Mirror 16

Rebuild the

55th Anniversary 1963-2018

Designed by Jack Holt using Barry Bucknell's structural stitch-and-glue system

Mirror 16 – HULL DESIGN

The objective of this document is to provide adequate information to construct a Mirror 16 hull in CAD/CAM software. Having the hull appropriately modeled will allow for the creation of flat panel templates.

This project attempts to be faithful to the original boat specifications and design. Wherever possible, we have relied on the original 1960's documentation (which was quite detailed). To supplement those documents, we gained fresh insight from remaining Mirror 16s including my boat #435 (shown below) as well as insight from the Boatdesign.Net/Mirror 16 forum.

This document is part of a series that I began in 2016. Future documents will provide detailed measurements for the interior sections including the floor, the bulkhead and seat panels.

OUTLINE

Sections:

1. Overview of project and this document
2. CAD/CAM image of hull and concluded hull coordinates (x-y-z)
3. Original 1969 measuring plan (drawing of hull)
4. Introduction to use of DELFTship for modeling hull

Appendix:

1. Logic used to identify key measurements
2. Approach used for missing information
3. Modern version of 1969 rules (cleaned up for consistency)
4. Supporting details for key measurements

OVERVIEW OF PROJECT

Created by Nook Fulloption from the Noun Project

MIRROR 16 WORTH SAVING

Why bother saving an old boat?

Fair Question

Modern boat design has come incredibly far with boat speed continuing to climb through the combined use of high tech materials and foils.

As such, why should anyone invest time and effort to save an old boat design, especially one constructed out of simple materials that you can build in your garage?

A Forgotten Experience

A while back, I began thinking about my own experience of learning to sail which in part was spent on a Mirror 16 built in our garage. At that time (1970) this was the most affordable way for our family to get on the water.

I still remember the smell of epoxy glue in the garage and my dad's attention to detail as the boat took shape.

Once built we took the boat camping, sailed it on inland lakes in Ohio and launched it off the beach into the Atlantic Ocean.

We only owned the M16 for a few years and moved onto a series of other boats. Looking back the Mirror 16 had an impact on our family and was a terrific dinghy.

Research Project

In 2016, I tried to find our old boat #366 but had no luck. I also researched M16 plans and templates and learned they were no longer available.

The start of a new project

As I surfed the internet researching the Mirror 16, I came across several forums with other folks also interested in rebuilding the boat and seeking plans and templates. That encouraged me to head down the path and begin this project.

Worth the Investment

I think the Mirror 16 is a design worth saving and hope you would consider participating in the project.

The Game Plan

My near term goal is to consolidate the Mirror 16 documentation and create modern CAD/CAM drawings that will facilitate creation of flat panel templates.

REVIEW OF THE BOAT

As described in 1967

The comments below are from a review of the boat presented in the 1967 Design Journal.
(URL link to full article)

The Mirror 16 is a brilliant do-it-yourself sailing dinghy. Designed by Jack Holt and using Barry Bucknell's structural stitch-and-glue system, she not only sails well but functions properly in many other ways.

Described in the glossy sales booklet as a fast camping dinghy, an hour in the Medway this spring in a blow that gusted to forces confirmed that she is fast. With three up, she planes (skims over the surface) easily.

There are no space-wasting side decks, and the heavily cambered foredeck provides ample stowage

As for camping, there is room for four on the flat floor under cover of a tent which uses the boom as a ridge pole. There is also room to stow sleeping bags, spare clothing and food in lockers under the full length seats, and a gas primus stove can be fitted to hinge neatly in and out of a forward locker.

However, the Mirror 16 is not a boat for beginners. Although she is responsive to controls and has no particular vices, there is a large sail area (the jib and mainsail total 178 sq ft) for an all up weight of only 260 lb.

The boat is 6 ft across the beam; has a hull draft of 6 inches.

The mainsail area is 126 sq ft; the Genoa 55 sq ft; and the spinnaker 120 sq ft.

The amount of sail area can, however, be quickly reduced. The jib is rolled in and out like a window blind to any required area. An alloy pole runs up the leading edge of the genoa and this ensures that the jib sets properly even when the sail is reefed.

The mainsail has two sets of reefing points, so the sail area can be adjusted to cope with strong winds. And it can be increased by a 120 sq ft spinnaker for light airs.

PROJECT MILESTONES

Progress so far...

- ✓ Obtain Original 1969 Documents
- ✓ Create 2016 list of Hardware
- ✓ 2016 list of Running Rigging
- ✓ 2016 list of Standing Rigging
- ✓ Identify 2016 Sailmaker
- Document Hull Dimensions
- CAD/CAM drawing of Hull

*In 2016 modern suppliers were identified for hardware & rigging including the cost per item and web links to each product. The **aggregate cost estimate is $4,119** for the items shown below. The scope of that project was to find components that closely matched the original specs and did not assess upgrading or downgrading the hardware which could increase or decrease the cost.* Link to 2016 document

45 individual parts | total cost $1,098

14 individual parts | total cost $206

34 individual parts | total cost $1,315

Main, Jib, Spin. | total cost $1,500

This document brings together all the information relevant to the measurement of the hull including data prepared for use in CAD/CAM.

Future tasks will include CAD/CAM drawing of the interior features like the bulkhead, floor boards and seats.

GATHER FACTS FROM SOURCE DOCUMENTS

GATHER FACTS FROM SOURCE DOCUMENTS

Finding any and all original documents...

Challenge

The original templates for the Mirror 16 are long gone which presents a unique challenge in creating new accurate plans.

Realizing the old templates no longer existed I focused on finding any original documents that would shed light on the boat specifications and design.

Two years ago the search began and took me many places. I visited with current and past boat owners, connected via email to Mirror Dingy groups in England and Australia and eventually made a Canadian connection with an old Mirror 16 owner who lent me his building instructions which I scanned and made available on the web.

Note: Most of my source documents are from 1969. I would be interested to know if anyone has older and/or other documents.

Source Documents

My primary source document is the 1969 official Mirror Class Association Measurement Form. This form was created to measure fully constructed boats and allowed for some flexibility in dimensions. This has over 70 measurements for the hull, sails and standing rigging.

The 1969 original Packing List has also been helpful since it is very detailed and includes the dimensions for some items that are not mentioned in other documents.

The third important document is the 77 page Building Instructions from 1969 which gives the reader a full appreciation of the hull construction and is filled with insightful details and photos.

Lastly, the 1967 Design Journal Article has some helpful sketches which provide an additional perspective on hull shape and an indication of the water line.

Source Document Links

1. 1969 Official Measurement Form
2. 1969 Building Instructions
3. 1969 Inventory Packing List
4. 1967 Design Journal

FILLING IN THE MISSING PIECES

Not everything we need was in the original documents

FILLING IN THE MISSING PIECES

Challenge

The original documents provide a large number of specific measurements but they are not fully robust.

The original rules specify details about the hull at four specific locations along the length of the boat (the transom (T.), the front (F.) and aft (A.) end of the center board case and the bulkhead (B.).

Unfortunately, that level of detail is not enough to properly model the hull or other interior features.

Other measurements are necessary, so we introduced three additional data points for the bow-tip (BT.), bow rake (BR.) and chine at gunwale (CG.)

Solution

A portion of the necessary and missing information can be inferred from facts that are disclosed in the original documents.

Combining a bit of math or geometry with some facts obtained from original documents we have been able to solve some of the missing pieces. This is the optimal approach and used wherever possible.

Certain important values had to be obtained using other methods which included observations or measurements from an existing Mirror 16 or gleaned from Mirror 16 forums like BoatDesign.net.

Partial List of Missing data

Below is a partial list of important but missing data that was filled in using one of the different techniques. See the appendix for a complete list.

- Bow-tip distance to transom
- Bow-tip distance to baseline
- Chine beam at bulkhead
- Chine termination point at bow
- Horizontal bulkhead beam
- Curved top edge of transom
- Curved foredeck surface
- Length and depth of bow-rake
- Details about the curve where the bow-rake transitions to the keel

In addition to the length, height and width data provided the four locations (T., A., F., and B.) we estimated data points every 12 inches along the baseline. We cover the approach to missing data in more detail later in the document.

DEFINITIONS

RULES, FACTS & ASSUMPTIONS

Rules, Facts (FA) & Concluded Assumptions (CA)

Overview

To provide transparency in this project, for each important data point we provide supporting information that fall into one of three categories.

Rules

Rule based measurements are straight forward, and just as the name indicates, these metrics and associated data points are directly tied to a specific rule in the official 1969 Mirror 16 Measurement Form.

Facts (FA)

Facts are just as accurate as information obtained from the rules, but the source came from a different official document or were mathematically derived from original information.

Concluded Assumptions (CA)

All other important data points not described by a Rule or Fact are indicated as being a Concluded Assumption (CA).

For each Concluded Assumption (CA) we have provided details on the methods used to arrive at the value.

For example, one of the missing data points is the length of the bow rake. We used a variety of techniques (observation on my boat & geometry from rule based data) to assess that length and found that a fair value would be 18”.

To make this overall project easy to follow for items like the bow rake we label them with a number and add them to our global data list.

For the bow rake length we assigned that to CA #205 and note that our concluded assumption for length is 18”.

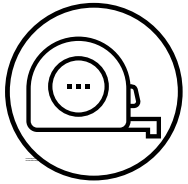
Global List

All of the Concluded Assumptions (CA) are added to a global list that also includes Facts and Rules.

To simplify the global list we followed the numbering schema associated with the 1969 rules, with the first rule being #1. That concept is extended for Facts which begin with the first fact being FA #101 followed by Concluded Assumptions in the 200 series with the first being CA #201.

MEASURE AND MEASURE AGAIN

Just like they say….measure twice cut once…



MEASURE AND MEASURE AGAIN

Challenge

When I started this project in 2016, I did not have access to a Mirror 16. Since then I have acquired boat #435 and have restored it to sailing condition.

Having a boat enabled me to take measurements for this project. I think I measured every data point five times or more!

Preparing for Measurement

The initial step in the measurement process was to follow the original rules by placing temporary stem boards on the bow and transom. From there I established a fixed lower boundary. I leveled the boat to the baseline by squaring two points 1) the bow-tip and 2) keel at the transom.

Step 1: Comparing my boat to the Original Rules

The first step was to benchmark my boat to the original rules. This was quite helpful because it refined my technique for taking measurements and gave me confidence for making the other measurements every 12 inches along the baseline.

Step 2: Comparing estimated values to my boat

As mentioned in the prior section some of the missing data could be calculated from the original rules. For each of those “derived value” I measured my boat to see if the values made sense.

For example, from original documents I could derive the distance of the bow-tip to the baseline. Once I had that value I then measured my boat to see how it compared.

An outcome of this process is that my boat #435 appears to be compliant with the majority of rules so it offers a fair proxy for measurement.

LOFT LINES

Defining the hull with battens

New Insight

Measuring the physical boat has been insightful but equally helpful was insight gained from creating loft lines.

Old School Method

Prior to the invention of computers, hull design included a step where lofting lines were used to help define the hull shape. I am quite certain Jack Holt used this approach for the Mirror 16 and as such I made an attempt to study the hull in that manner.

Overview of Process

Basically, wooden battens are used to recreate the long curves of the boat by bending them around a few strategically placed markers. Done properly, the flexible battens form an ideal curve or "fair curve" that has a smooth continuous flow.

Preparing the space

The initial step in the process was to layout a baseline on the floor and then based on the original 1969 rules note the specific height above the baseline at T., A,. F. and B. for the keel, the chine and the gunwale.

Step 2: Layout the Battens

Beginning at the transom (T.) I secured the batten to the floor using tape. I would have preferred nails but the floor is too nice. I then gently bent the lofting batten until it met the next forward data point (A.) and secured it to the floor with tape. This process was then repeated at F. and B. until I got to the bow tip.

Step 3: Measure every 12"

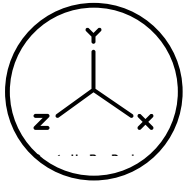
Having a new "fair curve" I then added markers on the baseline every 12" and measured the distance to my lofted lines for the keel, chine and gunwale. Shown in the picture.

Conclusion

The loft line results are amazingly close to the observations (every 12") for my boat. Keep in mind I only forced the location of the lofting batten at the five data points and the natural curve of the wooden batten took on the shape in between the fixed data points.

CREATE X/Y/Z DATA POINTS

A simple process



X/Y/Z DATA POINTS

Challenge
The original boat dimensions had to be converted into a usable format for CAD/CAM software.

This involved taking each measurement and converting It into a specific data point using a length/width/height or x/y/z format.

x = length (as measured from the transom to the bow)
y = height (as measured from the bottom to the top)
z = width (from the center line)

Data expressed as x/y/z coordinates can be imported into many different CAD/CAM programs and does not limit this project to DELFTship which I am using.

Solution
The solution is fairly straight forward. For each known data point, as described in the rules,

using excel I simply organized them into an x/y/z format. (using meters)

For example, let's consider a single data point, "the gunwale at the forward end (F.) of the center board slot" which has the concluded x/y/z data points of

x	y	z
2.8702	0.7461	0.8509

These values were gathered from three different rules shown below.

X: Original documents specify the forward end of center plank case to be 2.8702m from the transom.

Y: Rule #16 indicates the gunwale at (F.) is 0.7461m from the baseline.

Z: Rule #32 indicates the full boat beam at (F.) is 1.7018m and therefore half beam is 0.8509m.

CAD/CAM MODEL OF HULL

3 Dimensional Model

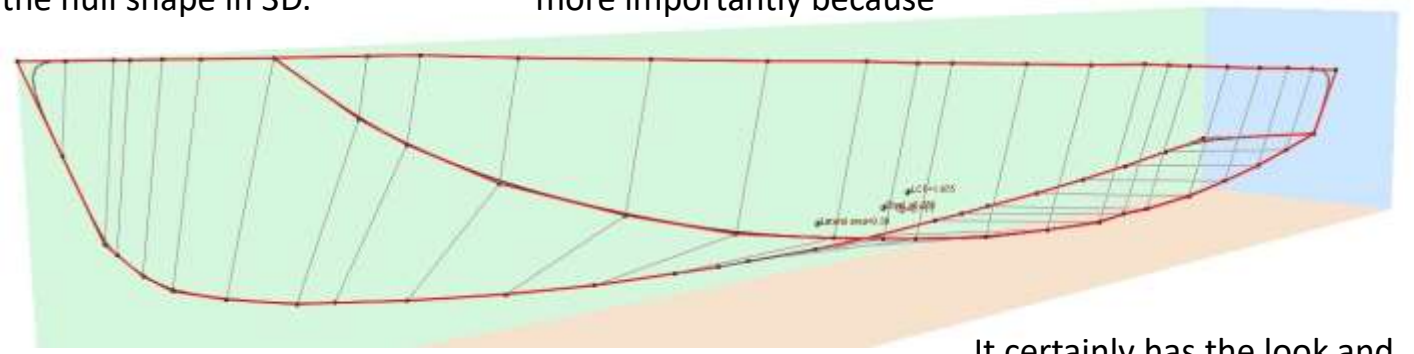
CAD

CAD/CAM MODEL OF HULL

Putting it all together
The collection of x/y/x data points are joined together in CAD/CAM software to create the hull shape in 3D.

DELFTship
I chose to model the hull with DELFTship, partly because it was free but more importantly because it is designed to model boats.

Conclusion: It works!
So far I am very pleased with the resulting 3D profile of the boat.



The image above shows how each data point has been connected along the length of the boat. Beginning at the bottom, the red lines represent the keel, the chine and the gunwale or sheer line at the top. The thin black vertical lines connect each data point to form the hull skin.

I also like DELFTship because it allows you to import a text file with x/y/z data points and has a fairly straight forward user interface.

It certainly has the look and shape of the original boat.

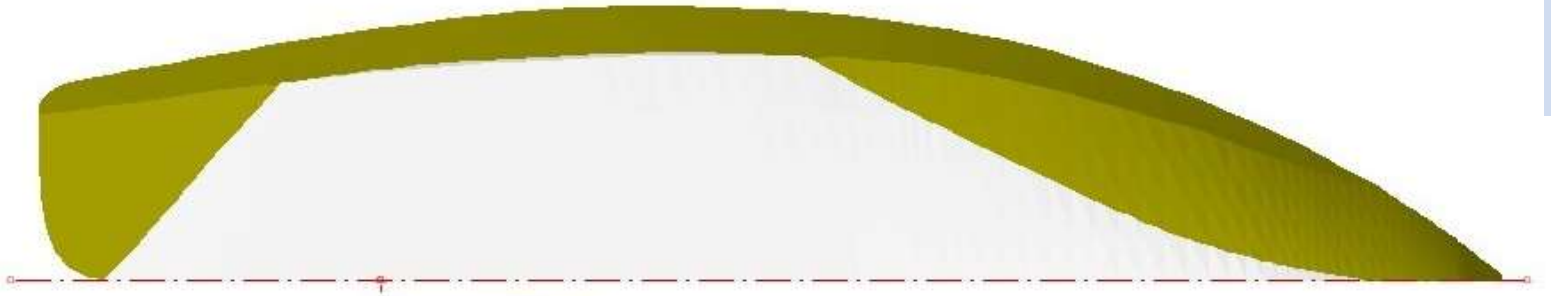
With a little more refinement of the datapoints we will have a fully modeled Mirror 16 hull!

