

At this point the operator moves the machine to its new location (or the object and the three points together to their new location) and redigitizes the same three points in the exact order they were taken in to begin with, that is Point #1, then Point #2 and finally Point #3. Once again, the operator takes multiple "hits" at each station to ensure accuracy. As the operator takes and records the points, the screen counts them and jumps to the next point after the rear button is pushed twice to advance. After redigitizing the three points, the operator is returned to the Utilities Menu and is then able to continue with the measurement of the object while maintaining the same object coordinate system.

If the machine determines that the leap frog method was not repeatable to under 0.10" it will not allow the operator to advance. This helps ensure accuracy and alerts the operator if the three points were digitized in the wrong order. This leads us to the third menu choice of the Leap Frog screen: (2)---<With spheres>

This choice operates in exactly the same way as the three-point method, except that it uses three machined spheres of a known radius as reference points. We will not use this method, however, as we have not purchased these spheres.

The fourth and final choice on the Leap Frog screen is the (3)---<Recover temporary system> menu choice. This screen allows the operator to recover the initial coordinate system from a power loss after the machine has been moved. Since this is its only function, and only works if the jig has not been moved, the chance of needing it is very slight. A full description of this function can be found in the Faro Arm manual. Remember that this is only to be used after a power loss. This finishes the discussion of the Leap Frog menu.

Collect 3D Points

The fourth selection on the Utilities Menu is:

(3)---<Collect 3d points>

This option, along with the next, provides the screens where the actual collection of data occurs. This option collects on a point-by-point basis, one at a time. The operator collects the data by placing the probe on the point of interest and then pushing the front button to take the point and the rear button to record it before moving on to the next point. If the operator is not happy with the point taken, he or she merely redigitizes it by pressing the front button again to clear the information and then records the new point. The old point is overwritten as long as the rear button is not pushed to record it.

After selecting this option, the operator is brought to a screen to enter the name of the file that the points to be gathered will be written to. No data can be taken without first naming this file. This screen will look like this:

```
                    Enter File Name


file name: c:\rawdata\



Alt-D   Directory        ALT-F   Format
```

It allows the operator to type in the name of the file. The name may be up to eight letters long and must consist of the usual characters allowed in DOS file names. No extension is required. The file, by default, will go into a directory named **RAWDATA**.

The operator may choose a separate directory location if desired, although it is best if it is a directory created by the operator rather than the Calip3D directory. This helps prevent unintended deletions of program files. To set the operator's directory as the default directory, use the Alt-D Directory option. By holding down the **ALT** key and then pushing down the **D** key the operator can enter the default directory for storage of the data files. Backspace through the directory **RAWDATA** and type in the new directory name. Pressing **ENTER↵** returns the operator to the File Name screen, where the name of the file can be entered. This screen also reflects the change in the default directory by displaying the new location.

By holding down the **ALT** key and then pressing the **F** key (ALT-F Format) the operator can choose to set the default format type for the files to be created. For the purposes of this project we will generally be using choice (3)---<XYZ>. Advanced users may make other choices, and if the information is to be directly imported into a CAD (**C**omputer **A**ided **D**esign) package then choice (5)---<DXF> is a better file type to choose.

If file name : t☺⇕⌖⌠♠p\, appears upon opening the file name screen, it is only because the default directory has not been previously set. Use the ALT-D function to change this from gibberish to a real directory. (Note: the directory should be in the form of **C:\\ *dirctoryname***)

After the operator picks the directory and the file type, both of which will be remembered for the next time, he or she types in the name of the file to be created and presses **ENTER↵**. This then brings up the now-familiar digitizing screen:

Collect 3D Points
Digitize Point

x: −0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

CNT: 00000
<F1> Help

Digitize Point #1

Hit < Front Button> to digitize point
Hit < Back Button> twice to exit/save

There is one difference from the digitizing screen we have seen before. This is the <F1> Help note below the point counter towards the bottom of the screen. This function button lists five options the operator has while taking point data. They are:

<F1>	help
<ESC>	no-save/quit
<RETURN>	save/exit
<R>	remark
<L>	lock angles

The **F1** key brings up the help screen. Hitting the **ESC** key discards all data collected and returns the operator to the Utilities Menu screen. Hitting the **ENTER↵** saves the data acquired and returns the operator to the Utilities Menu. By pressing the **R** key, the operator is given a small text screen where a remark can be typed to be saved with the point to be taken. This is helpful later on when trying to remember which points were which. The **L** key is supposed to lock the machine into taking a planer cut through the object. Although this function does not work in this mode, it is a very important function and will be addressed later in the chapter on gathering data for the production of ship's lines. Pressing the **ESC** key while the Help screen is open returns the operator to the Collect 3D Points screen.

The operator now begins the task of collecting the data points desired, pushing the front button to gather the point, and the rear button to store the point before moving on to collect the next point. When all of the points are taken, the operator pushes the rear button two more times. This saves all of the points to the file named previously and returns the operator to the Utilities Menu screen.