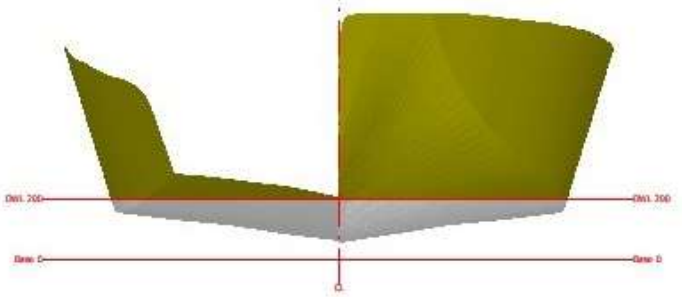
DELFTship Links

1 DELFTShip.net Official Site

3D MODEL OF MIRROR 16 HULL

These images are the result our first pass at that hull modeled in DELFTShip.





The DELFTship software is designed for boats and takes in x/y/z data points and creates smooth curved surfaces optimized for a sailing boat.

You can replicate this by importing the datapoints or email me and I will send you the DELFTship file.

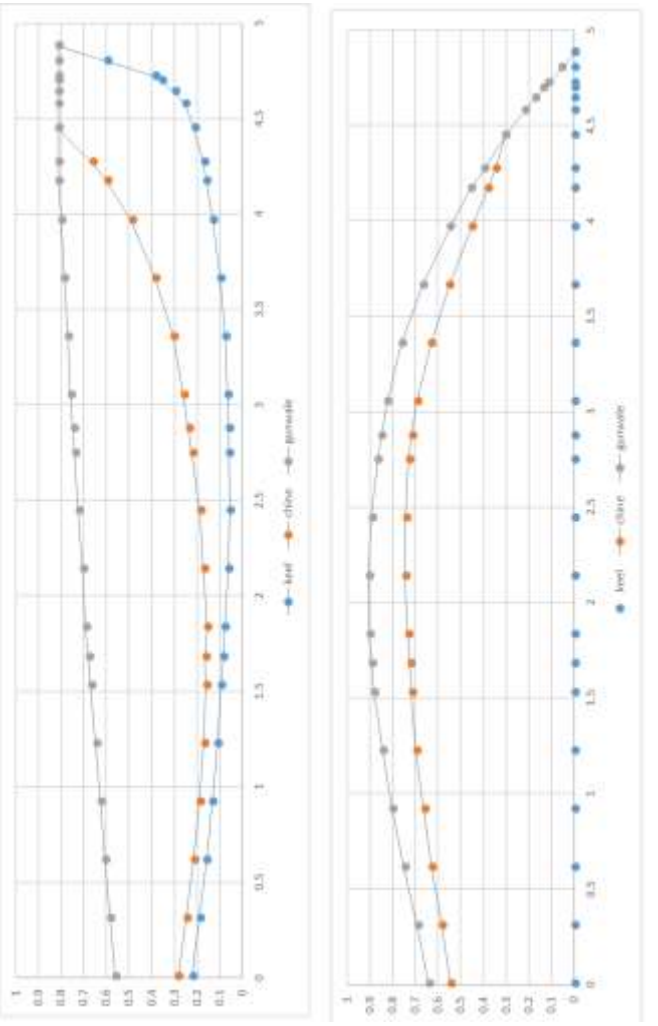
Importing the x/y/z coordinates from the following page into DELFTship will produce the three dimensional hull shown above.

This initial first step allows you to see and manipulate the basic 3D hull. Some additional finish work is necessary to complete the hull skin, including adding an arch to the upper edge of the transom.

CONCLUDED: HULL COORDINATES

Below are x/y/z coordinates (in meters) that can be imported into CAD/CAM software. The values have also been graphed in excel on the right. These dimensions are structured to include a distance from a fixed baseline (per the original rules) and are not from x=0, y=0, z=0.
Note the lower edge of the transom is located at x=0, y=0, z=0.2223.

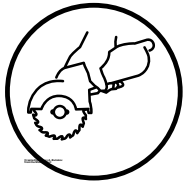
	length x keel	beam y keel	height z hull skin	length x chine	beam y chine	height z chine	length x gunwale	beam y gunwale	height z gunwale
bow-tip	4.8768	-	0.8128				4.8768	-	0.8128
	4.7974	-	0.5969				4.7974	0.0572	0.8128
	4.7181	-	0.3842				4.7181	0.1143	0.8128
	4.6930	-	0.3581				4.6930	0.1365	0.8128
	4.6380	-	0.2991				4.6380	0.1746	0.8128
	4.5720	-	0.2531				4.5720	0.2191	0.8128
CG.	4.4450	-	0.2123	4.4450	0.3048	0.8128	4.4450	0.3048	0.8128
	4.2672	-	0.1715	4.2672	0.3473	0.6636	4.2672	0.3969	0.8128
bulkhead	4.1656	-	0.1588	4.1656	0.3810	0.5969	4.1656	0.4572	0.8128
	3.9624	-	0.1302	3.9624	0.4540	0.4890	3.9624	0.5493	0.8001
	3.6576	-	0.0985	3.6576	0.5525	0.3842	3.6576	0.6699	0.7874
	3.3528	-	0.0763	3.3528	0.6318	0.3048	3.3528	0.7620	0.7715
	3.0480	-	0.0667	3.0480	0.6953	0.2604	3.0480	0.8255	0.7588
F.	2.8702	-	0.0604	2.8702	0.7176	0.2381	2.8702	0.8509	0.7461
	2.7432	-	0.0604	2.7432	0.7303	0.2223	2.7432	0.8668	0.7398
	2.4384	-	0.0572	2.4384	0.7430	0.1873	2.4384	0.8954	0.7239
	2.1336	-	0.0636	2.1336	0.7461	0.1715	2.1336	0.9081	0.7049
	1.8288	-	0.0794	1.8288	0.7334	0.1556	1.8288	0.9049	0.6922
A.	1.6740	-	0.0858	1.6740	0.7239	0.1651	1.6740	0.8938	0.6795
	1.5240	-	0.0953	1.5240	0.7176	0.1619	1.5240	0.8827	0.6699
	1.2192	-	0.1112	1.2192	0.6985	0.1715	1.2192	0.8446	0.6477
	0.9144	-	0.1334	0.9144	0.6636	0.1905	0.9144	0.8033	0.6255
	0.6096	-	0.1588	0.6096	0.6287	0.2159	0.6096	0.7493	0.6064
	0.3048	-	0.1906	0.3048	0.5842	0.2477	0.3048	0.6922	0.5842
Transom	-	-	0.2223	-	0.5461	0.2858	-	0.6414	0.5620



Note: ***This preliminary set of data points has some small inconsistencies and flaws that will be addressed in a future version.***

CUT A PATTERN OUT OF PLYWOOD

The real test



CUT A PATTERN OUT OF PLYWOOD

Pencils down

There is a point where we should stop measuring and drawing and test the process.

Will this 3D drawing result in accurate patterns?

With DELFTship we can export flat panel plans for the hull skin. I have experimented with that feature and it seems to work. Time for a real test.

Need some Garage Space

Looking for a volunteer (who has some garage space and would be willing to cut a full size pattern out of low cost material (5 mm ply wood or thin plastic) to test the plans.

The task would involve three steps. 1) transfer of the pattern onto the material, 2) cutting out the pieces, and 3) temporarily assembling them using the stich method with low cost plastic zip-ties.

The outcome of this process would be an assessment of the accuracy of the conversion from the 3D model to real life flat panel material. This task might take a few afternoons to complete and involve minimal costs.

CNC Router (DXF File)

DELFTship also produces DXF files that can be imported by CNC routing machines. Cutting plywood on a CNC router is the optimal long term solution due to precision of the final product.

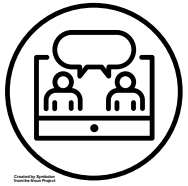
I have no experience with CNC routers or DXF files and would appreciate any assistance.

Near term, would it be possible to export a DXF file and cut a sample pattern via CNC? Any thoughts?

Long term, once the hull measurements are locked down I would hope to make DXF files available to anyone to use.

SHARE IDEAS AND COLLABORATE

Appreciate your help



SHARE IDEAS
COLLABORATE

Collaborate

Thanks to the many folks who have helped me advance this project so far. I have connected with many sailors on several continents via email, Facebook, on the phone and old fashion snail mail.

I hope you find this project of interest and would appreciate your help.

How You Can Help

There are many ways you can help. Any amount of assistance is appreciated.

My immediate priority is to finalize the hull dimensions. This document outlines all the critical measurements and assumptions that I have made.

I would appreciate your help conducting a final review so that the hull measurements can be locked down prior to investing time configuring the interior aspects (bulkhead, floor boards, seat tops).

Other ways you can participate are outlined later in the document. Thanks Don

Ways you can connect:

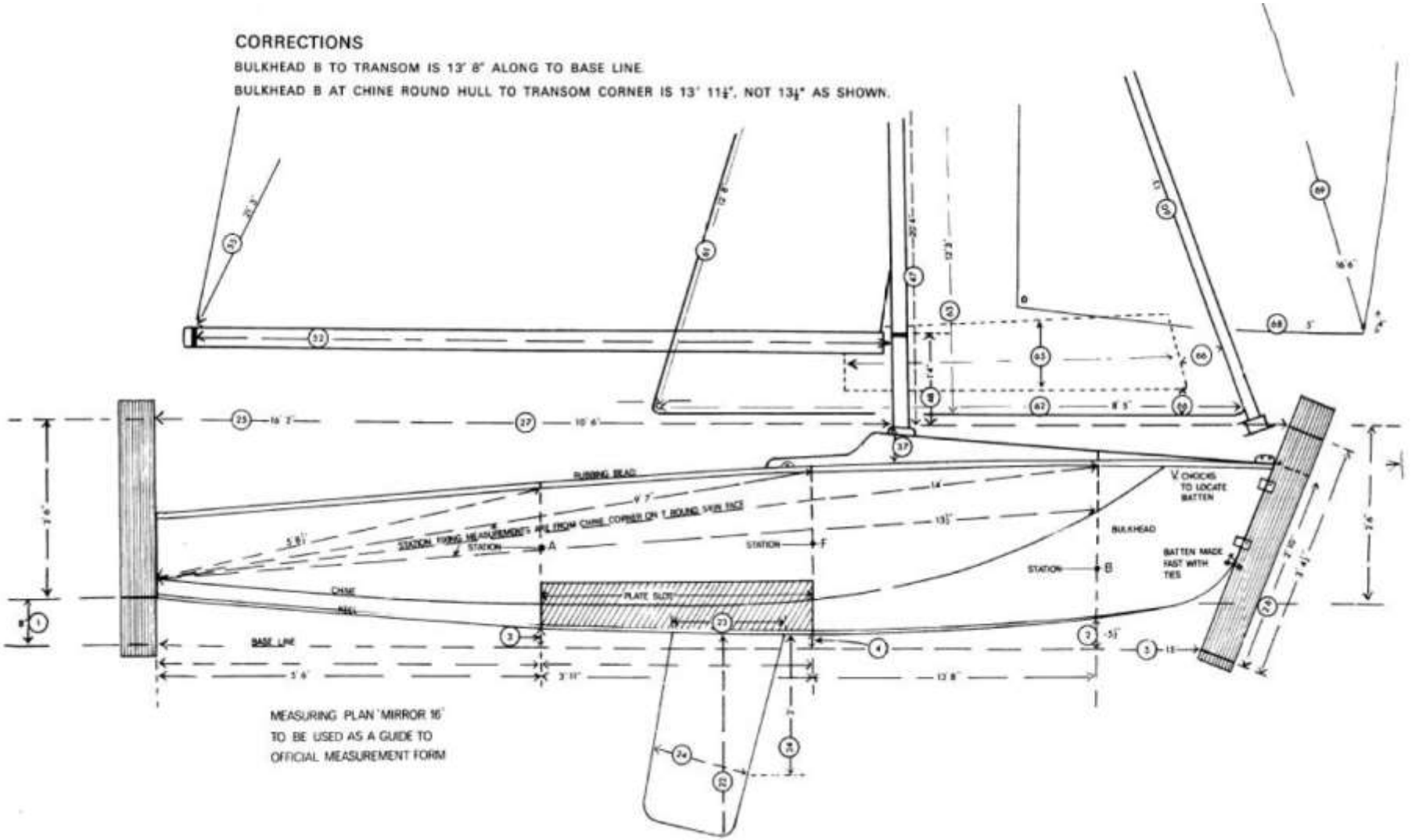
1. Email me at: rebuild_mirror_16@yahoo.com
2. Visit my Mirror 16 web page

Visit other General Interest Forums:

3. Facebook group for Mirror 16
4. Yahoo group for Mirror 16
5. BoatDesign.net Mirror 16 group

1969 MEASURING PLAN (SIDE VIEW)

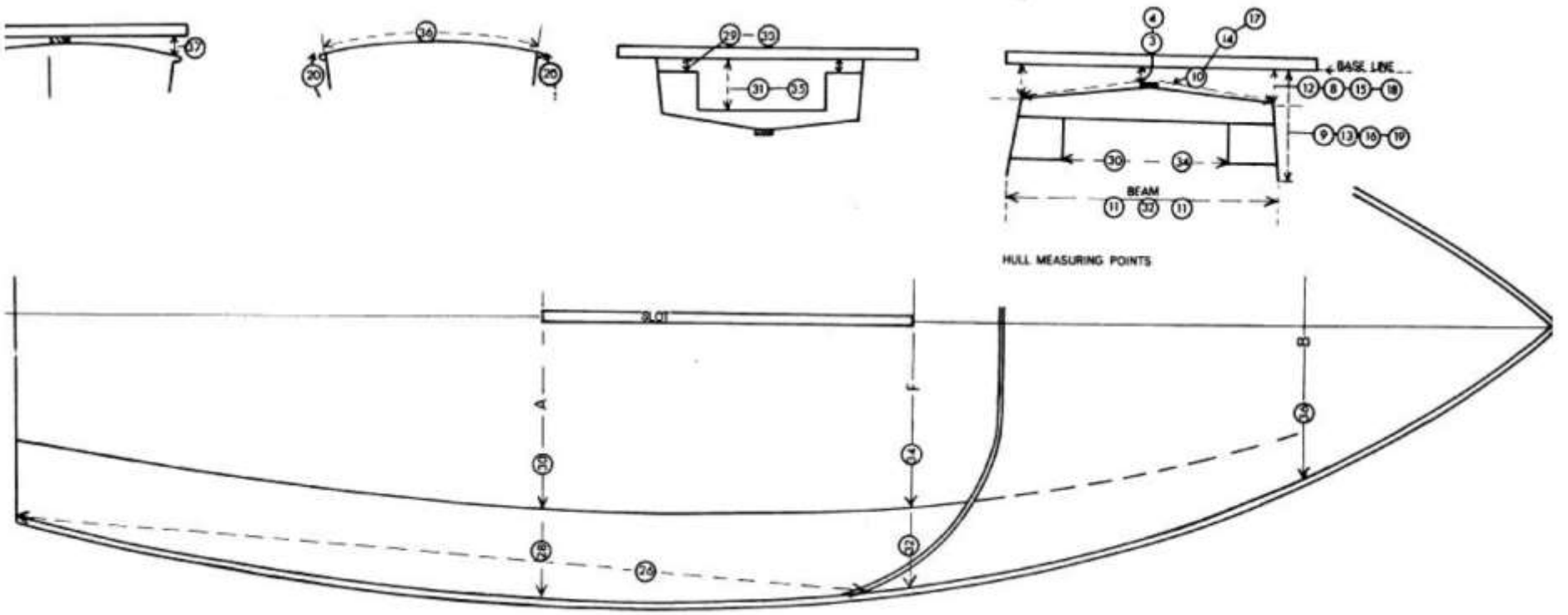
Mirror 16 Original Document



Original Diagrams

1969 MEASURING PLAN (TOP VIEW)

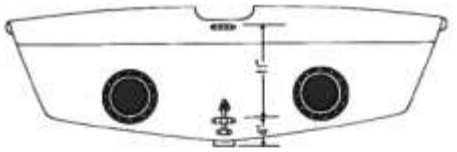
Mirror 16 Original Document

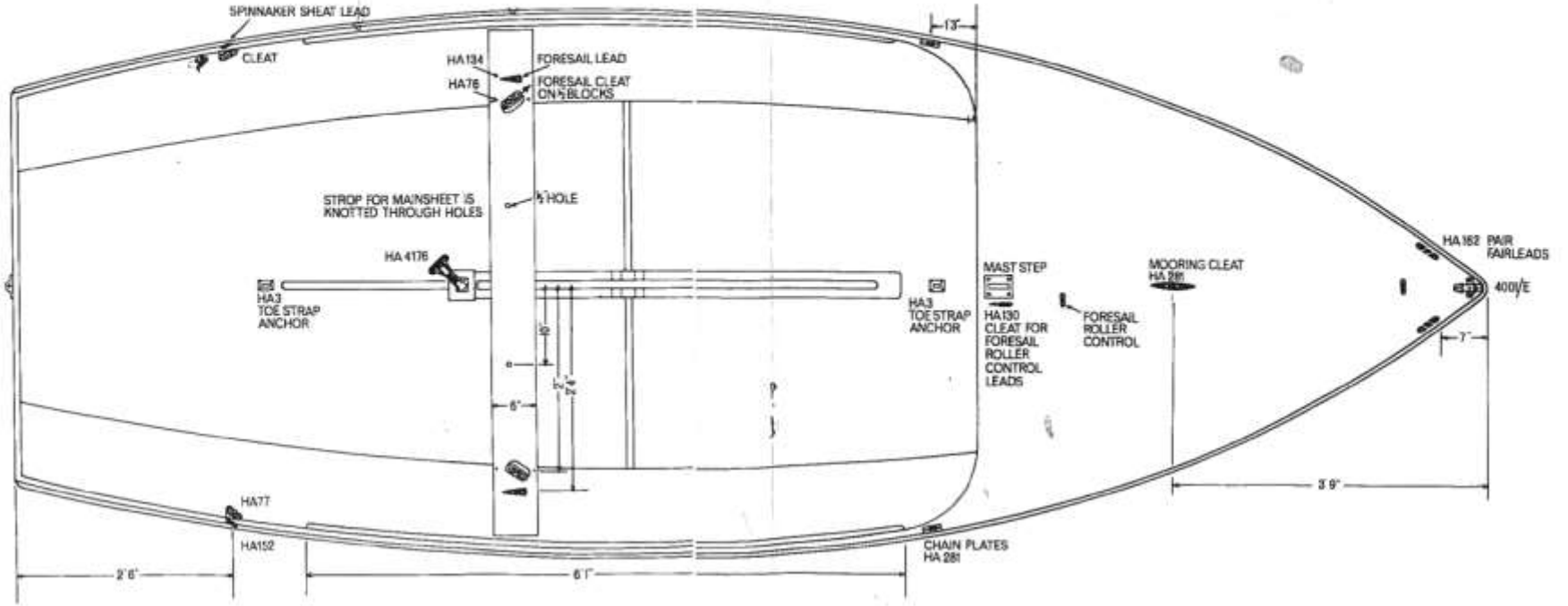


Original Diagrams

1969 HARDWARE LOCATION (TOP VIEW)

Mirror 16 Original Document

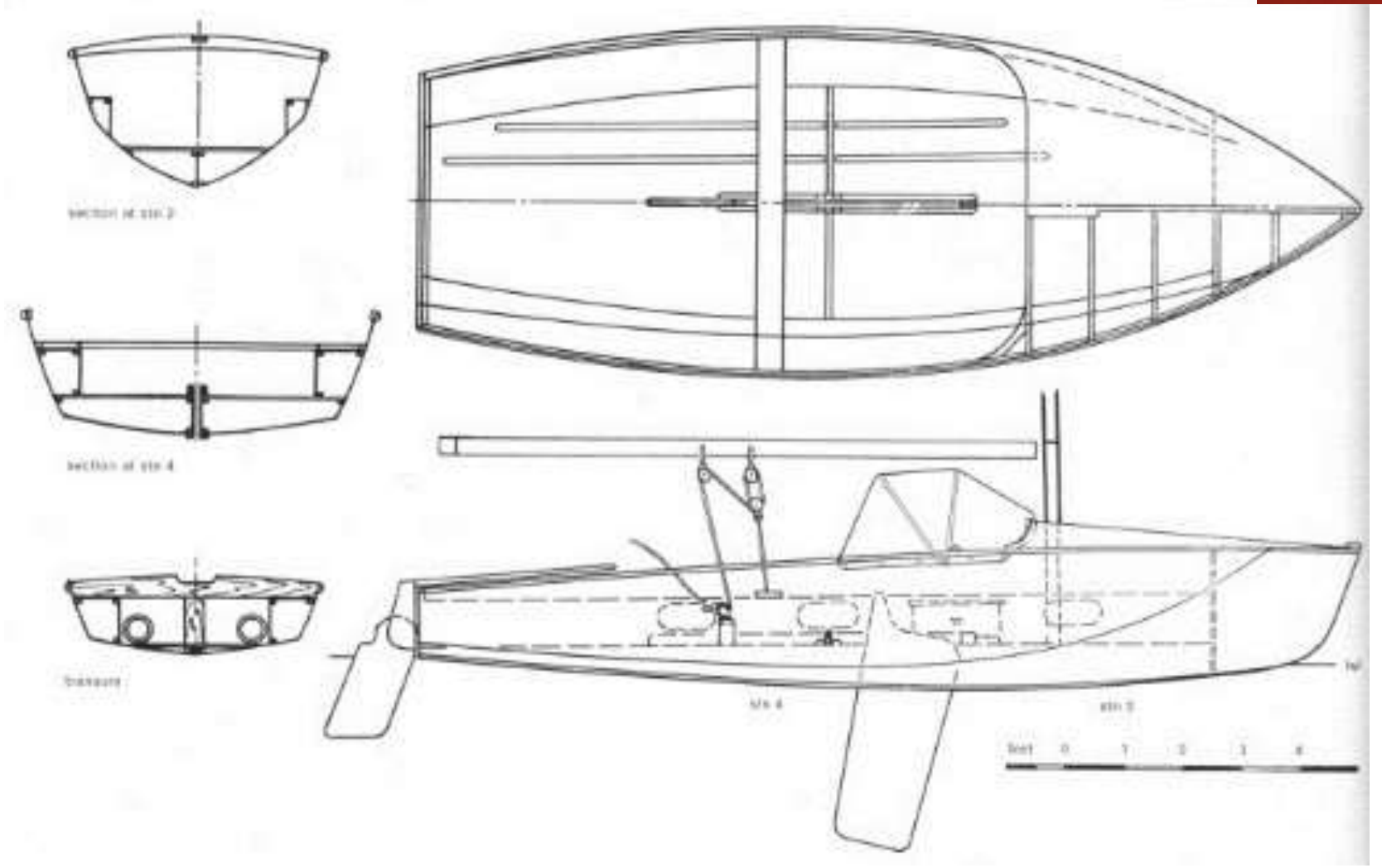




Original Diagrams

1967 DIAGRAM FROM DESIGN JOURNAL

Mirror 16 Original Document



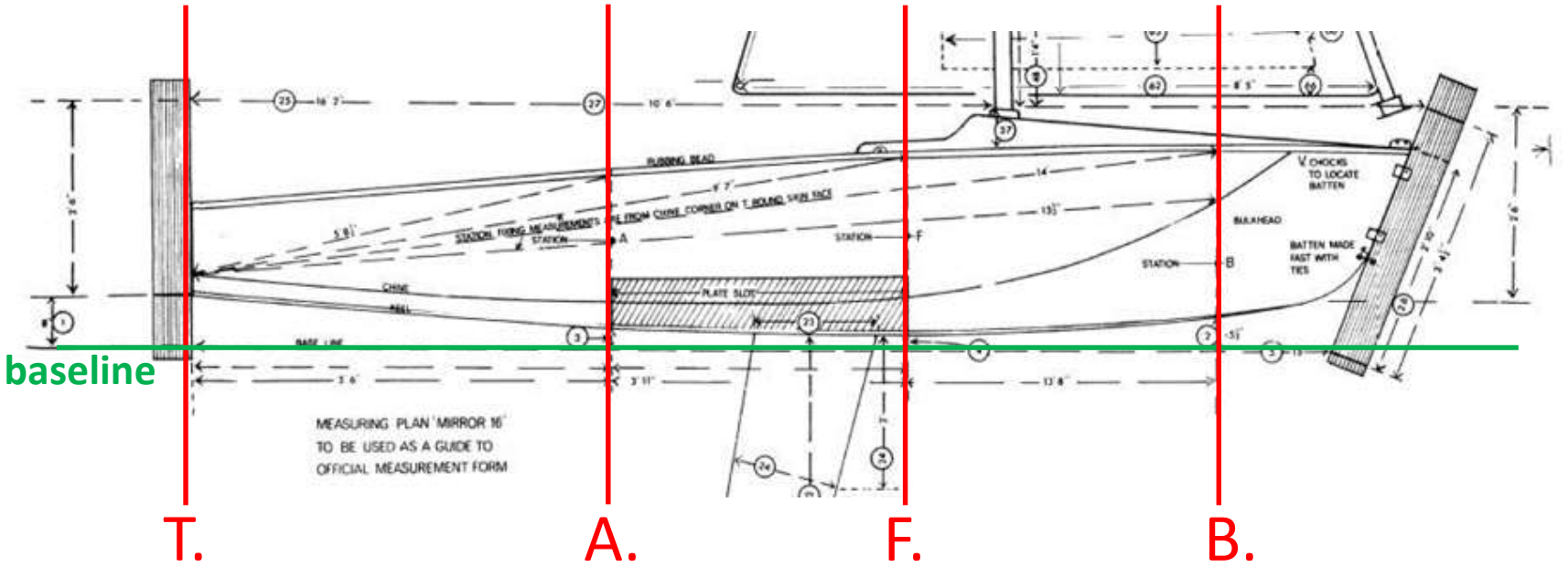
Original Diagrams

KEY ELEMENTS IN ORIGNAL RULES

Along the length of the boat:

Along the length of the boat, the original rules target four specific areas (highlighted with red lines below).

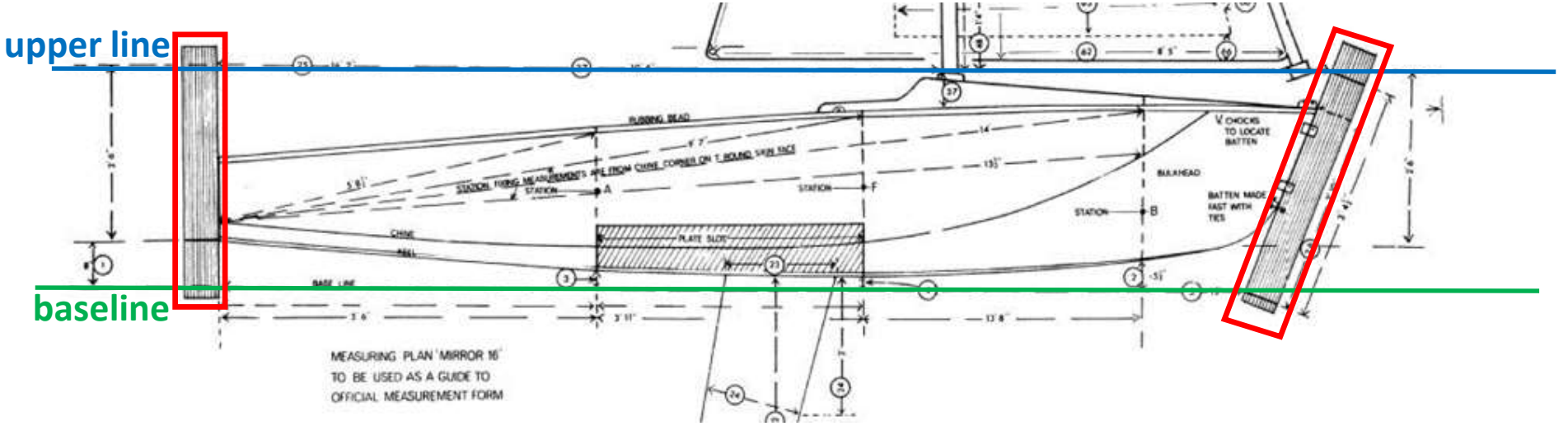
Starting from the left, the first is the **transom (T.)**, next is the **aft end of the centerboard case (A.)**, the **forward end of the centerboard case (F.)** and lastly (farthest to the right) the **bulkhead (B.)**. The bow-tip does not have any specific horizontal measurements along the baseline (the green line below) but does have some angled measurements along the stem board.



KEY ELEMENTS IN ORIGNAL RULES

Baseline, Upper Line & Stem Boards:

- To overcome the challenge of properly measuring the curved surfaces of a fully constructed boat, the original measurement rules added fixed boundaries on four sides.
- The red boxed in areas highlight temporary stem boards that form two of the measurement edges, the lower (green line referred to as the “baseline”) and parallel upper blue line comprise the other boundaries.
- These four boundaries are used in many calculations and references through this document.



KEY ELEMENTS IN ORIGNAL RULES

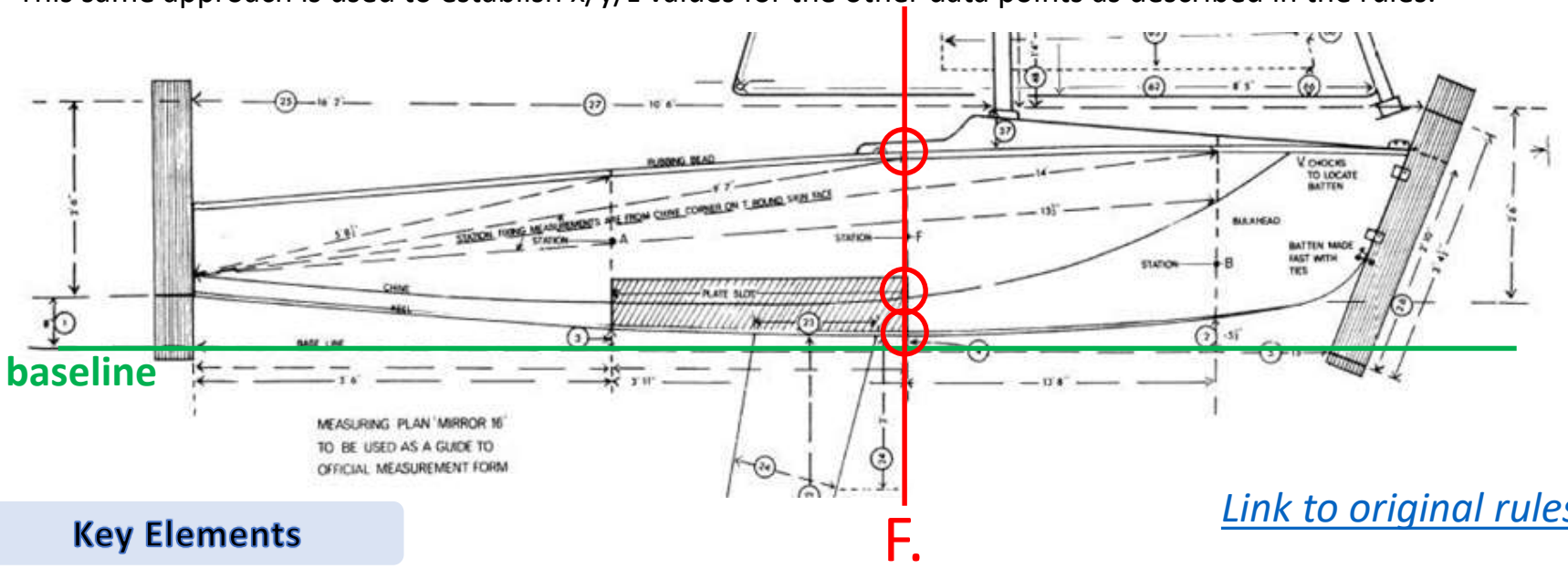
Individual data points & the connection to original rules:

At each of the four locations (T., A., F., B.) the original **rules specify details for the keel, chine and gunwale**. The red circles below highlight these spots at (F.) For each spot the **rules specify a plum distance to the baseline and a horizontal distance from the centerline** of the boat.

Let's review how the rules allow us to define the length, width and height (x/y/z) of the top red circle which is the **gunwale at (F.)**.

The height, or plum distance to the baseline for that spot is rule #16 (2' 5 3/8"). **The width**, or beam of the boat at that spot is rule #11 (4' 2 ½"). **The length** for all three data point at (F.) are 9' 5" forward of the transom based on the original diagram.

This same approach is used to establish x/y/z values for the other data points as described in the rules.



Key Elements

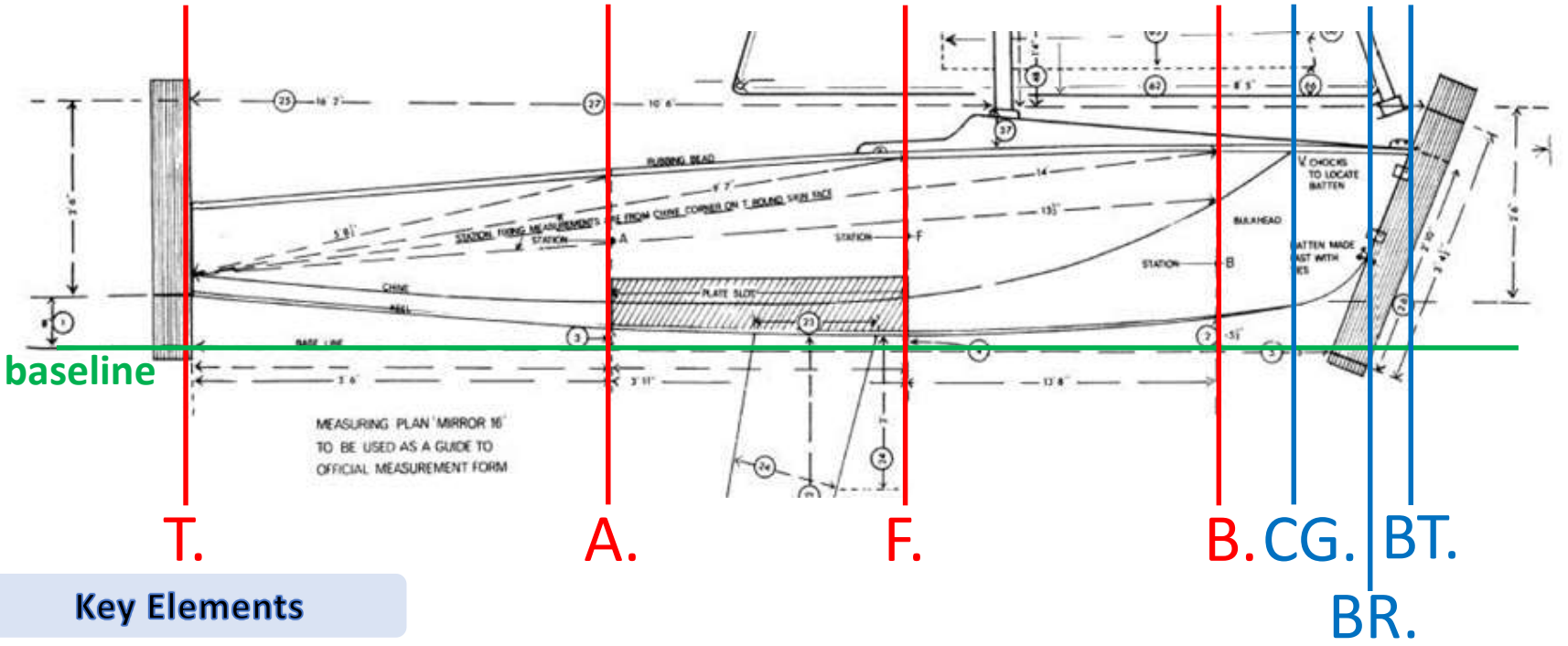
Link to original rules..