If it is necessary to return and digitize in more points on the model, the operator must once again go through the file naming screen before being allowed to collect data. If the file is named the same name as the previous file (or any other file already created with that name) this screen will appear:

That file already exists!
Point tip

File Name: Hull#1

(0)---<Append to old file>
(1)---<Over-Write old file>
(2)---<Enter a different name>
(3)---<Cancel>

[Enter Choice: 0]

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

Here the operator must decide whether or not to add the data to the existing file, get rid of the earlier data by overwriting the old file with the same name, name the file something completely new, or leave the program altogether and return to the Utilities Menu screen. After choosing the appropriate option the operator is sent to the digitizing screen to take more data or returned to the Utilities Menu if the (3)---<Cancel> option is taken.

It should be noted that the coordinate system described on the model will remain in effect, as this is stored in EPROM memory until changed through the coordinate system settings. It should also be noted that the system used on the model is good only as long as the model's location does not change in relationship to the Faro Arm. This ends the discussion of the collection of single 3d coordinate points.

Collect 3D Point Streams

The fifth selection on the Utilities Menu is:

(4)---<Collect 3d point streams>

This option, along with the previous one, is where the data is actually collected. Option three allowed the collection on a point-by-point basis, one at a time. This option allows for the gathering of point streams using three different methods. After selecting this option, the Select Stream Mode screen appears with four further options for the operator:

Select Stream Mode Point Tip

(0)---<Cancel>
(1)---<Free hand>
(2)---<Lock plane>
(3)---<Edge triggered>

——————[Enter Choice: 0]——————

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The first option allows the operator to return to the previous screen. The second choice, (1)---<Free hand>, allows the points to be taken in a continual free-hand stream. This means that as the operator moves the arm through space (or along the object to be measured) the arm records a continual stream of points as long as the front button is held down. The resolution of the point data taken is set through the stream resolution setting. The operator can tell the machine how often it should record a point in terms of linear travel of the tip. If the operator wants a point every quarter of an inch the resolution is set to 0.25". After setting this resolution, (Note: The resolution is set from choice (6)---<ENTER stream resolution> in the Default Settings Menu, which is choice (7)---<Change default settings> in the Utilities Menu). the points will be taken any time the arm moves a quarter of an inch from its last point in any direction.

After choosing (1)---<Free hand>, the operator is brought to a screen to enter the name of the file that the points to be gathered will be written to. No data can be taken without first naming a file for the information to be written to. This screen looks like this:

```
                    Enter File Name


file name: c:\rawdata\



      Alt-D   Directory        ALT-F   Format
```

This allows the operator to type in the name of the file he or she wishes to create. The name may be up to eight letters long and must consist of only the usual characters allowed in DOS file names. No extension is required. The default directory where the data will be stored is named **RAWDATA**.

The operator may choose a separate directory location if desired, although it is best if it is a directory created by the operator rather than the Calip3d software directory. This helps prevent unintended deletions of program files. To set the operator's directory as the default directory, use the Alt-D Directory option. By holding the **ALT** key down and then pushing down the **D** key, the operator can enter the default directory used to store the data files. Backspace through the directory **RAWDATA** and type in the new directory. Pressing **ENTER↵** returns the operator to the File Name screen where the name of the file can be entered. The screen reflects the change in the default directory by displaying the new location.

By holding down the **ALT** key and then pressing the **F** key (ALT-F Format), the operator can choose the default format type for the files to be created. For the purposes of this project we will generally be using choice (3)---<XYZ>. Advanced users may make other choices, and if the information is to be directly imported into a CAD (**C**omputer **A**ided **D**esign) package then choice (5)---<DXF> is a more appropriate file type to choose.

If this appears upon opening the file name screen: file name : t☺⇳⌖⌠♠p\, it is only because the default directory has not been previously set. Use the ALT-D function to change this from gibberish to a real directory. (Note: the directory should be in the form of **C:\ *dirctoryname***)

After picking the directory and the file type, both of which will be recorded for the next time, the operator types in the name of the file to be created and presses **ENTER↵.** This then brings up the digitizing screen:

3D Point Stream
Resolution: 0.25000"

x: -0006.9334"
y: +0010.7010"
z: +0002.8132"

Capt XYZ

CNT: 00000
<F1> Help

Digitize Point #1

Hold < Front Button> for stream
Hit < Back Button> twice to quit

Once again there are a few differences from the previous digitizing screen we have seen before. There is the <F1> Help note below the point counter towards the bottom of the screen. This function button lists five options the operator has while taking point data. They are:

<F1>	help
<ESC>	exit
<R>	remark
<S>	resolution
<L>	lock angles

As we have seen, the **F1** key brings up the help screen. Hitting the **ESC** key in this menu will only allow the operator to leave the digitizing screen if no data has been gathered. This helps prevent accidental data loss, as the operator must save the points before leaving this mode if points have been taken. If no data has been taken, the **ESC** key leaves the data collection screen and returns the operator to the Utilities Menu screen. By pressing the **R** key, the operator is given a small text screen where a remark can be typed and saved with the points to be taken. This is helpful later on when trying to remember which points were which. Pressing the **S** key while in this digitizing mode allows the operator to set the stream resolution without having to leave to go to the Default Settings screen. After pressing **S**, a screen pops up and the value of the resolution can be entered and saved. The **L** key is supposed to lock the machine into taking a planer cut through the object, however, this function does not work in this mode. Pressing the **ESC** key while the Help screen is open returns the operator to the 3D Point Stream screen.