MISSING FROM ORIGNAL RULES

Three additional points along the length of the boat:

Along the length of the boat, the original rules did not specify three important areas which we have defined and included throughout this document. (BT., BR., CG.)

Starting from the right, highlighted in blue we added:
the **bow-tip (BT.)** and to the left of that an indication of **lower end of the bow rake (BR.)** and a bit further to the left the point at which the **chine meets the gunwale (CG.)**
These three areas are each unique and impact drafting decisions. Later in the document we provide detail on how those areas have been evaluated.



Key Elements

HULL COORDINATES TIED TO 1969 RULES

- Below is a summary of the key data points (in meters). For each I have noted how they are connected to the original documents and rules. The appendix includes detailed support for each value.
- Each of these (rule based) values were incorporated in the concluded x/y/z data points in from the prior page.
- Some rules have a fixed stated amount and others include a range with a minimum and maximum value. For those with a range, this table shows the average or midpoint of the range.

Location	Keel distance from BL.		Keel depth		Hull distance from BL.		Chine distance from BL.		Gunwale distance to BL.	
B.	rule # 2 (fixed)	0.1390	rule # 6 (fixed)	0.0191	calculated	0.1581	rule #18 (average)	0.5969	rule #19 (average)	0.8128
F.	rule # 4 (average	0.0413	rule # 6 (fixed)	0.0191	calculated	0.0604	rule #15 (average)	0.2381	rule #16 (average)	0.7461
A.	rule # 3 (average	0.0667	rule # 6 (fixed)	0.0191	calculated	0.0858	rule #12 (average)	0.1651	rule #13 (average)	0.6795
T.	rule # 1 (fixed)	0.2030	rule # 6 (fixed)	0.0191	calculated	0.2221	rule #8 (average)	0.2858	rule #9 (average)	0.5620

The locations include:

Bulkhead (B.)

Forward end of the centerboard case (F.)

Aft end of centerboard case (A.)

Transom (T.)

Location	Distance from T.	
B.	original drawing	4.1656
F.	original drawing	2.8702
A.	original drawing	1.674
T.		0

Chine Girth		Gunwale Beam	
		full width=>	0.9144
no specified rule		rule #36 (average)	0.4572
full width=>	1.4351	full width=>	1.7018
rule #17 (average)	0.7176	rule #32 (average)	0.8509
full width=>	1.4478	full width=>	1.7875
rule #14 (average)	0.7239	rule #28 (average)	0.8938
full width=>	1.0922	full width=>	1.2827
rule #10 (average)	0.5461	rule #11 (average)	0.6414

Note: Beam values in the original rules are full width of boat. Our x/y/z measurements are for the port side of the boat, as such the beam and girth measurements are divided in half.

CONCLUDED: KEEL COORDINATES

				baseline to hull skin (adjusting for depth of keel)							
				Overall rule	meters	Adjust for Keel Depth	meters	Combined rules	grid point data	variance	
	T. + 16'	bow-tip	4.8768	fact |112| : |2' 8"| 32.000| in. |0.8128| m.	0.8128	N/A the keel does not extend this far foreward		0.8128	0.8128	-	
BT. - 3 1/8"	T. + 15' 8 7/8"	Bow Rake Mid-Point	4.7974	CA |212| : |1' 11 1/4"| 23.250| in. |0.5906| m.	0.5906				0.5969		
BT. - 6 1/4"	T. + 15' 5 3/4"	BR.	4.7181	CA |208| : |1' 3 1/8"| 15.125| in. |0.3842| m.	0.3842				0.3842		
BT. - 7 1/4"	T. + 15' 4 3/4"		4.6930						0.3581		
BT. - 9 3/8"	T. + 15' 2 5/8"		4.6380						0.2991		
BT. - 12"	T. + 15'		4.5720						0.2531		
BT. - 17"	T. + 14' 7"	CG.	4.4450						0.2123		
BT. - 24"	T. + 14'		4.2672						0.1715		
BT. - 28"	T. 13' 8"	bulkhead	4.1656	rule |2| : |5 1/2"| 5.500| in. |0.1397| m.	0.1397	rule |6| : |3/4"| 0.750| in. |0.0191| m.	0.019	0.1588	0.1588	-	
	T. + 13'		3.9624						0.1302		
	T. + 12'		3.6576						0.0985		
	T. +11'		3.3528						0.0763		
	T. + 10'		3.0480						0.0667		
	T. 9' 5"	F.	2.8702	rule |4| : |1 5/8"| 1.625| in. |0.0413| m.	0.0413	rule |6| : |3/4"| 0.750| in. |0.0191| m.	0.019	0.0604	0.0604	0.0000	
	T. + 9'		2.7432						0.0604		
	T. + 8'		2.4384						0.0572		
	T. + 7'		2.1336						0.0636		
	T. + 6'		1.8288						0.0794		
	T. +5' 6"	A.	1.6740	rule |3| : |2 5/8"| 2.625| in. |0.0667| m.	0.0667	rule |6| : |3/4"| 0.750| in. |0.0191| m.	0.019	0.0858	0.0858	0.0000	
	T. + 5'		1.5240						0.0953		
	T. + 4'		1.2192						0.1112		
	T. + 3'		0.9144						0.1334		
	T. + 2'		0.6096						0.1588		
	T. + 1'		0.3048						0.1906		
	T. + 0'	Transom	-	rule |1| : |8"| 8.000| in. |0.2032| m.	0.2032	rule |6| : |3/4"| 0.750| in. |0.0191| m.	0.019	0.2223	0.2223	-	

This page shows each and every x/y/z data point for the keel. The following pages have similar details for the chine and gunwale. These are the same values used in the CAD/CAM model

CONCLUDED: GUNWALE COORDINATES

				Gunwale beam				Gunwale distance to baseline			
				Overall rule	meters	grid point data	variance	Overall rule	meters	grid point data	variance
	T. + 16'	bow-tip	4.8768			-				0.8128	
BT. - 3 1/8"	T. + 15' 8 7/8"	Bow Rake Mid-Point	4.7974			0.0572				0.8128	
BT. - 6 1/4"	T. + 15' 5 3/4"	BR.	4.7181			0.1143				0.8128	
BT. - 7 1/4"	T. + 15' 4 3/4"		4.6930			0.1365				0.8128	
BT. - 9 3/8"	T. + 15' 2 5/8"		4.6380			0.1746				0.8128	
BT. - 12"	T. + 15'		4.5720			0.2191				0.8128	
BT. - 17"	T. + 14' 7"	CG.	4.4450			0.3048				0.8128	
	T. + 14'		4.2672			0.3969				0.8128	
	T. 13' 8"	bulkhead	4.1656	rule |36| : |3'| 36.000| in. |0.9144| m.	0.4572	0.4572	-	rule |19| : |2' 8"| 32.000| in. |0.8128| m.	0.8128	0.8128	-
	T. + 13'		3.9624			0.5493				0.8001	
	T. + 12'		3.6576			0.6699				0.7874	
	T. +11'		3.3528			0.7620				0.7715	
	T. + 10'		3.0480			0.8255				0.7588	
	T. 9' 5"	F.	2.8702	rule |32| : |5' 7"| 67.000| in. |1.7018| m.	0.8509	0.8509	-	rule |16| : |2' 5 3/8"| 29.375| in. |0.7461| m.	0.7461	0.7461	(0.0000)
	T. + 9'		2.7432			0.8668				0.7398	
	T. + 8'		2.4384			0.8954				0.7239	
	T. + 7'		2.1336			0.9081				0.7049	
	T. + 6'		1.8288			0.9049				0.6922	
	T. +5' 6"	A.	1.6740	rule |28| : |5' 10 3/8"| 70.375| in. |1.7875| m.	0.8938	0.8938	(0.0000)	rule |13| : |2' 2 3/4"| 26.750| in. |0.6795| m.	0.6795	0.6795	0.0000
	T. + 5'		1.5240			0.8827				0.6699	
	T. + 4'		1.2192			0.8446				0.6477	
	T. + 3'		0.9144			0.8033				0.6255	
	T. + 2'		0.6096			0.7493				0.6064	
	T. + 1'		0.3048			0.6922				0.5842	
	T. + 0'	Transom	-	rule |11| : |4' 2 1/2"| 50.500| in. |1.2827| m.	0.6414	0.6414	-	rule |9| : |1' 10 1/8"| 22.125| in. |0.5620| m.	0.5620	0.5620	0.0000

Note: we use the half beam measurement and the rules are for the full beam

CONCLUDED: CHINE COORDINATES

				Chine beam				Chine distance to baseline			
				Overall rule	meters	grid point data	variance	Overall rule	meters	grid point data	variance
	T. + 16'	bow-tip	4.8768			-				-	
BT. - 3 1/8"	T. + 15' 8 7/8"	Bow Rake Mid-Point	4.7974			-				-	
BT. - 6 1/4"	T. + 15' 5 3/4"	BR.	4.7181			-				-	
BT. - 7 1/4"	T. + 15' 4 3/4"		4.6930			-				-	
BT. - 9 3/8"	T. + 15' 2 5/8"		4.6380			-				-	
BT. - 12"	T. + 15'		4.5720			-				-	
BT. - 17"	T. + 14' 7"	CG.	4.4450			0.3048				0.8128	
	T. + 14'		4.2672			0.3473				0.6636	
	T. 13' 8"	bulkhead	4.1656	no rule for horizontal beam		0.3810		rule |18| : |1' 11 1/2"| 23.500| in. |0.5969| m.	0.5969	0.5969	-
	T. + 13'		3.9624			0.4540				0.4890	
	T. + 12'		3.6576			0.5525				0.3842	
	T. +11'		3.3528			0.6318				0.3048	
	T. + 10'		3.0480			0.6953				0.2604	
	T. 9' 5"	F.	2.8702	rule |17| : |4' 8 1/2"| 56.500| in. |1.4351| m.	0.7176	0.7176	-	rule |15| : |9 3/8"| 9.375| in. |0.2381| m.	0.2381	0.2381	(0.0000)
	T. + 9'		2.7432			0.7303				0.2223	
	T. + 8'		2.4384			0.7430				0.1873	
	T. + 7'		2.1336			0.7461				0.1715	
	T. + 6'		1.8288			0.7334				0.1556	
	T. +5' 6"	A.	1.6740	rule |14| : |4' 9"| 57.000| in. |1.4478| m.	0.7239	0.7239	-	rule |12| : |6 1/2"| 6.500| in. |0.1651| m.	0.1651	0.1651	-
	T. + 5'		1.5240			0.7176				0.1619	
	T. + 4'		1.2192			0.6985				0.1715	
	T. + 3'		0.9144			0.6636				0.1905	
	T. + 2'		0.6096			0.6287				0.2159	
	T. + 1'		0.3048			0.5842				0.2477	
	T. + 0'	Transom	-	rule |10| : |3' 7"| 43.000| in. |1.0922| m.	0.5461	0.5461	-	rule |8| : |11 1/4"| 11.250| in. |0.2858| m.	0.2858	0.2858	0.0000

Note: we use the half beam

HOMEWORK

Appreciate your help

How you can help

There are many remaining tasks in this project, some small and some large. If you have a free hour or afternoon we would appreciate your help.

We have identified some specific tasks, some are related to CAD/CAM software and others are related to original documents or the measurement of actual boats.

For each we have noted the missing information and provide some insight into what data and approach might be used to solve the task.

Overview

The next steps in this project require resolution of some open questions.

Questions about the slope of the floor and the precise termination point of the chine among other items need to be refined and locked down prior adding interior features.

Existing Boat Owners

Measurements from your boat can help clarify values which have been difficult to identify from the documents. Your boat also provides an additional benchmark to measurements from my boat.

Review of Documents

Further review of the original documents including the building instructions may shed light on some of the missing information.

Review of Calculations

I would benefit from an independent review of my calculations to ensure I did not make any errors.

Thank You

I really appreciate the help and assistance to keep this project moving forward.

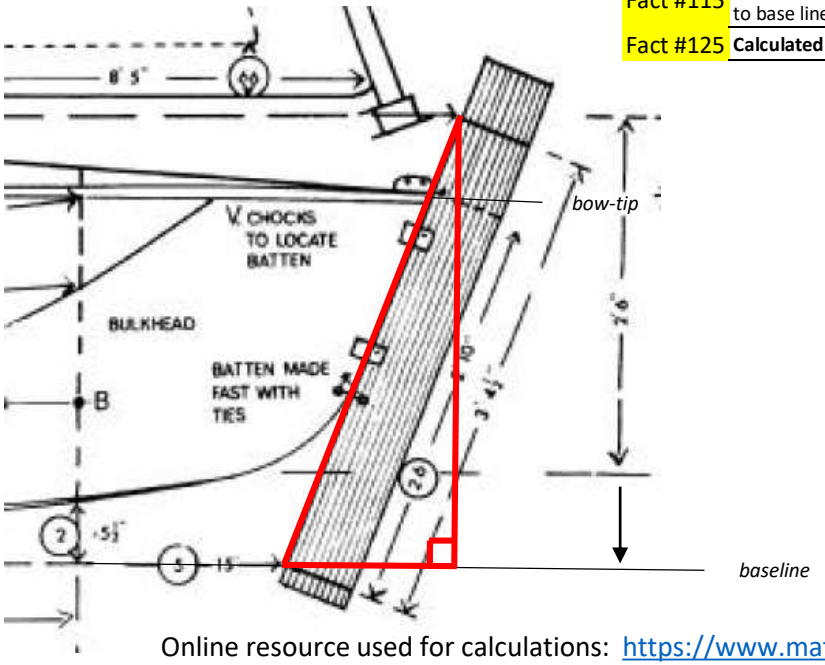
Don

SOLVING: STEM BOARD ANGLE

Approach & Conclusion:

- The original documents and rules specify angled measurements for the bow unfortunately, it is difficult to directly use those measurements in our project. We need vertical (plum) measurements. To overcome this limitation we use the stem board angle and back into several important metrics using a bit of geometry.
- The diagram below, from the original documents, shows the temporary stem board attached to the angled rake portion of the bow. Using basic geometry and other facts from the original documents, we were able to calculate the stem board angle to be 20.2367 degrees (FA #125)

Solving Stem Board Angle = Alpha Angle of a right triangle			inches	meters	
Fact #113	Right **Triangle Hypotenuse =** angled length of stem board at bow (full length)	3' 4 1/2"	40.50	1.0287	per original documents
Fact #115	Right **Triangle Side b =** the plum length of upper line to base line as measured at transom	3' 2"	38.00	0.9652	per original documents
Fact #125	**Calculated result** for a **Alpha Angle** of a right triangle			20.2367	calculated



Online resource used for calculations: https://www.mathportal.org/calculators/plane-geometry-calculators/right-triangle-calculator.php

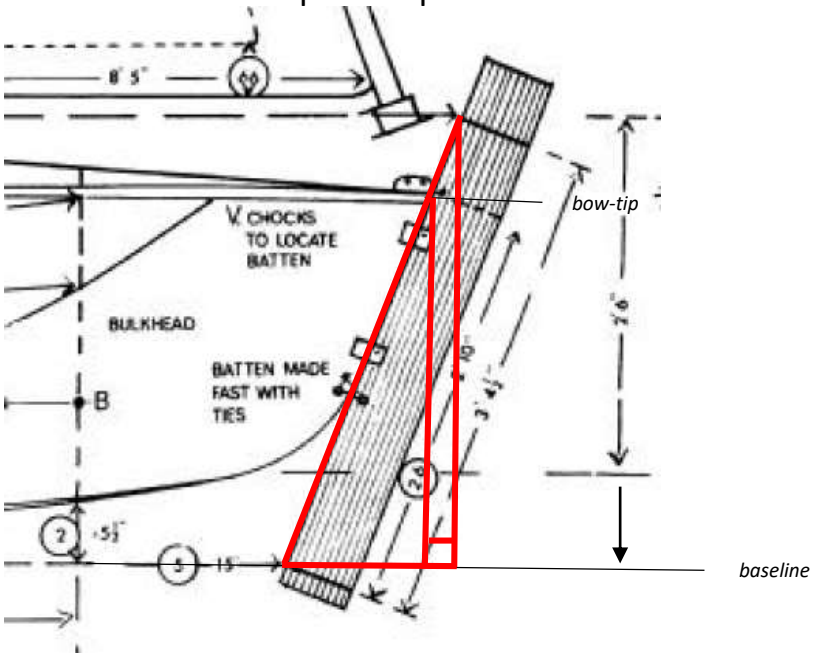
SOLVING: BOW-TIP DISTANCE TO BASELINE

Approach & Conclusion:

- The original documents and rules do not specify the bow-tip to baseline (plum distance)
- The documents provide an angled measurement (along the stem board)
- Using basic geometry we converted the angled measurement to a plum measurement
- The concluded plum bow-tip to baseline distance is 32” or 0.8128m (FA #112)

Additional Considerations:

- Based on original drawings the bow-tip appears to be level with gunwale at the bulkhead (B.)
- Rule #19 is the measurement of the baseline to G. at B. with an average of 2' 8" or 0.8128m
- The rounded results from step 2 (below) for the bow-tip to baseline is 2' 8" or 0.8128m
- My boat measures 31 7/8” just 1/8th inch shy of the concluded value of 2' 8" or 0.8128m
- The bow-tip is not pointed but rather a flat edge extending no further forward than the hull skin



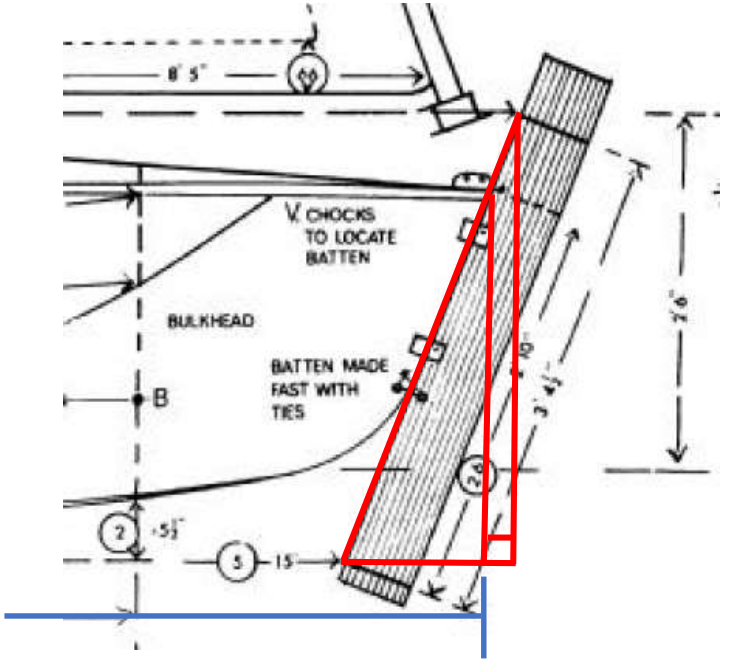
Fixed data obtained from original drawings	Imperial	Inches	Metric (m.)	
Length base line to upper line along the angled stem board fixed at bow	3' 4 1/2"	40.50	1.0287	per original documents
Length base line to bow-tip along the angled stem board at bow	2' 10"	34.00	0.8636	per original documents
Plum length of base line to upper line 3' 2" = (2' 6" + 8")	3' 2"	38.00	0.9652	per original documents
Step 1) Solve for Alpha Angle for a right triangle				
Right **Triangle Hypotenuse** = angled length of stem board at bow (full length)	3' 4 1/2"	40.50	1.0287	per original documents
Right **Triangle Side b** = the plum length of upper line to base line as measured at transom	3' 2"	38.00	0.9652	per original documents
Calculated result for a Alpha Angle of a right triangle			20.2367	calculated
Step 2) Solve for bow-tip distance to baseline using the Alpha Angle and revised Hypotenuse length				
Right Triangle Hypotenuse = angled length of stem board at bow (base line to bow-tip)	2' 10"	34.00	0.8636	per original documents
Right triangle alpha angle from the calculation above in step 1			20.2367	from calculation above in step 1
Calculated result for right triangle side B is the plum distance bow-tip to base line		31.90	0.8103	calculated
Estimated plum distance bow-tip to baseline (rounded up)	2' 8"	32.00	0.8128	**my final concluded estimate**

Online resource used for right triangle calculations: https://www.mathportal.org/calculators/plane-geometry-calculators/right-triangle-calculator.php

SOLVING BOW-TIP LENGTH FROM TRANSOM

Approach:

- The original documents and rules do not specify straight line length of boat (transom to bow-tip)
- Rule #25 provides a total length at upper boundary to the angled stem board along the raked bow. This distance (16’ 2” Fact #107) is slightly longer than the actual boat.
- Using basic geometry and the angle of the stem board, we solved for the straight line transom to bow-tip length. The solution is a multi-step process. First we solve for the baseline of the ***full length of stem board*** (3’ 4 ½”) and then the ***shorter portion of the stem board*** (2’ 10”). The baseline difference between these two measurements is then used in the bow-tip calculation.
- The complete calculations are shown on the next page which results in a baseline difference of 2 ¼”.



Additional Considerations:

- Using the approach described above, the length of the boat would be 15' 3/4“ resulting from 16’ 2” less 2 ¼”
- My own boat hull #435 measures 16’ 1/4”
- Based on my observations of the boat and seeing many rounded values I assume Jack Holt would have assumed an even length of 16’ and not 15’ ¾” as implied by the geometry resulting from the measurement form.

Conclusion:

- For purpose of drafting the hull , I concluded the **horizontal straight line transom to bow-tip** to be **16’ or 192” or 4.8768m (CA #204)**

SOLVING BOW-TIP LENGTH FROM TRANSOM

Approach & Conclusion:

- **Step 1** solves the baseline measurement for the larger of the two triangles.
- **Step 2** solves the baseline measurement for the smaller of the two triangles.
- **Step 3** the baseline variance of the two triangles is identified.
- **Step 4** the total length of boat is estimated .
- See prior page for additional details

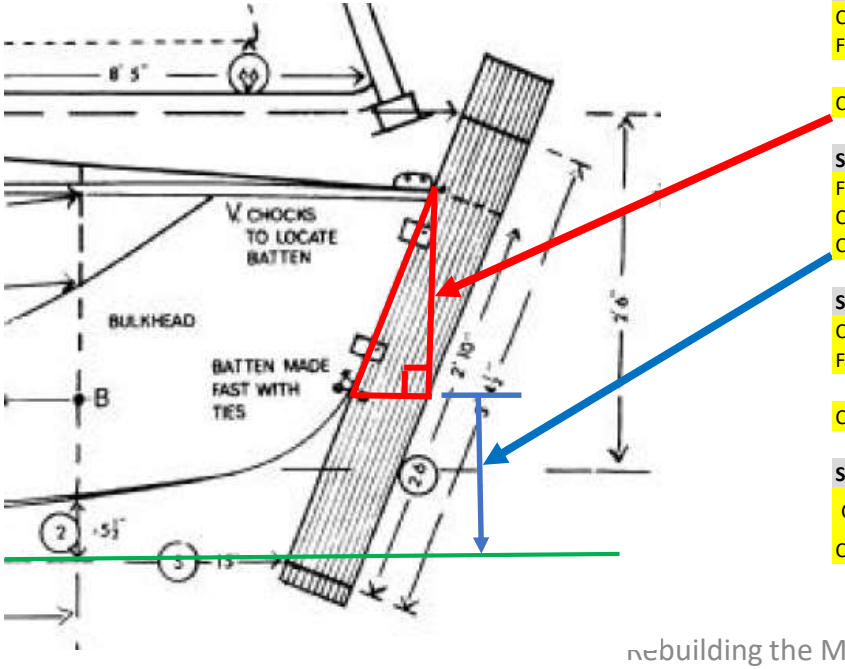
Solving Stem Board Angle = Alpha Angle of a right triangle			inches	meters	
Fact #113	Right **Triangle Hypotenuse =** angled length of stem board at bow (full length)	3' 4 1/2"	40.50	1.0287	per original documents
Fact #115	Right **Triangle Side b =** the plum length of upper line to base line as measured at transom	3' 2"	38.00	0.9652	per original documents
Fact #125	**Calculated result** for a **Alpha Angle** of a right triangle			20.2367	calculated
Step 1) Full length of the stem board: solve for length of base side (A)					
Fact #113	Right **Triangle Hypotenuse =** angled length of stem board at bow (full length)	3' 4 1/2"	40.50	1.0287	per original documents
Fact #115	**Stem Board Angle (Alpha Angle)**			20.2367	from prior calculations
	Calculated result for right triangle side a (the base line horizontal length)	1' 2"	14.00	0.3556	calculated
Step 2) Short length of the stem board: solve for length of base side (A)					
Fact #114	Right Triangle Hypotenuse = angled length of stem board at bow (base line to bow-tip)	2' 10"	34.00	0.8636	per original documents
Fact #115	**Stem Board Angle (Alpha Angle)**			20.2367	from prior calculations
	Calculated result for right triangle side a (the base line horizontal length)	11 3/4"	11.75	0.2985	calculated
Step 3) Calculate the difference in base side (base line) measurements					
	Base line length from step 1 above	1' 2"	14.00	0.3556	calculated
	less: Base line length from step 2 above	11 3/4"	11.75	0.2985	calculated
	Compute base line variance	2 1/4"	2.25	0.0572	calculated
Step 4) Calculate total length of boat: (transom to bow-tip)					
Fact #107	length of upper line (transom to angled stem board at bow)	16' 2"	194.00	4.9276	per original documents & Rule #25
	Less base line variance from step 3 above	2 1/4"	2.25	0.0572	from prior calculations
	Estimate boat length (horizontal straight line from transom to bow-tip)	15' 3/4"	191.75	4.8705	calculated
CA #204	total boat length - horizontal distance from transom to bow-tip	16'	192.00	4.8768	Concluded assumption

SOLVING: BOW RAKE (BR.) DIMENSION

Approach:

- The Mirror 16 has a raked bow that slants from the water to the deck (a flat angle without a curve).
- The angle of the bow rake is identical to stem board which we calculated in a prior step. (FA #125)

- **Observed Length:** On my boat I attached a temporary stem board to the bow and found the angled flat portion (or rake) to be 18” or 0.4572m long (CA #205).
- **Second Step:** Using a right triangle calculator with the angle of the stem board (FA #125) and the angled length of the bow rake (CA #205) we solve for the plum distance to the baseline of 16 7/8” or 0.4286m (CA #208).
- **Third Step:** Calculate plum distance from the lower edge of the bow rake to the baseline.
- **Fourth and Fifth Steps**: Calculate lower edge of bow rake distance to transom of 15’ 5 ¾” or 4.7181m



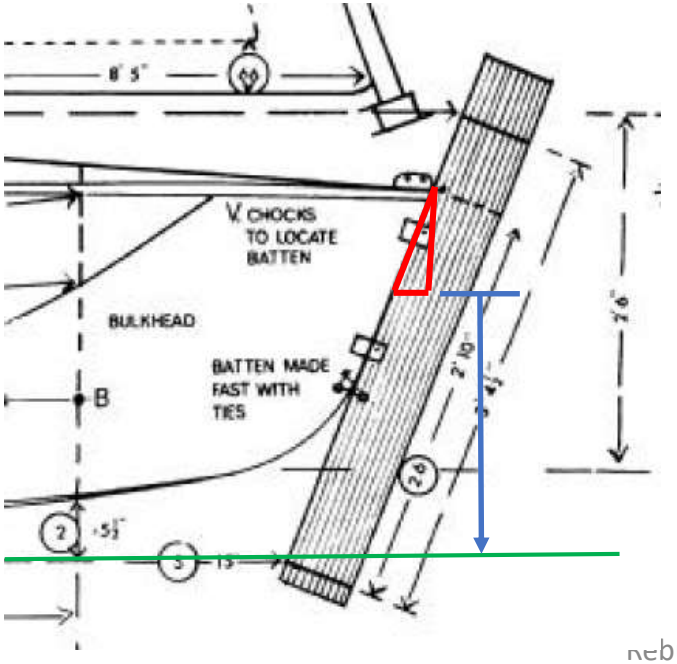
Step 2) Calculate plum length of bow rake (using observed angled bow-rake length)					
CA #205	angled length of bow rake (along stem board)	1' 6"	18.000	0.4572	observation on my boat
Fact #125	angle of stem board			20.2367	calculated from original
	plum length of bow rake		16.890	0.4290	calculated with right triangle
CA #206	plum length of bow rake (rounded to 1/8")	1' 4 7/8"	16.875	0.4286	rounded results
Step 3) Lower edge of bow rake to baseline plum length					
Fact #112	Bow-tip to baseline (plum distance)	2' 8"	32.000	0.8128	calculated from original
CA #206	plum length of bow rake (rounded to 1/8")	1' 4 7/8"	16.875	0.4286	calculated in prior step
CA #208	Lower edge of bow rake to baseline plum length	1' 3 1/8"	15.125	0.3842	caclulated (#112 - #206)
Step 4) Calculate bow-rake length (along the baseline) as measured from bow-tip					
CA #205	angled length of bow rake (along stem board)	1' 6"	18.000	0.4572	observation on my boat
Fact #125	angle of stem board			20.2367	calculated from original
	length of bow rake to bow-tip (along the baseline)		6.224	0.1581	calculated with right triangle
CA #207	length of bow rake to bow-tip along the baseline	6 1/4"	6.250	0.1588	rounded results
Step 5) Lower edge of bow rake distance to transom (T.)					
CA #204	total boat length - horizontal distance from transom to bow-tip	16'	192.00	4.8768	Concluded assumption
CA #207	length of bow rake to bow-tip along the baseline	6 1/4"	6.250	0.1588	Concluded assumption
	lower edge of bow rake distance to transom (T.) as measured along the baseline	15' 5 3/4"	185.750	4.7181	rounded results

SOLVING: MID-POINT OF BOW RAKE

Approach & Conclusion:

- To ensure the CAD/CAM software models the rake as a true flat edge I have calculated the mid-point.
- We follow the same steps used on the prior page except we solve for the mid-point of the rake.

- For purpose of drafting the hull , I concluded
  The mid-point of the bow rake has a length of 9” (as measured along the stem board)
  The plumb (or vertical) length of the rake (bow-tip to mid-point of rake) is 8.5” or 0.2159
  The mid-point of the rake terminates 3 1/8” aft of the bow-tip (as measured along the baseline)
  The mid-point of the rake terminates 23 1/2” from the baseline (blue line in image below)
  The mid-point of the rake is 15’ 8 7/8” or 4.7974m from the transom (T.) (as measured along the baseline)



Data obtained from observations on my boat					
		Imperial	Inches	Metric (m.)	
CA #205	angled length of bow rake along stem board	1' 6"	18.000	0.4572	observation on my boat
	mid-pont bow rake	9"	9.000	0.2286	observation on my boat
Step 2) Calculate plum length of mid-point bow rake (using observed angled bow-rake length)					
	angled length of mid-point bow rake (along stem board)	9"	9.000	0.2286	observation on my boat
Fact #125	angle of stem board			20.2367	calculated from original
	plum length mid-point of bow rake		8.445	0.2145	calculated with right triangle
	plum length of mid-point bow rake (rounded to 1/8")	8 1/2"	8.500	0.2159	rounded results
Step 3) Lower edge of mid-point bow rake to baseline plum length					
Fact #112	Bow-tip to baseline (plum distance)	2' 8"	32.000	0.8128	calculated from original
	plum length of mid-point bow rake (rounded to 1/8")	8 1/2"	8.500	0.2159	calculated in prior step
	Lower edge of mid-point bow rake to baseline plum length	1' 11 1/2"	23.500	0.5969	calculated with hybrid info
Step 4) Calculate mid-point bow-rake length (along the baseline) as measured from bow-tip					
	angled length of mid-point bow rake (along stem board)	9"	9.000	0.2286	observation on my boat
Fact #125	angle of stem board			20.2367	calculated from original
	length of bow rake (along the baseline)		3.114	0.0791	calculated with right triangle
	length of mid-point bow rake along the baseline (rounded) as measured from bow-tip	3 1/8"	3.125	0.0794	rounded results
Step 5) mid-point of bow rake distance to transom (T.)					
CA #204	total boat length - horizontal distance from transom to bow-tip	16'	192.00	4.8768	Concluded assumption
	length of mid-point bow rake along the baseline (rounded) as measured from bow-tip	3 1/8"	3.125	0.0794	from prior step
	mid-point of bow rake distance to transom (T.) as measured along the baseline	15' 8 7/8"	188.875	4.7974	rounded results

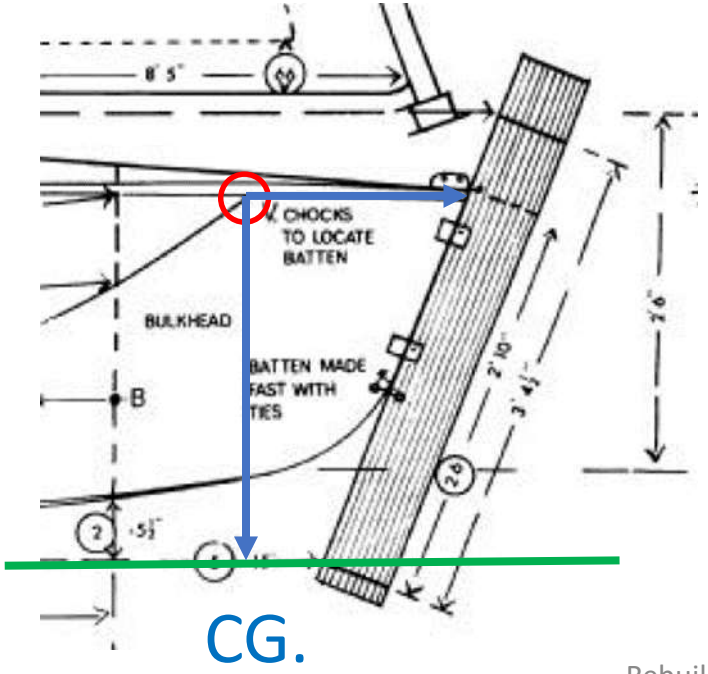
ESTIMATE: LENGTH FROM T. TO CG.