After the resolution has been entered (if it has not been entered the machine uses the last setting made), the operator is ready to begin the task of collecting the data points desired. By pushing the front button down and holding it down while the probe travels over the desired surface, multiple points are gathered at the resolution specified. These points are collected and held until the operator releases the front button. At this point, the operator can continue the stream by re-pressing the front button and moving the arm along further, or press the rear button once to end that particular stream and either Hit <FRONT BUTTON> to discard stream or Hit <REAR BUTTON> to save stream . The operator pushes the front button to discard the last points taken if they are not correct, and records the stream by pressing the rear button once again. After pushing either of the two buttons, the operator can then continue adding multiple streams of data or push the rear button two times more to leave the digitizing process and return to the Utilities Menu.

The operator can return to digitize in more points on the model later in any of the modes available. In returning to the digitizing screen, if the operator does not give the file a new name, a That file already exists! screen will appear:

That file already exists! Point tip

File Name: Hull#1

(0)---<Append to old file>
(1)---<Over-Write old file>
(2)---<Enter a different name>
(3)---<Cancel>

——————————[Enter Choice: 0]——————————

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

Here the operator must decide if he or she wants to add the data to the existing file, get rid of the earlier data by over-writing the old file with the same name, name the file something completely new, or leave the program altogether and return to the Utilities Menu. After choosing the appropriate option, he or she is sent to the digitizing screen to take more data or sent back to the Utilities Menu.

The next option on the Select Stream Mode screen is the (2)---<Lock Plane> choice. This mode allows the operator to lock the collection of data points onto a particular plane. This method is handy for taking cross-sections of an object, as it uses the software to track the location of the point probe in space for the operator.

The operator defines a planer cut through an object and then moves the point probe over the object, back and forth, crossing the imaginary plane previously defined. Every time the probe crosses this plane, the Faro Arm records the point at that crossing. This is a software lock only; the arm is not physically locked into an axis, so the operator is free to move it wherever desired.

After making this choice, the File Name screen appears:

Enter File Name

file name: c:\rawdata\

Alt-D Directory ALT-F Format

The operator types in the name of the data file to be created in the locked plane mode. The next screen is a Step Increment screen:

Step Increment

Increment: 0.0000"

<RETURN> accept <ESC> cancel

This allows the operator to type in the distance the planer cuts should be apart from each other. In other words, to space cuts 0.5" (one-half inch) apart from each other, type in **.5** and press **ENTER↵**. It is not necessary to type in the units. This sets the

Faro Arm up to take points only in planer cuts 0.5" apart from each other, resulting in a topographic-like map of the object being measured. Please note that a positive **0.5"** means that when the operator advances to the next plane, the plane will be in the positive direction of the defined object coordinate system. A negative value (**-0.5"**) will step the planer cuts in the opposite direction. As this is how ship's lines have been defined in two dimensions in the past, it is entirely possible to measure the models by defining waterline cuts, station cuts, buttock cuts and diagonal cuts by defining the planes with this menu choice.

After defining the increments, the operator is presented with this screen:

Locked Plane
Point Tip

0)---<Cancel>
1)---<XY>
2)---<XZ>
3)---<YZ>
4)---<Define>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

Here the operator defines the planer cut to be made. This is the direction of the cut in relation to the coordinate system previously defined. If the backboard of the model to be measured was defined as the **XY** Plane, and the operator wanted to make planer cuts parallel to the backboard, (called buttock cuts), he or she would merely pick 1)---<XY> as the definition of the cuts to be made. All points of data then gathered would then be in a plane parallel to the backboard, and at some multiple of 0.5" from the backboard (if that was the step increment assigned). Note that three planes are defined for the operator- the **XY**, the **XZ** and the **YZ.** Choice 4)---<Define> allows the operator to define a plane that is different from any of the previous choices, such as an angular cut through the object coordinate system. If this selection is made, the operator is asked to digitize any three points to define the desired plane. (These points are picked from the digitizing menu with the Faro Arm by placing the arm on the points and pressing the front button to pick the points and the rear button to record them). After choosing the plane to be defined, or after defining a separate plane, this screen appears:

Point On Locked Axis
Set location of locked plane

x: -0006.9334" y: +0010.7010" z: +0002.8132"		
Capt XYZ		
	CNT: 00000 <F1> HELP	

Digitize Point #1

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

This screen is asking for the operator to digitize a point defining the location of the initial planer cut to be made. If the operator wants to begin on the backboard itself, then the Faro Arm is used to digitize a point on the backboard. If the cut should be above or below the backboard, pick a point above or below the backboard the desired distance. From then on all cuts will be on a plane at that height or 0.5" away from that height. To advance to the plane 0.5" away from the current working plane, the operator simply pushes the space bar. The measurement plane will then jump 0.5" in the positive direction if the step increment was entered as a positive number or jump in the negative direction the same amount if the step increment was entered as -0.5". After digitizing the location of the plane to begin working with, this next screen appears:

Axis Locking Stream
Plane XY Locked At: Z=0002.9376"

<table>
<tr><td colspan="2">x: -0006.9334"
y: +0010.7010"
z: +0002.8132"</td><td colspan="2"></td></tr>
<tr><td colspan="2">Capt XYZ</td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2">CNT: 00000
<F1> HELP</td><td></td></tr>
</table>

Hold < Front Button> to take points
Twice < Back Button> to quit

The operator can see that the axis lock is on and the "height" or location of the initial plane is at 0002.9376" above the XY plane. At this point, the operator takes the tip of the Faro Arm and moves it back and forth across the surface of the object roughly 2.9376" above the base. The arm will start to gather points every time it crosses this imaginary line. The serial controller box will beep each time a point is acquired to let the operator know where this line is and how many points are being taken. After taking all of the points desired on the planes desired, the operator pushes the rear button two more times to leave the digitizing mode and return to the Utilities Menu screen.