Not final – still under review:
See homework section for details

The chine is the sharp edge or crease that runs along the length of the hull. It is important to identify where this distinct feature terminates so we can create proper flat panel templates. The original documents do not specify the termination point where the chine meets the gunwale (CG.)

By observation on my boat I determined the chine meets the gunwale 17" aft of the bow tip (CA #220) or 14' 7" forward from the transom (CA #219). Both as measured along the centerline of the boat. Discerning the exact location on my hull is difficult because this section is quite flat and covered by a layer of fiberglass cloth I am hopeful that another Mirror 16 owner can help refine this measurement.

For this same data point we need a distance to baseline. Earlier we documented the distance to baseline for the bow-tip (FA #112) and the bulkhead at G. (rule #19) and found them to be equal at 32". As such we are assigned the same distance to baseline for where the chine meets the gunwale. Conclusion: The baseline below G. at CG. is 32" (CA #222)



CA #219 length from T. to CG.
CA #220 length from BT. To CG.
CA #222 Baseline below G. at CG.

ESTIMATE: BASELINE BELOW K. AT CG.

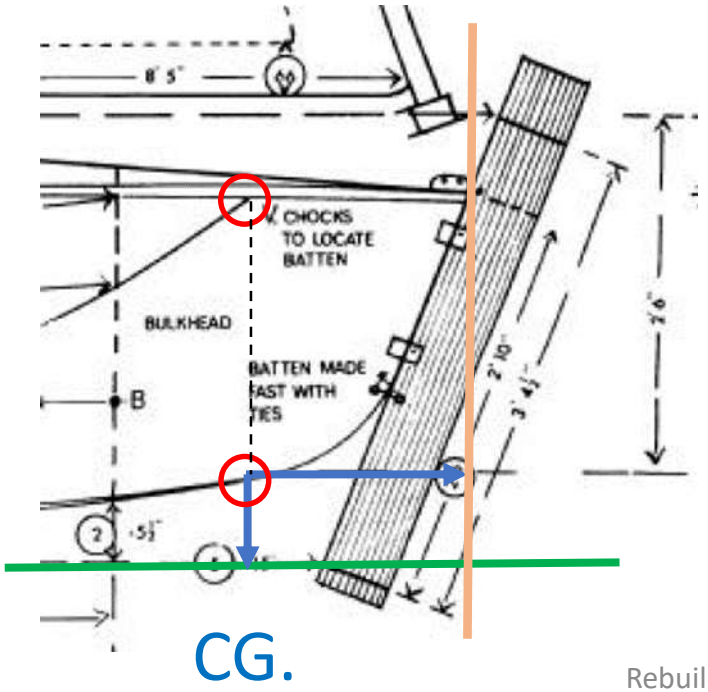
Not final – still under review:
See homework section for details

Rebuilding the Mirror 16

A Keel distance to the baseline (plum distance) is also necessary for where the chine meets the gunwale.

A measurement from my boat was used for this data point know as baseline below K. at CG. CA#221 or

On my boat the keel is a full depth of ¾" running from the transom to about 15" aft of the bow-tip (BT.). The keel thins and tapers between BT. less 15" to BT. Less 12" and then finally for the last 12" there is no keel. At CG. the keel is full thickness (3/4").

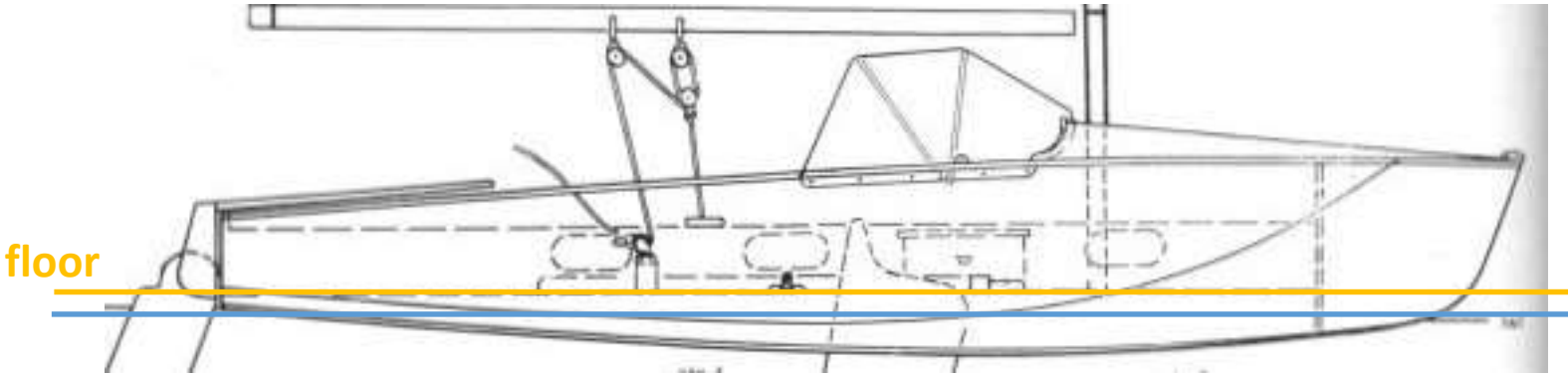


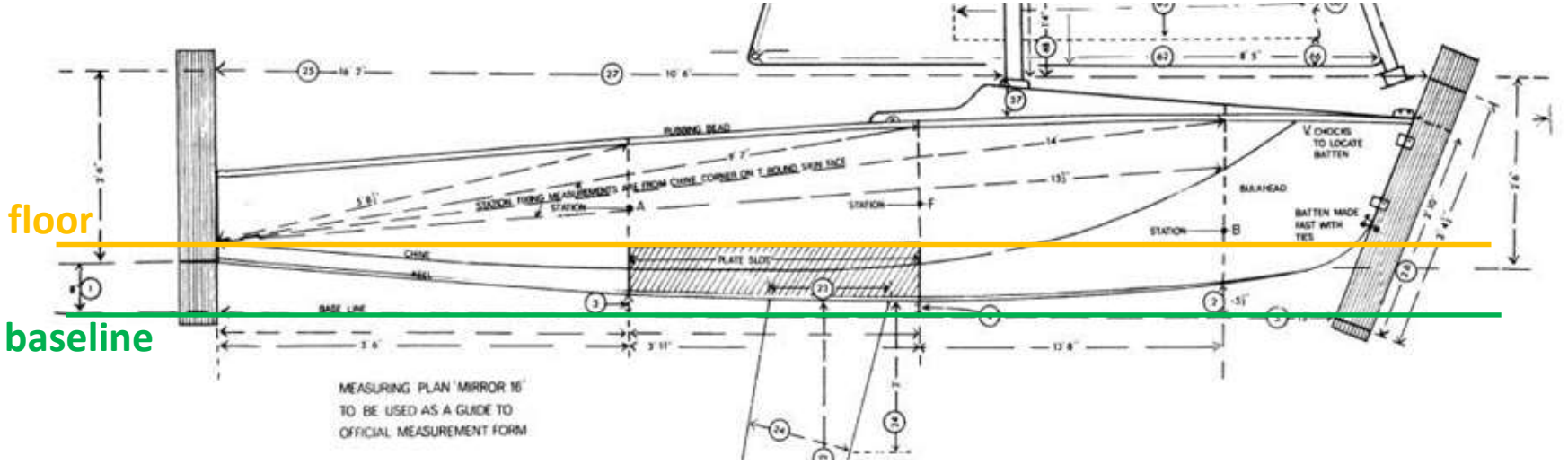
CA #221 Baseline below K. at CG.

SOLVE: SLOPE OF INTERIOR FLOOR

Does the floor have a slope?:

The rule based metrics indicate the floor has a small slope relative to baseline.
The floor, based on observation, (in the lower image) appears to be parallel to the baseline. The upper image, has a waterline notation (LWL) and it looks like the floor may not be perfectly level with the waterline.





SOLVING: FLOOR DISTANCE TO BASELINE

Challenge & Counterintuitive information:

- Reviewing the original rules, **I was surprised to find the interior floor has a small slope downward toward the bow.**
- Based on observation of the 1969 drawings the floor appears to be parallel to the baseline and waterline.
- My intuition is also that the interior floor would be parallel to the baseline and waterline. Although the original documents have very limited information on the waterline location, so **I don't have anyway to compare the waterline to the baseline**.
- If the interior floor of a boat were to have a slope, I assume it would slope backward toward the transom drains and not slope toward the bow. Although, could the boat be designed (sitting empty with no passengers) to have a small downward slope to the bow that is leveled out once the crew of two or three people are sitting toward the aft end of the boat. QUESTION: By design, is the floor intended to be level or slope slightly downward toward the transom assuming the weight of the crew and/or outboard motor?

Insight about the floor from original rules:

- The original rules provide a few data points about the profile of the interior floor and the distance to the baseline.

Similar result for seat tops:

- The original rule also include two references to the seat top locations and you can infer a distance to the baseline.
- We find a similar downward (toward the bow) slope of ¼" drop across the length of the center plank slot (3' 11").
- From other original documents we know the seat tops are to be a fixed 10" above and parallel to the floor.

Observation from Original Drawings:

- Based on observation of the 1969 drawings the floor appears to be parallel to the baseline and waterline. to baseline prior to drafting the center case assembly.

SOLVING: FLOOR DISTANCE TO BASELINE (continued)

Why is this an important measurement?:

- The floor is aligned with the upper edge of the center case assembly that runs the length of the boat.
- The center case assembly is the backbone of the boat and intersection for the floor webs. Defining the center case assembly is a critical first step for drafting the interior portion of the boat.
- We need to firmly establish the floor distance to baseline and slope prior to drafting the center case assembly.

HOMEWORK

Homework:

- What additional research is necessary to resolve the open question about the slope of the floor?
- Over the full length of the floor the slope is a 7/8” drop. Is that a fair assumption?
- The original rules were designed to measure fully complete boats allowing for some flexibility and were not intended to be overly precise, as such, should I assume the floor is parallel to the baseline?
- How do we decide?
- What is the consensus opinion on slope?

SOLVE: INTERIOR FLOOR RULES

Calculate “floor to baseline” using rules for “gunwale to floor”

The original rules offer a few perspectives on the interior floor profile and distance to baseline.

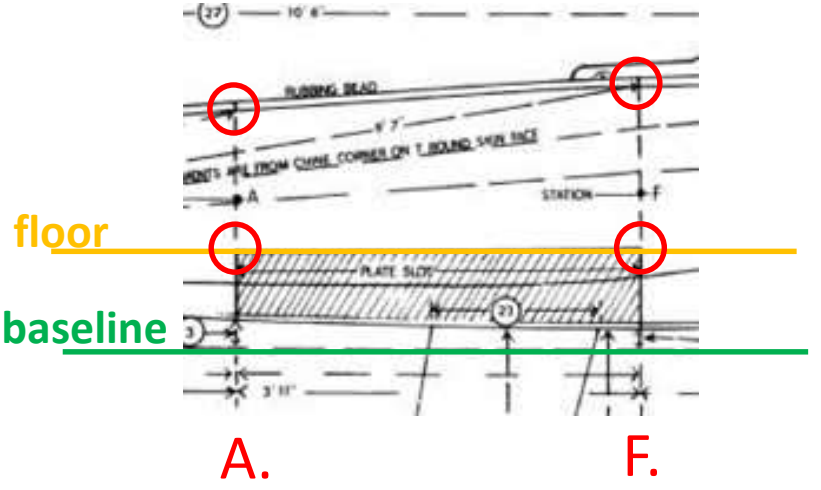
Based on those rules (using the average of min. & max. for each rule) **the floor appears to have a small slope of about ¼” across the length of the center plank slot (3’ 11”).** The same ¼” slope results if you perform the calculation using the min. or max. value for each rule.

The slope appears to be downward toward the bow, i.e. the forward end of the floor is ¼’ closer to the baseline than the aft end. The distance at A. is 10.625” and 10.375” at F.

If I were to extend that same slope (0.3048 degrees) across the length of the floor (13’ 8”) the total drop is 7/8”.

Baseline to Floor evaluated at A.

		inches
baseline to gunwale	rule |13| : |2' 2 3/4"| 26.750| in. |0.6795| m.	26.750
gunwale to floor	rule |31| : |1' 4 1/8"| 16.125| in. |0.4096| m.	16.125
baseline to floor	calculated	10.625



Baseline to Floor evaluated at F.

		inches
baseline to gunwale	rule |16| : |2' 5 3/8"| 29.375| in. |0.7461| m.	29.375
gunwale to floor	rule |35| : |1' 7"| 19.000| in. |0.4826| m.	19.000
baseline to floor	calculated	10.375

SOLVE: INTERIOR SEAT RULES

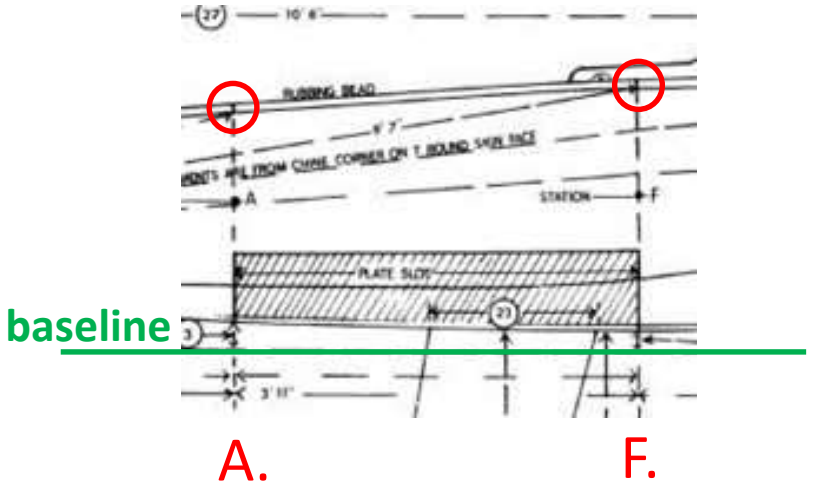
Calculate “seat to baseline” using rules for “gunwale to seat”

The original building instructions specify that the seat top is a fixed distance 10” and parallel to the floor. The original rules also specify the seat to gunwale distance at A. and F.

Similar to the results on the prior page for the floor, we find the seats to have **a small slope of about ¼” across the length of the center plank slot (3’ 11”).** The same ¼” slope results if you use the min. or max. instead of average for each rule. The distance is 21.00” at A. and 20.75” at F. for a variance of ¼”.

The slope appears to be downward toward the bow, i.e. the forward end of the seat is ¼’ closer to the baseline than the aft end.

Baseline to Seat evaluated at A.		inches
baseline to gunwale	rule |13| : |2' 2 3/4"| 26.750| in. |0.6795| m.	26.750
gunwale to seat	rule |29| : |5 3/4"| 5.750| in. |0.1461| m.	5.750
baseline to seat	calculated	21.000



Baseline to Seat evaluated at F.		inches
baseline to gunwale	rule |16| : |2' 5 3/8"| 29.375| in. |0.7461| m.	29.375
gunwale to seat	rule |33| : |8 5/8"| 8.625| in. |0.2191| m.	8.625
baseline to seat	calculated	20.750

REVIEW: MAST STEP LOCATION

The original rules specify several measurements for the location of the mast step which is a simple square piece of wood **4" x 4" and 1"** thick. On my boat the aft edge is 7/8" thick and forward end is 1" thick due to the slope of the deck. The mast step is supported below by the deck beam and king plank.

The mast step is located **10' 6"** (fixed distance) from the transom to the aft side of the mast step as measured along the baseline per the original documents.

Rule #27 indicates the distance from the transom to the aft side of the mast step as **10' 5 ¾"** (avg. of rule)
Rule #37 indicates the height of the mast step above the gunwale as **6 ¼"** (average of the rule)

In the original drawings it seems to appear that the mast step might be aligned with the the upper boundary. Based on my measurements, I do not think that is a valid assumption.

Unfortunately, the original rules do not specify the gunwale to baseline distance at the mast step.

This measurement does allow us to understand the arch of the deck

Conclusion: For modeling a new hull assume the aft side of mast step is **10'6"** from Transom (**FA #106**).

REVIEW: CURVATURE OF TRANSOM (TOP EDGE)

The upper edge of the transom is curved, below are some considerations and observations from my boat.

Rule #11 indicates the transom beam at the gunwale is **50 ½" or 1.2827m** (average of the rule)
On my boat the transom beam at G. is **49 ¾"** <u>just shy of the min value of 50" per the rule</u>.

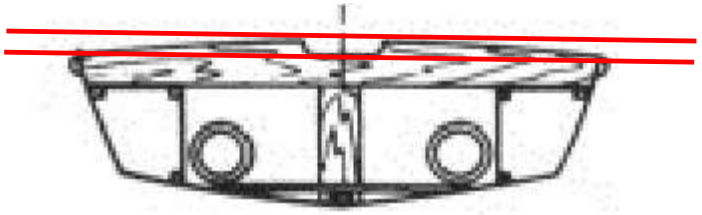
On my boat using a straight edge, I measure a 1 ½" drop from the peak arch of the transom edge to a level line spanning gunwale to gunwale.

Note: Some original drawings (like the one shown below) have an indentation along the top center edge of the transom. My boat and many other boats do not have an indentation.

HOMEWORK

Homework:

- Can another Mirror 16 owner measure and confirm if 1 ½" arch is fair for the transom.
- Within the DELFTship software the current transom edge is flat and not curved. DELFTship has advanced features that allow for the creation of a curved edge. I have not research how to use that feature and would appreciate help learning how to create a curved edge.



REVIEW: CURVED HULL MEASUREMENTS

The original rules specify several measurements along the outside of the curved hull

My initial phase of building the hull in DELFTship I did not incorporate any curved measurements. It would be optimal to confirm these stated rules in the 3D model in DELFTship. At this point with my limited 3D modeling experience I do not know how to assess the length of a curved line. Appreciate any help.

HOMEWORK

Homework:
Need assistance building out the curved hull measurements

Curved Measurements along the length of the boat:

- Chine at T. to G. at A. Rule is _____ measurement on my boat is _____
- Chine at T. to G. at F. Rule is _____ measurement on my boat is _____
- Chine at T. to G. at B. Rule is _____ measurement on my boat is _____
- Chine at T. to chine at B. Rule is _____ measurement on my boat is _____

- There is also a curved rule for the shape of the hull at the bulkhead. Unlike other rules this rule measures the curved hull surface (underside of the hull) extending from the port gunwale to the starboard gunwale. Rule is _____ measurement on my boat is _____

- DELFTship: Are there features within the CAD/CAM software to assess curved measurements along the outside of the hull skin?

SOLVING: WATERLINE

The original rules and diagrams do not specify a location for the waterline. Additionally, the original documents do not specify the distance between the baseline and the waterline. Below on the left is a sketch from a 1967 design journal that does include a short line indicating where the length at water line (lwl) would be measured. I added a red line to extend that point as the possible waterline.

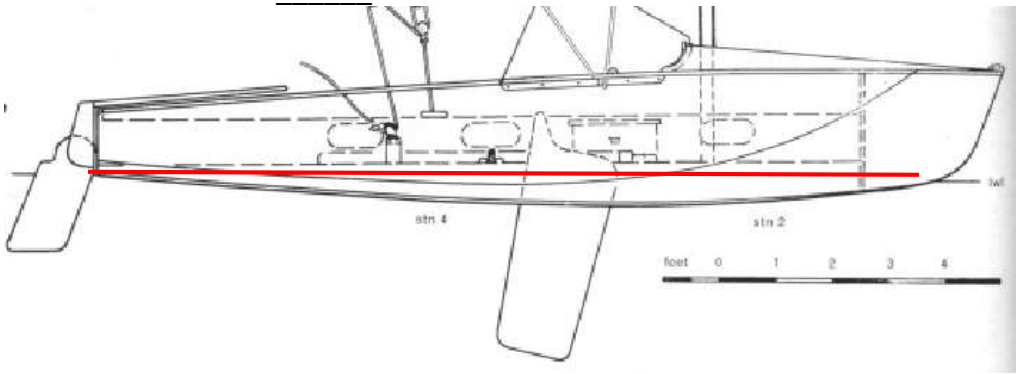
Based the pictures on the right and observations from my boat, this seems like a fair location.

Profile of waterline:

At the bow, the waterline begins it is slightly aft of the curve (below the rake). Midship it is just above the chine and appears to be just slightly above the lower edge of the transom.

Assumption for modeling:

For DELFTship modeling I have assumed a waterline begin ___" above the lower edge of the keel at the transom and a distance of _____m from the baseline.



OBSERVATIONS: SLOPE OF DECK

Observations on the slope of the deck from my boat. (slope along the centerline)

Rule #37 indicates the height of the mast step above the gunwale as **6 ¼"** (average of the rule)

Using a level I measured the plumb drop from mast step to bow-tip and found 6 ½". Prior to making this observation I adjusted the boat such that the interior floor was level. (see prior notes on slope of floor)

On my boat, using a straight edge I measure the height of the mast step as 6 ½" above gunwale.
Less the 1" thick mast step, the deck skin is 5 ½" above the gunwale on my boat.
Using a level straight edge I then measured the slope of the deck at the following points.

5' aft of bow tip deck skin arch is 5 ¼" above gunwale
4' aft of bow tip the deck skin peak arch is 3 ¼" above gunwale
3' aft of bow tip the deck skin peak arch is 2 ½" above gunwale
2' aft of bow tip the deck skin peak arch is 1 ½" above
1' aft of bow tip the deck skin peak arch is 1" above gu

HOMEWORK

Homework:
Can we infer the slope of the deck from these observations and then compare that slope to a rule based slope?
A rule based slope can be derived using the original rules and a bit of geometry.

VIEW OF INTERIOR HULL AND BULKHEAD

This image from my father's boat #366 (being built in 1970) gives you a good view of the four interior floor panels, bulkhead and seat tanks.

This also shows insight into the building process for the gunwales and inwales. Early into the building process the gunwales (outer edge) and inwales (inside edge) are fixed to the hull beginning at the transom but are not fully secured toward the bow. The gunwales and inwales will be secured during a later process when that bow webs are being installed.

Lower left corner is a closeup view of the gunwales and inwales.

HULL CONSTRUCTION MATERIAL

The hull is constructed using a stich and glue method using 5mm marine grade plywood.

The original kits included 4 large pieces per side of the boat.

- The upper chine section arrived in two separate pieces “topside forward” and “topside aft”. (inv. #13, #14)
- The lower section arrived in two separate pieces “bottom forward” and bottom aft”. (inv. #11, #12)
- Prior to assembly of the hull the forward and aft section are joined together using a short piece of 5mm ply (inventory #15 and #15a).

See page 5 of the 1969 building instructions for details on assembling the hull panels.

Homework: In order to properly make the flat panels we need to know where the location of the seam. Based on observations from remaining Mirror 16s, the panel seam for the upper and lower panels is located ____m forward of the transom.

Image of joined topside panels from page 7 of the original building instructions.

Plate 2a

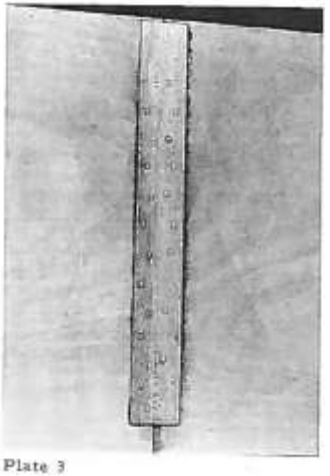


Plate 3

Original 1969 packing list details for the hull material:

11. ✓	2	Bottom Skin Forward	5mm Ply
12. ✓	2	Bottom Skin Aft	5mm Ply
13. ✓	2	Topside Skin Forward	5mm Ply
14. ✓	2	Topside Skin Aft	5mm Ply
15. ✓	2	Butt Straps	2'3" x 2½" x 5mm Ply
15A. ✓	2	Butt Straps	1'9" x 2½" x 5mm Ply

VIEW OF HULL AND KEEL

This image gives a good view of the four hull skin panels and the keel.

The keel is a ¾” thick oak board that begins full depth at the transom and tapers at the bow.

Original rules for keel width and depth are:

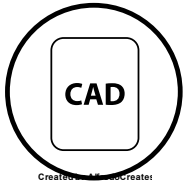
Rule #xx

Rule #xx

On the transom you can see the two small drain holes located very close to the keel to allow water to drain from the bilge area below the floor boards.

The other two larger 4” inspection ports to allow water to drain from inside of the boat on the Top side of the floor boards. The boat also has two small drainage holes that allows cockpit water to flow out of the centerboard case.

INTRODUCTION TO DELFTSHIP



CAD/CAM MODEL OF HULL

Intro....

Import x/y/z file
DELFTship allows you to import a text file with x/y/z data points. Once the data points are imported you connect the dots to form a mesh or 3D surface.

In DELFTShip software you build the port side of the hull and once it is fully designed there is a replicate function that automatically creates the symmetrical starboard side.

Build new model
Select New Project and then in the upper left area of the screen select “blank project”. In the center of the screen toggle the units to metric and enter length 4.0, draft 0.2 and beam 0.9. Then click the green accept button.

Import Markers
On the top left menu select “tools” which then brings up an option toward the right hand side of the screen “import marker curves”. Left click that option and select the text file with your x/y/z datapoints. Click OK once the file loads. Also select “Yes” when asked about intersections.

Extract points from Markers
Hold down the Control button and select each of the three curves. Release the Cntl button ad select “Home” in the top left menu which brings up the option “Extract”. Click on this and the imported data is “extracted” or converted into DELFTship points.

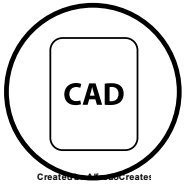
Delete Markers
Under the “Tool” menu you can select “delete markers” which are no longer needed. This leaves you with a set of data points that will be joined in pairs of 4 or 3 to form the control mesh.

Add Control Surface
Start by pressing control and then selecting four points to join. Once selected on the “home” menu click on “Add” to make these 4 points a control surface. Continue this process until all points are connected.

More details to come
This should get you started. I will add more details in the future and am willing to email you a fully functioning model if that helps.

DELFTSHIP IMPORT FILE

Text file details



CAD/CAM MODEL OF HULL

0

4.8768	0	0.8128
4.7974	0	0.5969
4.7181	0	0.3842
4.6930	0	0.3581
4.6380	0	0.2991
4.5720	0	0.2531
4.4450	0	0.2123
4.2672	0	0.1715
4.1656	0	0.1588
3.9624	0	0.1302
3.6576	0	0.0985
3.3528	0	0.0763
3.0480	0	0.0667
2.8702	0	0.0604
2.7432	0	0.0604
2.4384	0	0.0572
2.1336	0	0.0636
1.8288	0	0.0794
1.6740	0	0.0858
1.5240	0	0.0953
1.2192	0	0.1112
0.9144	0	0.1334
0.6096	0	0.1588
0.3048	0	0.1906
0	0	0.2223

4.4450	0.3048	0.8128
4.2672	0.3473	0.6636
4.1656	0.3810	0.5969
3.9624	0.4540	0.4890
3.6576	0.5525	0.3842
3.3528	0.6318	0.3048
3.0480	0.6953	0.2604
2.8702	0.7176	0.2381
2.7432	0.7303	0.2223
2.4384	0.7430	0.1873
2.1336	0.7461	0.1715
1.8288	0.7334	0.1556
1.6740	0.7239	0.1651
1.5240	0.7176	0.1619
1.2192	0.6985	0.1715
0.9144	0.6636	0.1905
0.6096	0.6287	0.2159
0.3048	0.5842	0.2477
0	0.5461	0.2858

4.8768	0	0.8128
4.7974	0.0572	0.8128
4.7181	0.1143	0.8128
4.6930	0.1365	0.8128
4.6380	0.1746	0.8128
4.5720	0.2191	0.8128
4.4450	0.3048	0.8128
4.2672	0.3969	0.8128
4.1656	0.4572	0.8128
3.9624	0.5493	0.8001
3.6576	0.6699	0.7874
3.3528	0.7620	0.7715
3.0480	0.8255	0.7588
2.8702	0.8509	0.7461
2.7432	0.8668	0.7398
2.4384	0.8954	0.7239
2.1336	0.9081	0.7049
1.8288	0.9049	0.6922
1.6740	0.8938	0.6795
1.5240	0.8827	0.6699
1.2192	0.8446	0.6477
0.9144	0.8033	0.6255
0.6096	0.7493	0.6064
0.3048	0.6922	0.5842
0	0.6414	0.5620

EOF

The DELFTship import file is a text file that has three distinct sections shown above. The first section, to the left begins with the number 0 indicating the measurements are in meters. The zero is followed by a blank row and then the x/y/z data for the keel. The middle section contains the x/y/z data for the chine and will be separated from the keel data by a blank row. The third section on the right is the x/y/z data for the gunwale and will be separated by a blank row from the chine data. At the very bottom of the third section there is a blank row and the letters EOF (which represent End of File). To make an import file simply copy the three sections into notepad and save the file as mirror_16.txt The values shown above are the actual values used to create the 3D hull shown earlier in this presentation.

NUMBER OF WOODEN PARTS

48 unique templates

The big box of parts
I still remember the large box in our garage filled with all the parts that eventually became our boat.

Overall there are 214 wooden parts necessary to fully construct a Mirror 16.

Luckily many of the parts are comprised of flat stock and do not require a pattern or template.

The complexity of this project is reduced because the majority of the parts are flat stock and can be cut on-site as there are needed.

There are 48 unique parts that need a pattern. For example the hull skin is made of 5mm ply wood and for each side of the boat there are four large unique parts. The upper hull (chine section) which has a forward and aft section, and the lower hull that has forward and aft sections.

Floor Webs & Seats
The majority of the parts with unique patterns are associated with the floor web and seat tank assemblies.

There is a small number of curved edge flat stock for example the bow beams.

Scope of Project
The scope of this project does seem quite large, but when you break down the effort, the CAD/CAM process will result in templates or patterns for 48 unique parts. The remainder of the parts are cut on-site, when needed, from flat wood stock purchased at local suppliers.

WOODEN PARTS BY ASSEMBLY

10 Assemblies are required to build a complete the Mirror 16

241 wooden parts are required to build a complete the Mirror 16

152 are flat stock wooden parts that do not need a template

more...

	Assembly	custom shaped wood	flat stock wood	marine plywood	round wood stock	Grand Total
1	Bow Assembly	6	16	6		28
2	Bulkhead Assembly		3	2		5
3	Center Case Assembly		11	4		15
4	Fittings Assembly	2	10	3	1	16
5	Floor Assembly			6		6
6	Floor Web Assembly		26	24		50
7	Hull Assembly			12		12
8	Side Tank Assembly		36	20		56
9	Transom Assembly		11	1		12
10	Trim Assembly		39	2		41
	Grand Total	8	152	80	1	241

88 of the parts have a custom shape. Many come in pairs of two.

48 of the wooden parts have a unique template

FLAT WOOD STOCK BY ASSEMBLY

Type of Stock	Quantity
marine plywood	80
5 mm ply	71
6 mm ply	7
8 mm ply	2
flat stock wood	152
1/2"	68
3/4"	19
3/8"	12
5/8"	3
7/16"	6
7/32"	1
7/8"	13
9/16"	2
1 1/2"	2
1' 11"	2
1 3/8"	2
1"	4
unspecified	18
round wood stock	1
round wood stock	1
custom shaped wood	8
3/4" curved edge	6
custom shaped wood	2
Grand Total	241

Flt Wood Stock by Assembly	length inches	% by Assembly	Sum of Quantity
Bow Assembly	600	11%	16
Bulkhead Assembly	9	0%	3
Center Case Assembly	354	6%	11
Fittings Assembly	31	1%	10
Floor Web Assembly	664	12%	26
Side Tank Assembly	1,502	27%	36
Transom Assembly	327	6%	11
Trim Assembly	2,035	37%	39
Grand Total	5,521	100%	152

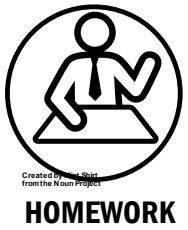
Overall there are 152 flat stock wooden parts in the assembly of a Mirror 16.

The majority of the flat stock (70%) is associated with the side tank and trim assemblies that run the length of the boat.

We have calculated the aggregate length (in inches) based on the original 1969 packing list. On the right side is a list of the particular flat stock dimensions. There are several items remaining with an unspecified dimension.

Flat Stock	length inches	Sum of Quantity
1 1/2" x 1"	149	2
1 1/2" x 1/2"	72	2
1 1/2" x 3/8"	299	6
1 1/2" x 1"	75	1
1 1/4" x 7/8"	20	2
1 1/8" x 7/16"	408	2
1 3/16" x 7/32"	54	1
1 3/4" x 1"	22	1
2 1/2" x 3/8"	120	2
2 1/2" to 2 7/8" x	46	2
2 5/8" x 1 3/8"	3	1
2 7/8" x 3/8"	10	2
2" x 3/4"	99	3
2" x 7/8"	153	6
3" x 1 3/8"	7	1
3" x 3/4"	181	1
3" x 7/16"	31	4
3/4" x 3/4"	663	14
3/8" x 1/2"	16	2
4" x 1 1/2"	6	1
4" x 7/8"	9	1
5/8" x 1/2"	1,954	64
7/8" x 3/8"	252	2
7/8" x 5/8"	408	2
1 1/2" x unspecified	0	1
3/4" x 5 3/4"	69	1
5/8" x unspecified	0	1
7/8" x unspecified	0	4
9/16" x unspecified	396	2
unspecified	0	18
Grand Total	5,521	152

HOMEWORK: WOODEN PARTS



Incomplete Information:
Below is a list of wooden parts with incomplete information. Most are missing a length or width dimension.