The last item on the (4)---<Collect 3D point streams> menu is the (3)---<Edge triggered> mode. This mode can be very handy in the right application. It is set up to determine a hard edge of an object by taking points in a stream mode as the probe move across and down an edge. After ending the stream, the software calculates the edge by averaging and deletes the points gathered that were not on the edge. This method requires the use, however, of a ball probe and probe compensation offsets to work. It will also only work well on the outside edges of an object, and therefore has little use in the measurement of ships' half-hulls, whose edges are mostly against a backboard. The operator should feel free to experiment with this option after reading the Faro Arm manual if it seems to be a suitable technique. This ends the discussion of the collection of 3D point streams.

END EFFECTOR TIPS

The sixth choice on the Utilities Menu is the (5)---<End effector tips> choice. This is where the operator tells the software which probe is currently on the Faro Arm, where the tip is calibrated and where the probe compensation is turned on or off for ball probes. These tips are called end effector tips, tips, or probes throughout this manual. The initial End Effector screen looks like this:

End Effector Point Tip

(0)---<Cancel>
(1)---<Select Tip>
(2)---<Calibrate Tip>
(3)---<Enter tip length>
(4)---<Turn Probe Comp On>

[Enter Choice: 0]

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The first menu choice cancels this screen and returns the operator to the previous screen. The second menu choice (1)---<Select Tip> allows the operator to choose the tip installed on the end of the Faro Arm. This screen looks like this:

Select End Effector
Point Tip

(0)---<Cancel>
(1)---<Point Tip>
(2)---<1/4" Ball Tip>
(3)---<Custom tip #1>
(4)---<Custom tip #2>

[Enter Choice: 0]

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The operator selects the probe that is installed on the end of the Faro Arm. In most cases, for the purpose of this grant, choice (3)---<Custom tip #1> or (4)---<Custom tip #2> describe the probe most likely to be used. This allows the operator to use any of the Teflon tips made for this project. The choice (1)---<Point Tip> is used if the steel point tip from Faro is being used. A quarter inch ball probe is provided with the arm and can be used if desired. If this is the case, the next choice should be used: (2)---<1/4" Ball Tip>. The last two choices are custom tip settings where a custom tip's information can be set and stored. With any of the point tips provided, the operator should pick the tip and then calibrate it to ensure accuracy. After selecting choice (3)---<Custom Tip #1> the operator is returned, unfortunately, to the Utilities Menu screen again, where he or she must then return to the (5)---<End effector tips> choice to calibrate the newly chosen tip. From here the next step is to (2)---<Calibrate Tip>. This process is to let the software know the actual length of the installed tip by using the machine itself to measure its length.

After choosing to calibrate the tip, the screen displays this information:

```
Select End Effector
Point Tip

(0)---<Cancel>
(1)---<Point Tip>
(2)---<1/4" Ball Tip>
(3)---<Custom tip #1>
(4)---<Custom tip #2>

[Enter Choice: 0]

<FRONT BUTTON >   or ↑↓   to Navigate
<BACK  BUTTON >   or ↵     to Select
```

The operator picks (1)---<Point Tip> and is then asked to furnish the diameter of the tip. In the case of a point tip it is 0.0000", which is displayed on the screen as the default value. This screen looks like this:

```
Tip Diameter

Diameter:      0.0000"

<RETURN>  accept  <ESC>  cancel
```

By merely pressing **ENTER↵** the value of 0.000" is entered and the next screen appears:

Calibration Technique Point Tip

(0)---<Cancel>
(1)---<Single hole>
(2)---<1" Reference sphere>

——————[Enter Choice: 0]——————

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The operator is given three choices again. Canceling out of the operation is the first choice. The second uses a single machined .0200" hole that the ball probe fits into to gauge its length, and the third choice uses the one inch sphere located on the machine itself to determine the length of the probe. Once again, since there is no machined hole to use with this machine, we will only consider using the one inch reference sphere method, which also happens to be the most accurate method. After choosing (2)---<1" Reference sphere> this digitizing screen appears:

Calibrate New End Effector
Digitize 27 Points on Ball.

x: -0006.9334" y: +0010.7010" z: +0002.8132"		
Capt XYZ		
	CNT: 00000	

Digitize Point #1

Hit < Front Button> to digitize point
Hit < Back Button> twice to quit

At this point the operator digitizes in 27 points on the one-inch sphere located at the base of the Faro Arm itself. In digitizing these points the operator should try to keep the point probe normal to the sphere's surface as much as possible. The operator should also take the points from as many different angles as possible on the sphere and should concentrate on exercising each of the arm's joints as much as possible to ensure greater accuracy. Move evenly around the sphere, from side to side and top to bottom. As the operator takes points, the number of points is counted and displayed. When the twenty-seventh point is taken, the machine calculates the calibration error for the tip and displays the results:

Tip Calibration Results
Point Tip

<Calibration:> 000.007018"

<Length X:> +000.445584"
<Length Y:> -001.990719"
<Length Z:> +004.617659"

Hit any Key or Button to continue

The calibration error for the machine should always be lower than the machine's stated accuracy. That is, it should always be less than 0.012". If the error comes back more than this value, it could be that one or more points was not taken on the sphere and are throwing the calibration out. The operator should re-calibrate the tip until there is a good reading. Once the tip has been satisfactorily calibrated, the operator is dropped back to the Utilities Menu.

If the operator has the quarter inch ball probe installed, the procedure for calibrating is the same as with the point probe. The same screens appear, but the operator picks the ball probe rather than the point probe when asked which tip is installed, and types in its radius.

The next choice in the End Effector Tips menu is (3)---<Enter tip length> This menu choice is only used with custom tips that are not a ball-type probe or a point-type probe. Since none of these probes are supplied with the Faro Arm, this menu selection will not be made during this project.

The final choice in the End Effector Tips menu is the (4)---<Turn Probe Comp On> toggle. (This menu choice is a toggle, meaning that if it is selected by highlighting it and pressing **ENTER↵**, it will change from **ON** to **OFF** or from **OFF** to **ON**, rather like a light switch). This choice is used only if there is a ball probe on the arm. This will automatically compensate for the radius of the ball. If this is not turned **ON**, all measurements taken with the ball probe are to the center of the probe. With the compensation turned **ON** and the appropriate diameter of the sphere entered, the software will calculate the actual point chosen on the surface of the object rather than the center of the probe. There is no compensation required for the point tip and the toggle switch can be left with the compensation turned off. This ends the discussion of the End Effector Tips menu.

Certification of the Faro Arm

This menu choice on the Utilities Menu screen, (6)---<Certification>, allows the operator to check the accuracy of the Faro Arm in the field. This function need not be performed regularly; it is intended more as a periodic check on the machine or as a check if there is some fear that the machine has been damaged in some way. For this operation, the operator should install the factory calibrated quarter-inch ball probe that came with the machine. Please note, however, *that this tip is never to be used in the measurement of an object*. It is only supplied for the purposes of calibrating the machine in the field. Use of this tip will lead to its wear, and this will decrease accuracy in the calibration of the machine. *After this calibration has been performed, the factory calibrated tip should be removed and stored away from possible accidental use later in the measurement process.* This probe need not be calibrated after installation for this operation. The certification screen looks like this:

Select End Effector
1/4" Ball Tip

0)---<Cancel>
1)---<Point tip>
2)---<1/4" Ball tip>
3)---<Custom tip #1>
4)---<Custon tip #2>

Enter Choice: 0
<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

As usual, the first choice quits this screen and returns the operator to the previous screen. The machine can be calibrated with 1)---<Point tip>; however, it is not recommended. Instead, the operator should use choice 2)---<1/4" Ball tip> as the method of calibration. Once again, this is a more accurate way of calibrating the machine and all of the necessary equipment is supplied with the machine itself to perform this operation. After selecting the quarter-inch ball probe as the end effector, a new screen appears:

Certification
1/4" Ball Tip

0)---<Cancel>
1)---<Ball-Bar>
2)---<Sphere-to-Sphere>
3)---<Step Gauge>

———————— Enter Choice: 0 ————————

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

Since there are no spheres or step gauges provided with the Faro Arm, the operator can only choose to cancel the operation or proceed with the 1)---<Ball-Bar> option. After selecting this option, the screen changes to the Ball-Bar digitizing screen:

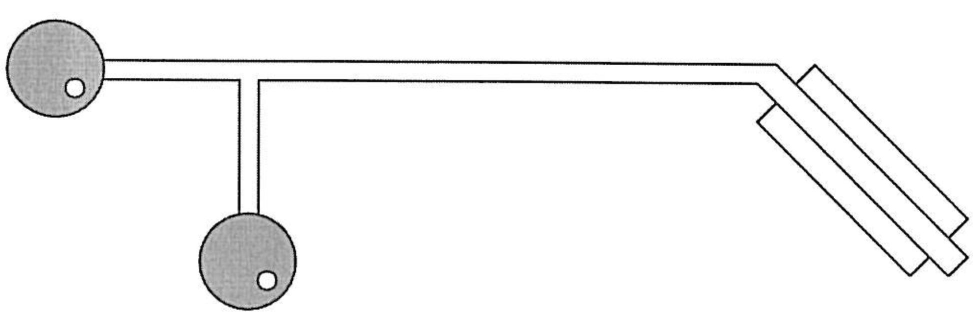
Ball Bar
Digitize Point

x: −0006.9334" y: +0010.7010" z: +0002.8132"	Length
Capt XYZ	+0003.9140"
CNT: 00000	

Digitize Point #1

Hit < Front Button> to digitize point
Hit < Back Button> twice to exit/save

At this point the operator installs the ball-bar on the machine itself. This gauge can be found in the large Faro Arm case and looks something like this:



To install this gauge, the operator takes the one-inch sphere off of the base of the Faro Arm (it is held there magnetically and only needs to be pulled off by hand) and snaps the ball at the end of the long shaft of the gauge into the same socket. At the other end of the gauge, the end with the foam handle, is a cone that the quarter-inch ball tip at the end of the Faro Arm will fit into. After placing the end effector into this cone, the operator then takes a series of *at least 50 points* while moving the gauge throughout its entire working envelope to exercise all of the Faro Arm joints. The operator should make certain that the two spheres remain firmly located in their sockets during the collection of these points, and that none of the joints reach their end stops while taking these measurements. It should be noted that if the front button is pushed and the operator is aware that the quarter-inch probe was not fully seated in the socket at the time of measurement, all that needs to be done is not record that point by pushing the rear button, but rather, seat the probe again and push the front button again. This over-writes the inaccurate point.