Ways you can help: Review the original documents and help us find the missing metrics. If you own a Mirror 16 can you make some measurements?

assembly	Part_Num	Old_Num	Description	Quantity	Assembly	Material	length	stock	length inches
Bulkhead Assembly	V1.RES.BH.03	17	Bulkhead Top Edge	1	Bulkhead	flat stock wood	?	5/8" x unspecified	?
Side Tank Assembly	V1.RES.ST.08	61	ST Sheet Lead Blocks (Fairleads)	2	Side Tank	flat stock wood	?	unspecified	?
Transom Assembly	V1.RES.TR.02	23	Transom Top Edge Back Beam	1	Transom	flat stock wood	?	7/8" x unspecified	?
Transom Assembly	V1.RES.TR.03	24	Transom bottom beam	1	Transom	flat stock wood	?	7/8" x unspecified	?
Bow Assembly	V1.RES.BW.05	66	Deck Beam A	1	Bow	custom shaped wood	?	3/4" x curved unspecified	?
Bow Assembly	V1.RES.BW.06	67	Deck Beam B	1	Bow	custom shaped wood	?	3/4" x curved unspecified	?
Bow Assembly	V1.RES.BW.07	68	Deck Beam C	1	Bow	custom shaped wood	?	3/4" x curved unspecified	?
Bow Assembly	V1.RES.BW.08	69	Deck Beam D mahogany	1	Bow	custom shaped wood	?	3/4" x curved unspecified	?
Bow Assembly	V1.RES.BW.09	76	Carved Carlins	2	Bow	custom shaped wood	?	3/4" x curved unspecified	?
Bow Assembly	V1.RES.BW.17	73	King Post Stop	1	Bow	flat stock wood	?	7/8" x unspecified	?
Trim Assembly	V1.RES.TM.02	63	Inwales	2	Trim	flat stock wood	16' 6"	9/16" x unspecified	396
Trim Assembly	V1.RES.TM.05	84	Coamings	2	Trim	flat stock wood	?	unspecified	?
Trim Assembly	V1.RES.TM.06	103	Inner Coaming	2	Trim	flat stock wood	?	unspecified	?
Trim Assembly	V1.RES.TM.15	82	Hatch Cover Slides	2	Trim	flat stock wood	?	unspecified	?
Trim Assembly	V1.RES.TM.16	82A	Hatch Cover Slides	2	Trim	flat stock wood	?	unspecified	?
Trim Assembly	V1.RES.TM.17	83	Hatch cover Handles	2	Trim	flat stock wood	?	unspecified	?
Trim Assembly	V1.RES.TM.19	86	Centerplate mahogany	1	not sure	flat stock wood	?	unspecified	?
Trim Assembly	V1.RES.TM.22	80	Mast Step	1	Trim	flat stock wood	?	1 1/2" x unspecified	?
Fittings Assembly	V1.RES.FT.01	n/a	Centerboard	1	Fittings	custom shaped wood	?	custom shaped wood	?
Fittings Assembly	V1.RES.FT.07	101	Paddle	1	Fittings	round wood stock	?	round wood stock	?
Fittings Assembly	V1.RES.FT.10	88	Cheeks Stock	2	Fittings	marine plywood	?	5 mm ply	?
Fittings Assembly	V1.RES.FT.12	104	Cleat Blocks	2	Fittings	flat stock wood	?	unspecified	?
Fittings Assembly	V1.RES.FT.13	90	Tiller	1	Fittings	flat stock wood	?	unspecified	?
Fittings Assembly	V1.RES.FT.14	91	Tiller Extension	1	Fittings	flat stock wood	?	unspecified	?
Fittings Assembly	V1.RES.FT.15	87	Rudder Blade mahogany	1	Fittings	custom shaped wood	?	custom shaped wood	?

DELFTSHIP HOMEWORK

Refinements to the basic model

Basic Hull is Complete

My goal for this phase of the project was to create and share a basic Mirror 16 hull in 3D CAD/CAM software. The majority of the effort has been placed on ensuring the hull measurements conform to the original rules and documents.

Now that a basic hull has been modeled in DELFTship we can refine the hull using some of the CAD/CAM's advanced features.

I remain a beginner at DELFTship and have not yet researched how features such as "control grids" or "hull thickness" can be used to refine the hull shape.

Three Curves

The entire shape of the hull has been described by three curves (the keel, the chine and the gunwale) as represented by the x/y/z values that we imported.

Within DELFTship we join the datapoints into a "control mesh" and the software does some calculations to create the smoothed hull surface.

Area of Focus

The majority of the hull surface looks fine, but the bow area (between the bow-tip and the bulkhead) may need some refinement.

This section seems to be a bit concave and does not have an anticipated curved shape along the vertical grid lines (gunwale to keel).

Additional Data Points

Question: For the bow-tip to bulkhead area of the hull would it be helpful to provide additional data points (along the vertical axis) that would force a more typical curved surface?

Are there imbedded features within DELFTship that can be applied to this section to refine the shape?

Could we using lofting line concepts to evaluate this section of the hull?

Appreciate the Help

I am looking for ideas and insight to address these questions and appreciate any and all help.

Rules from 1969 Measurement Form

rule	Actual			Note:
	Imperial	Inches	Metric (m.)	
1 Base line below K. at T.	8"	8	0.2032	Measured at transom, distance of Keel to Base Line
2 Base line below K. at B.	5 1/2"	5.5	0.1397	Measured at bulkhead, distance of Keel to Base Line

	Minimum			Average			Maximum			Note:
	Imperial	Inches	Metric (m.)	Imperial	Inches	Metric (m.)	Imperial	Inches	Metric (m.)	
3 Base line below K. at A.	2 1/8"	2.125	0.0540	2 5/8"	2.625	0.0667	3 1/8"	3.125	0.079	Measured at aft end of center plate slot, distance of Keel to Base Line
4 Base line below K. at F.	1 1/8"	1.125	0.0286	1 5/8"	1.625	0.0413	2 1/8"	2.125	0.054	Measured at fore end of center plate slot, distance of Keel to Base Line
5 Length of baseline	14' 10 1/2"	178.500	4.5339	14' 11 1/2"	179.500	4.5593	15' 0 1/2"	180.500	4.585	Measured at transom, length of flat board at transom to angled board at bow
6 Projection of K. below skin	5/8"	0.625	0.0159	3/4"	0.750	0.0191	7/8"	0.875	0.022	Measured at various points, Thickness or depth keel (Keel is a length of wood attached to bottom of hull. A thin aluminum keel band is also attached and not included in the measurement)
7 Width of K.	n/a	n/a	n/a	n/a	n/a	n/a	3 1/8"	3.125	0.079	Measured at various points, Keel is fixed width at aft end of boat and tapered at bow
8 Base line to chine at T.	10 3/4"	10.750	0.2731	11 1/4"	11.250	0.2858	11 3/4"	11.750	0.298	Measured at transom, distance of chine to Base line
9 Base line to G. at T.	1' 9 5/8"	21.625	0.5493	1' 10 1/8"	22.125	0.5620	1' 10 5/8"	22.625	0.575	Measured at transom, distance of Gunwale to Base line
10 Chine girth at T.	3' 6 1/4"	42.250	1.0732	3' 7"	43.000	1.0922	3' 7 3/4"	43.750	1.111	Measured at transom, girth of chine
11 Beam at T. (where top of G. meets topside if extended)	4' 2"	50.000	1.2700	4' 2 1/2"	50.500	1.2827	4' 3"	51.000	1.295	Measured at transom, beam of gunwale
12 Base line to chine at A.	6"	6.000	0.1524	6 1/2"	6.500	0.1651	7"	7.000	0.178	Measured at aft end of center plate slot, distance of chine to baseline
13 Base line to G. at A.	2' 2 1/4"	26.250	0.6668	2' 2 3/4"	26.750	0.6795	2' 3 1/4"	27.250	0.692	Measured at aft end of center plate slot, distance of gunwale to baseline
14 Chine girth at A.	4' 8 1/4"	56.250	1.4288	4' 9"	57.000	1.4478	4' 9 3/4"	57.750	1.467	Measured at aft end of center plate slot, chine girth
15 Base line to chine at F.	8 7/8"	8.875	0.2254	9 3/8"	9.375	0.2381	9 7/8"	9.875	0.251	Measured at fore end of center plate slot, distance of chine to baseline
16 Base line to G. at F.	2' 4 7/8"	28.875	0.7334	2' 5 3/8"	29.375	0.7461	2' 5 7/8"	29.875	0.759	Measured at fore end of center plate slot, distance of gunwale to baseline
17 Chine girth at F.	4' 8"	56.000	1.4224	4' 8 1/2"	56.500	1.4351	4' 9"	57.000	1.448	Measured at fore end of center plate slot, chine girth
18 Base line to chine at B.	1' 11"	23.000	0.5842	1' 11 1/2"	23.500	0.5969	2'	24.000	0.610	Measured at bulkhead, distance of chine to base line
19 Base line to G. at B.	2' 7 1/2"	31.500	0.8001	2' 8"	32.000	0.8128	2' 8 1/2"	32.500	0.826	Measured at bulkhead, distance of gunwale to base line
20 G. girth at B. to underside of beads	5' 7 1/4"	67.250	1.7082	5' 8"	68.000	1.7272	5' 8 3/4"	68.750	1.746	or Measured at bulkhead, (I think this is the distance measured from one gunwale to the other gunwale - around the hull not over the deck)
21 Base line to top of deck at stem - straigth line of stem cuts base line	2' 10 5/8"	34.625	0.8795	2' 11 1/4"	35.250	0.8954	2' 11 7/8"	35.875	0.911	Measured at stem, straight line of stem cuts baseline
22 Extension of C.P. below K.	n/a	n/a	n/a	n/a	n/a	n/a	3' 0 3/4"	36.750	0.933	Measured at center plank and keel
23 Width of C.P. at K. when fully down	n/a	n/a	n/a	n/a	n/a	n/a	1' 7"	19.000	0.483	Measured at center plank and keel
24 Width of C.P. 2' below K. at 90°	n/a	n/a	n/a	n/a	n/a	n/a	1' 6 1/4"	18.250	0.464	Measured at center plank and keel

Rules from 1969 Measurement Form (continued)

		Minimum			Average			Maximum			Note:
		Imperial	Inches	Metric (m.)	Imperial	Inches	Metric (m.)	Imperial	Inches	Metric (m.)	
25	Length from extension of T. face and stem fore edge	16' 1"	193.000	4.9022	16' 2"	194.000	4.9276	16' 3"	195.000	4.953	Measured at transom, length to stem fore edge
26	T. face where it meets gunwale to eye on chain plate	9' 2 1/2"	110.500	2.8067	9' 3"	111.000	2.8194	9' 3 1/2"	111.500	2.832	Measured at transom, length to chain plate
27	Length from extension of T. at face to aft side of mast step	10' 5 1/4"	125.250	3.1814	10' 5 3/4"	125.750	3.1941	10' 6 1/4"	126.250	3.207	Measured at transom, length to aft side of mast step (mast step is 4" x 4")
28	Beam at A. (where top of G. meets face of topside if extended)	5' 9 7/8"	69.875	1.7748	5' 10 3/8"	70.375	1.7875	5' 10 7/8"	70.875	1.800	Measured at aft end of center plate slot, beam
29	Depth of G. to side seat top at A.	5 1/4"	5.250	0.1334	5 3/4"	5.750	0.1461	6 1/4"	6.250	0.159	Measured at aft end of center plate slot
30	Width between side seat tops at A.	3' 9 3/4"	45.750	1.1621	3' 10 1/4"	46.250	1.1748	3' 10 3/4"	46.750	1.187	Measured at aft end of center plate slot
31	Depth G. to floor at A.	1' 3 5/8"	15.625	0.3969	1' 4 1/8"	16.125	0.4096	1' 4 5/8"	16.625	0.422	Measured at aft end of center plate slot
32	Beam at F. measured at gunwale	5' 6 1/2"	66.500	1.6891	5' 7"	67.000	1.7018	5' 7 1/2"	67.500	1.715	Measured at fore end of center plate slot, beam
33	Depth of G. to side seat top at F.	8 1/8"	8.125	0.2064	8 5/8"	8.625	0.2191	9 1/8"	9.125	0.232	Measured at fore end of center plate slot, seat top to gunwale
34	Width between side seat tops at F.	3' 6 3/4"	42.750	1.0859	3' 7 1/4"	43.250	1.0986	3' 7 3/4"	43.750	1.111	Measured at fore end of center plate slot, width between seats
35	Depth G. to floor at F.	1' 6 1/2"	18.500	0.4699	1' 7"	19.000	0.4826	1' 7 1/2"	19.500	0.495	Measured at fore end of center plate slot, seat top to floor
36	Beam at B. over deck	2' 11 1/2"	35.500	0.9017	3'	36.000	0.9144	3' 0 1/2"	36.500	0.927	Measured at bulkhead, beam (across deck - curved distance - not a straight line.
37	height of mast step above G.	5 3/4"	5.750	0.1461	6 1/4"	6.250	0.1588	6 3/4"	6.750	0.171	Measured at mast step, height above gunwale, measured from top of mast step
38	Top of deck to underside of bead - depth of bead	3/4"	0.750	0.0191	15/16"	0.938	0.0238	1 1/8"	1.125	0.029	measured at various points, (depth of bead)

This was created using the original 1969 measurement form.

There were a few values changed for clarity. For example the original documents were imperial and converted to metric. There were a few instances where the original conversion to metric was incorrect.
This list only reflects the rules associated with the hull.

K. equals Keel
G. equals Gunwale, where the topside if extended would cut the top of the deck
A. equals the aft end of center plate slot
F. equals to fore end of center plate slot
B. equals Bulkhead
T. equals Transom
BT. equals Bow-tip

Facts and Concluded Assumptions (DRAFT May 2018)

		Fact		
		Imperial	Inches	Metric (m.)
102	Length T. to A.	5' 6"	66	1.6764
103	Length A. to F. (along base line)	3' 11"	47	1.1938
104	Length F. to B. (along base line)	4' 3"	51	1.2954
105	Length T. to B. (along base line)	13' 8"	164	4.1656
106	Length from extension of T. at face to aft side of mast step	10' 6"	126	3.2004
107	Length from extension of T. face and stem fore edge	16' 2"	192	4.8768
108	Length of center plate slot	3' 11"	47	1.1938
109	Width of center plate slot			-
110	aft edge of mast step to aft edge of fore deck	2 1/4"	2.25	0.0572
111	aft edge of thwart from outer face of transom	5' 8"	68	1.7272
112	Bow-tip to baseline (plum distance)	2' 8"	32	0.8128
113	Length of angled stem board baseline to upper line	3' 4 1/2"	40.5	1.0287
114	Length of angled stem board baseline to bow-tip	2' 10"	34	0.8636
115	Length of plum stem board baseline to upper line	3' 2"	38	0.9652
116	Length of plum stem board baseline to keel	8"	8	0.2032
117	Length of plum stem board keel to upper line	2' 6"	30	0.7620
118	Length of baseline Transom to lower edge of angled stem board	15'	180	4.5720
119	Length of upper line stem board to stem board	16' 2"	194	4.9276
120	Length of bulkhead to bow-tip	2' 4"	28	0.7112
121	Chine at T. to G. at A. (Curved distance around hull)	5' 8 1/2"	68.5	1.7399
122	Chine at T. to G. at F. (Curved distance around hull)	9' 7"	115	2.9210
123	Chine at T. to G. at B. (Curved distance around hull)	14'	168	4.2672
124	Chine at T. to chine at B. (Curved distance around hull)	13' 11 1/2'	167.5	4.2545
125	Angel of stem board			20.2367

		Concluded Assumption (CA)		
	Concluded assumptions based on estimates and observations	Imperial	Inches	Metric (m.)
201	Length Bulkhead to Bow-tip	2' 4 1/2"	28.5	0.7239
202	Length Transom to Bow-tip	16'	192	4.8768
203	Length aft side of mast step to bow-tip	5' 7"	67	1.7018
204	Length of hull (transom to bow-tip along the base line	16'	192	4.8768
205	Length of bow rake (along the stem board edge)	1' 6"	18	0.4572
206	Bow-tip to lower edge of bow rake (plum distance)	1' 5 5/8"	17.625	0.4477
207	Length from bow-tip to lower edge of bow rake(along the baseline)	6 1/2"	6.5	0.1651
208	Length from lower edge of bow rake to baseline (plum)	1' 3 1/8"	15.125	0.3842
209	Length of bow rake mid-point (along the stem board edge)	9 3/8"	9.375	0.2381
210	Bow-tip to mid-point of bow rake (plum distance)	8 7/8"	8.875	0.2254
211	Length from bow-tip to mid-point of bow rake(along the baseline)	3 1/4"	3.25	0.0826
212	Length from mid-point of bow rake to baseline (plum)	1' 11 1/4"	23.25	0.5906
213	Gunwale to baseline at maststep			
214	length from T. to where Chine edge terminates at G. (along baseline)			
215	Length from T. to Chine panel seam	7' 5/8"	84.875	2.1558
216	Width of chine panel seam	3 1/4"	3.5	0.0889
217	Length from T. to where Shroud support meets seat top			
218	Width of shroud support beam			
219	Chine meets gunwale (CG.) distance to transom	1' 5"	17	0.4318
220	Chine meets gunwale (CG.) distance to bow-tip	14' 7"	175	4.4450
221	Baseline below Keel at (CG.) plum distance			
222	Chine meets gunwale (CG.) plum distance to baseline	2' 8"	32	0.8128

Mirror 16 Rebuilding

R.E.S. on Mirror 16 #366

rebuild_mirror_16@yahoo.com
Vermilion, Ohio USA
http://www.ancestrypaths.com/misc/mirror-sixteen/