After having taken at least 50 points, the operator can push the rear button two more times to end the calibration operation. At this point this screen appears:

Metrecom Serial Number:	B08-02-94-
00676	
Software Version:	2.04
Calibration Date:	12/12/94
Number of Points Taken:	56
Mean Bar Length:	20.75196"
Maximum Bar Length:	+20.7550
Minimum Bar Length:	+20.7500
(Max−Min)/2:	0.0025"

Hit any Key or Button to continue

This screen provides basic summary information of the measurements taken. After progressing to the next screen, the operator is allowed to save the data on all of the points taken and the above information to a named file. (This will be stored wherever the operator chooses, under a given file name, the extension being **.txt**). This merely provides a record for future comparison of the Faro Arm accuracy. The operator should get a total (Max-Min)/2 error of less than 0.012" to satisfy accuracy requirements. If the operator receives an error greater than this, he or she should recertify the Faro Arm again until he or she gets this accuracy or determines that the machine is indeed out of the desired range. If the machine is determined to be out of range, please contact **Mark Starr** at **Mystic Seaport Museum (860-572-0711, ext. 5092)** for further information.

Change Default Settings

The eighth item on the Utilities Menu screen is the (7)---<Change default settings> option. After choosing this number, the Default Settings Menu screen appears:

Default Settings Menu
Point Tip

(0)---<No change>
(1)---<Sound/Color>
(2)---<Communications>
(3)---<Units>
(4)---<Output file options>
(5)---<Control options>
(6)---<Enter stream resolution>
(7)---<Reset serial box to factory >
(8)---<Show defaults>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

This is where defaults may be set or changed. (Note that many of these settings can be modified in other screens as well). The first choice returns the operator to the Utilities Menu screen. The next choice (1)---<Sound/Color> brings up this menu:

Sound/Colors
Point Tip

(0)---<Cancel>
(1)---<Toggle Calip3D Sound To (OFF)>
(2)---<Toggle Alarm Sound To (OFF)>
(3)---<Toggle SerBox Main Sound TO (OFF)>
(4)---<Set frequency for back button>
(5)---<Set frequency for front button>
(6)---<Toggle End-Stop-Warning to (OFF)>
(7)---<Set Foreground Color>
(8)---<Set Background Color>
(9)---<Set Highlight Color>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

The first choice returns the operator to the previous screen. The next two choices, (1)---< Toggle Calip3D Sound To (OFF)> and (2)---<Toggle Alarm Sound To (OFF)> are toggle switches. I have not found that they turn anything on or off, regardless of their settings, and so can be ignored. Choice (3)---<Toggle SerBox Main Sound TO (OFF)> does work however, and turns the serial controller box tones for the Faro Arm **ON** or **OFF**. It is recommended that they be left on as it is the only convenient way to be sure that a point has been taken and recorded. The next two choices, (4)---<Set frequency for back button> and (5)---<Set frequency for front button> allow the operator to set the volume of the beeps issued by the serial controller box. They are currently set for **100 Hz** for the front button and **150 Hz** for the rear button.

To change either of these values, select the button and type in a new value. It is not necessary to type in the **Hz.**

Although it is possible to (6)---<Toggle End-Stop-Warning to (OFF)>, it is not recommended. This tone, while annoying, does keep the operator from damaging any of the end stops by applying too much torque to the delicate joints.

The next three choices allow the operator to set the colors on the screen. The operator can set the foreground, the background and the highlight colors of Calip3D. Note, however, that if the foreground and background colors are the same, the text will not appear.

The next choice on the Default Settings menu is (2)---<Communications>. This is where the settings connecting the serial controller box to the computer can be changed. Since the computer does a scan of all of the ports available to the serial box and configures itself, there is little need for the operator to change these settings. If they are changed, it should be noted that the current operating settings are these:

(1) Select COM Port: **COM1**
(2) Set Baud Rate: **9600**
(3) Select COM Configuration: **8, N, 1**

The (3)---<Units> option allows the operator to set the measurements taken to either English or Metric units. After selecting this option, the operator simply chooses either (0)---<No change>, (1)---<Inches> or (2)---<Millimeters. The units are currently set for inches.

The next selection in the Default Settings menu is the (4)---<Output file options>. This is one place where the file type to be created (that is to say the format that the data collected will be in) can be set. As in the previous menu choice, there are three options. The first is to cancel the operation and return to the previous menu. The next is (1)---<Select default format>. This screen menu looks like this:

Select File Format
Point Tip

(0)---<No change>
(1)---<#, 3D pts, Euler>
(2)---<#, 3D pts, ijk (in)>
(3)---<#, 3D pts, ijk (out)>
(4)---<#, 3D pts>
(5)---<Special>
(6)---<DXF>
(7)---<IGES v6.0 >
(8)---<ACL 494-A>

Enter Choice: 0

<FRONT BUTTON > or ↑↓ to Navigate
<BACK BUTTON > or ↵ to Select

Choice number (1)---<#, 3D pts, Euler> provides Eulerian Angles along with the point number and the point data collected by the Faro Arm. This information is needed when a computer is going to drive a numerical cutting machine. This does not apply to our general measurement needs, and will not normally be chosen for output format.

The next two options (2)---<#, 3D pts, ijk (in)> and (3)---<#, 3D pts, ijk (out)> are similar in that they collect information on the angle that the Faro Arm itself approaches the object being measured. These angles are also useful in determining if a cutting machine will be able to approach the object to be manufactured with a certain cutting tool in its grasp. Once again, we need not be concerned with these angles, or these two file formats.

The next option, (4)---<#, 3D pts> is one of the two options we will use the most for the purposes of this project. It stores the file generated in a simple ASCII text file and gives the operator the point number, the coordinates of the 3D point, as well as any of the remarks typed in during the measurement process. A typical file looks like this:

Index	X"	Y"	Z"
0001	+0017.5630	+0002.9110	+0001.9510
0002	+0018.2380	+0002.3850	+0002.6690
0003	+0018.3790	+0000.7650	+0003.6160
0004	+0015.6730	+0001.0200	+0000.0400
0005	+0016.1480	+0001.2980	-0002.0820
REM	beginning of sheer at stem		
0006	+0017.6370	+0001.1580	-0001.1110
0007	+0016.4730	-0000.5500	+0004.2050
0008	+0018.5910	-0001.7200	+0004.9670
0009	+0016.8040	-0000.6280	+0003.1970
0010	+0014.7910	-0000.5510	+0002.0900

It should be noted that this file can be imported into a spread sheet such as *Excel* if the operator wishes to parse out the data.

The (5)---<Special> option is undefined by the Faro Arm manual. In retaliation, we will simply ignore this option. The next two options, however, are very useful for transferring the point data collected into CAD (Computer Aided Design) software. The operator should choose either of these options, (6)---<DXF> or (7)---<IGES v6.0 >, depending upon which format the CAD package recognizes. Most high-end packages will recognize both of these formats, as they are the industry standards to date. The final output option, (8)---<ACL 494-A> stands for the *ASCII*

Cutter Language, which once again deals with cutting machines driven by computers. This is beyond the scope of this project and is therefore not a choice to be used.

The third selection on the File Output Utility screen is (2)---<Recover/Translate>. This is used only if power is lost during the measurement process. After a power loss, there exists a file of the points collected up to that time stored in a file with the name given by the operator before the measurement process began with the extension **.mtr.** This menu option will translate the **.mtr** file into any of the file formats already discussed. The operator, after choosing this option, types in the name of the file to be translated, and then the name of the file to be created during the translation. The software then converts the information into the desired format. It should be noted that the **.mtr** file exists for every set of measurements taken, and the operator can take and translate that file into any of the above-described file formats later with this command option (it works if there was a power loss or not!)

The next item on the Default Settings menu is (5)---<Control Options>. The first two options on this screen (1)--<Toggle Aux Switch To (ON)> and (2)--<Toggle Options Port To (ON)> are for controlling a contact-triggered tip. This tip automatically takes a point when it comes in contact with the object to be measured. As this tip is not included in this project, this menu choice is of no interest. The last two options, (3)---<Toggle Arm Scrolling To (ON)> and (4)---<Arm Scroll sensitivity> allow the operator to scroll up and down through menu choices without having to press the front button repeatedly. (Note! While in menu screens, the operator can use the front button on the Faro Arm to scroll down through the menu and the rear button to make the menu choice). The arm scrolls in response to motion down the Y axis. As I have found the results to be less than ideal, I have left this option off. The scroll sensitivity, or the speed at which the arm scrolls down the list, can be set with this last option. Its current setting is **95**. The operator should feel free to experiment with these last two options.

The next option on the Default Settings menu is (6)---<Enter stream resolution>. This is one place where the distance between points taken in a stream mode can be set. After making this choice, the operator simply types in the decimal value of the spacing required and hits the **ENTER↵** key. It is currently set for 0.2500" or 1/4".

The next menu choice in the Default Settings menu is (7)---<Reset serial box to factory >. This option sets all parameters (tips, units, coordinate systems and communication values) back to the factory defaults. The operator should not normally do this. If this item is picked, there are only two choices: **Yes** or **No**. After making the choice the operator is returned to the Default Settings menu with either the same old settings or the default values.

The final choice on the Default Settings menu is (8)---<Show defaults>. This screen displays all of the current default settings. This screen looks like this:

```
Default Settings
V 2.09
Connected with Arm 308-02-94-00676
Calibrated 12-12-94

Current Tip------------------------->Point Tip
Tip's X---------------------------> +000.4425"
Tip's Y---------------------------> -001.3453"
Tip's Z---------------------------> +004.9328"
Tip Calibration-------------------> ≅ 0.0066"
Probe Compensation----------------> Off
Communications-------------------->1 9600 N 8 1
Snd: Main/alrm/Box/Stop------------>on/on/on/on
Freq1/Freq2------------------------>100/200
Save File Format------------------->xyz
Aux Switch------------------------->Off
Options Port----------------------->Off
Units---------------------- ---->Inches
Stream Resolution------------------>0.25"
Arm Temperature-------------------->+24.13 (deg C)
Arm Controlled Scroll-------------->Off

Hit any Key or Button to Continue
```

This ends the discussion of the Defaults Menu screen options.

Build Mode

The Build Mode option on the Utilities Menu screen is used when the operator wishes to find a particular point in the 3D space that he or she is working in. It will guide the point probe through space to the desired location. We will not be using this option on this project, and so I will leave the description of this function up to the Faro Arm manual.

Diagnostic

The Diagnostic choice on the Utilities Menu screen has three functions. The first is, of course, the cancel option, which returns the operator to the previous screen. Choice (1)---<Diagnostic Display> first asks the reader to name a file. This is the file that the diagnostic information will be written to for later use by the operator. After typing in the name of the file to be created and pushing **ENTER↵**, the operator is faced with this screen:

Diagnostic Report

ENC1 : −0139.8458°
ENC2 : +0004.5834°
ENC3 : −0340.2934°
ENC4 : +0130.6354°
ENC5 : −0045.1832°
ENC6 : +0006.2845°

FRNT BTN : 0
BACK BTN : 0

TEMP : +026.3826° C

Machine Coord

X: +0001.8937"
Y: −0002.2760"
Z: −0001.0283"

#00

Hit < ANY BUTTON/SPC BAR> to get angles
Hit < ESC KEY> to quit

The diagnostic mode enables the operator to check the Faro Arm's joint angles, the tip's position in 3D space, the ambient testing temperature and the status of the front and back buttons on the Faro Arm itself.

The ENC1 : -0139.8458° means that joint #1 (encoder #1) is currently at a -0139.854° angle. If the operator presses either the front or rear button the values in that column will change to 1 if they are functioning properly. After moving the arm around to the desired attitude, the operator can push any of the keys or the space bar to record the angles of the joints to a file. Once again, this option is largely intended to be used by cutting machines driven by the computer and has little application in this particular project.

The last choice in the Diagnostic Menu is the (2)---<Stabilize Temperature> option. This option, used in precision measurements, is for when the operator needs to be assured that the temperature that the machine is operating at is stable. After launching this choice and typing in a file name to write the gathered information to, the software starts a five-minute running sample of the ambient temperature of the machine. After five minutes, it writes the information to the file. The file created looks like this:

```
Metrecom Serial Number:    B08-02-94-00676
Software Version:          2.04
Calibration Date:          12-12-94
Date of test: 2-28-1996

(0001) 00:00:10 +26.23øC
(0002) 00:00:20 +26.24øC
(0003) 00:00:30 +26.23øC
(0004) 00:00:40 +26.23øC
(0005) 00:00:50 +26.23øC
(0006) 00:01:00 +26.23øC
(0007) 00:01:10 +26.23øC
(0008) 00:01:20 +26.23øC
(0009) 00:01:30 +26.23øC
(0010) 00:01:40 +26.22øC
(0011) 00:01:50 +26.22øC
```

(0012) 00:02:00 +26.22øC
(0013) 00:02:10 +26.22øC
(0014) 00:02:20 +26.22øC
(0015) 00:02:30 +26.23øC
(0016) 00:02:40 +26.22øC
(0017) 00:02:50 +26.22øC
(0018) 00:03:00 +26.22øC
(0019) 00:03:10 +26.22øC
(0020) 00:03:20 +26.21øC
(0021) 00:03:30 +26.21øC
(0022) 00:03:40 +26.21øC
(0023) 00:03:50 +26.21øC
(0024) 00:04:00 +26.21øC
(0025) 00:04:10 +26.21øC
(0026) 00:04:20 +26.21øC
(0027) 00:04:30 +26.20øC
(0028) 00:04:40 +26.21øC
(0029) 00:04:50 +26.21øC
(0030) 00:05:00 +26.21øC

Total Elapsed Time:	00:05:02
Number of Samples Taken:	30
Max Temp in Last 5Min:	+26.21øC
Min Temp in Last 5Min:	+26.21øC
Max–Min for Last 5Min:	+00.00øC
Global Max Temp:	+26.24øC
Global Min Temp:	+26.20øC
Global Max–Min:	+00.03øC

If the temperature has not fluctuated beyond the allowed parameters, measurements can be taken. Once again, this is for extremely accurate measurement of machined parts, and need not be a worry for objects made of wood, which fluctuate in size depending on their moisture content more than these temperature differences matter to their measurement. Temperature fluctuation is mostly a concern if the Faro Arm has just been brought in from a cold environment and is just being set up. Normally the Faro Arm is ready to operate after the time needed to set it up has past, but this is a good place to check to make certain that the machine's temperature has stabilized. This ends the discussion of the diagnostic screen.

Getting Help With This System

If you encounter any problems with or have any questions about the equipment, software or measurement procedures described here, please feel free to call **Mark Starr** at Mystic Seaport Museum, Mystic, Connecticut. The Museum's phone number is **(860) 572-0711**. I am at **ext. 5092**. If I am not in the office, please leave your name and number and I will return your call as soon as possible. In case of problems with equipment or software, please call me rather than the manufacturer as Mystic Seaport holds all of the appropriate registration numbers and licenses.