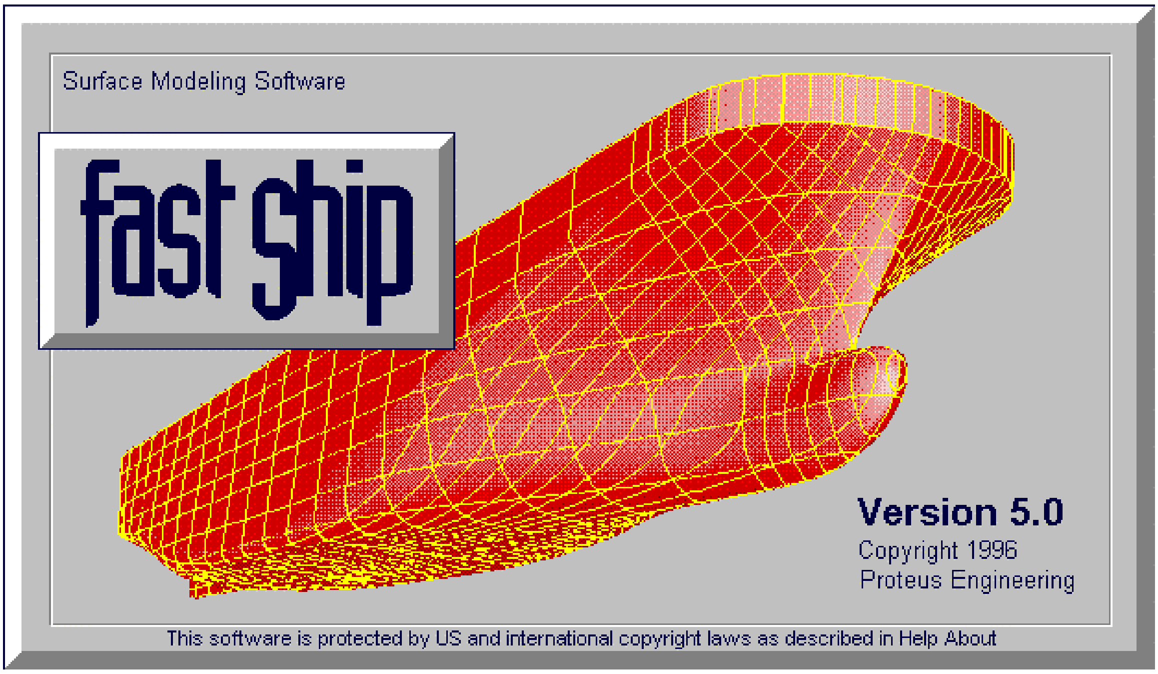
FastShip™
Version 5

Parametric FastShip Parent Hull Creation



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FastShip Parent Hull Creation Guidance

1 Introduction

This document is intended to help the user create a parent hull form for Parametric FastShip (PMFS). The document is organized into four sections. The first section discusses the topology of a parent hull. It delves into the criteria that define a good parent hull form. The second section discusses the *.PMF file, the file that maps the net topology in ways that PMFS understands. The third section consists of an annotated example of a *.pmf file. Finally, the recommended procedures are defined. It is recommended that the user already have a familiarity with the basics of FastShip.

2 Topology of a Parent Hull

The role of the parent hull form is to possess and pass desired design traits to the new hull form. Because the children derive from the parent, similar general characteristics and performance, given a similar Froude number and moderate changes, will be passed onto the child. In addition, the same local features that are present in the hull form will necessarily be present to some degree in the children. With this in mind, the parent hull form needs to be chosen and modeled according to the following criteria.

1. The parent hull form should be a pinnacle of its class.

2. The parent hull form should be similar in general characteristics to the children hull forms.
3. The parent hull form should have the same local features as the New design.
4. The density of the net should be sufficient to permit local control, yet should be coarse to maximize the natural fairing characteristics of the NUPBS surface.
5. The surface file must conform to standards for file names, waterline placement and coordinate system orientation.

Like most tools, PMFS relies on the user to modify the hull in an appropriate and intelligent way. However, a parent hull form that meets these criteria will increase the likelihood of a successful new hull form, regardless of the user's skill level. The above criteria are explained in more detail below.

2.1 Criterion # 1

The parent hull form should be a pinnacle of its class. Careful forethought needs to go into the development of a parent hull form, for the performance of the children will be dependent upon the parent. The chosen parent geometry should possess outstanding qualities that are desired in the new designs. Because of the global nature of the changes that PMFS can perform, it is likely that the dominant traits of the parent hull will continue through to the children hull forms. This is merely an affirmation of the adage, "Garbage in, garbage out."

AE-36 was chosen as the parent hull example for this document. The AE-36 is a superb example of an ammunition ship, because she has surprisingly low resistance and good powering performance for a hull form with Cp=0.671. In addition, the ship has good stability traits and large amounts of deck area, important traits when ammunition is loaded onto warships. Because of these excellent and desirable traits, the AE-36 may be a logical choice as parent hull for the next generation of auxiliaries.

2.2 Criterion #2

The parent hull form should be similar in general characteristics to the children hull forms. The best parent hull form is likely to be similar to the anticipated new design. In a way, PMFS can be thought of as an extrapolation method for hull design. From a parent hull starting point, PMFS extrapolates the characteristics to meet a new set of design criteria. The parent and the child will have similar performance, to the extent that the child is similar to the parent hull form. The further away a design varies from the parent hull form, the less likely the details of the geometry, such as bulb and transom shape, are appropriate to the new hull. The recommended practice is for parent hull forms to be in the same class of ships as the children hull forms: a destroyer parent for a destroyer design, and a tanker parent for a tanker design.

2.3 Criterion #3

The parent hull form should have the same local features as the new design. Parametric FastShip is good at large geometry manipulations, but PMFS can not add or subtract local features, like an integral skeg or a flared foredeck. There is no provision in PMFS for the addition or removal of bulbous bows, tunnel sterns, integral skegs, flared foredecks, or other local details. Therefore, any local features in the hull that are desirable for the children should also be present in the parent. In particular, **a parent hull must be built with a net topology that supports parallel midbody,** even if the parent hull form has none.

For a ship with no parallel midbody, a very small length of midbody can be added by creating two columns with knuckles at the waist of the ship. This is done in the following steps.

- Position a net column at the midship section. This is the aft end of the parallel midbody.

- Add a second net column just forward of the waist, say 0.0 1 units.

This is the forward end of the parallel midbody.

- Insert triple knots on the two columns. This creates slope discontinuities at the beginning and the end of the parallel midbody. They are necessarily knuckles, because there is typically a curvature discontinuity at the edges of the parallel midbody.

- The parallel midbody will now have six columns, consisting of the two freshly created knuckles, and two slope control columns straddling each of two knuckles. Rework the six columns so that all are identical in section shape. This guarantees slope continuity across the parallel midbody.

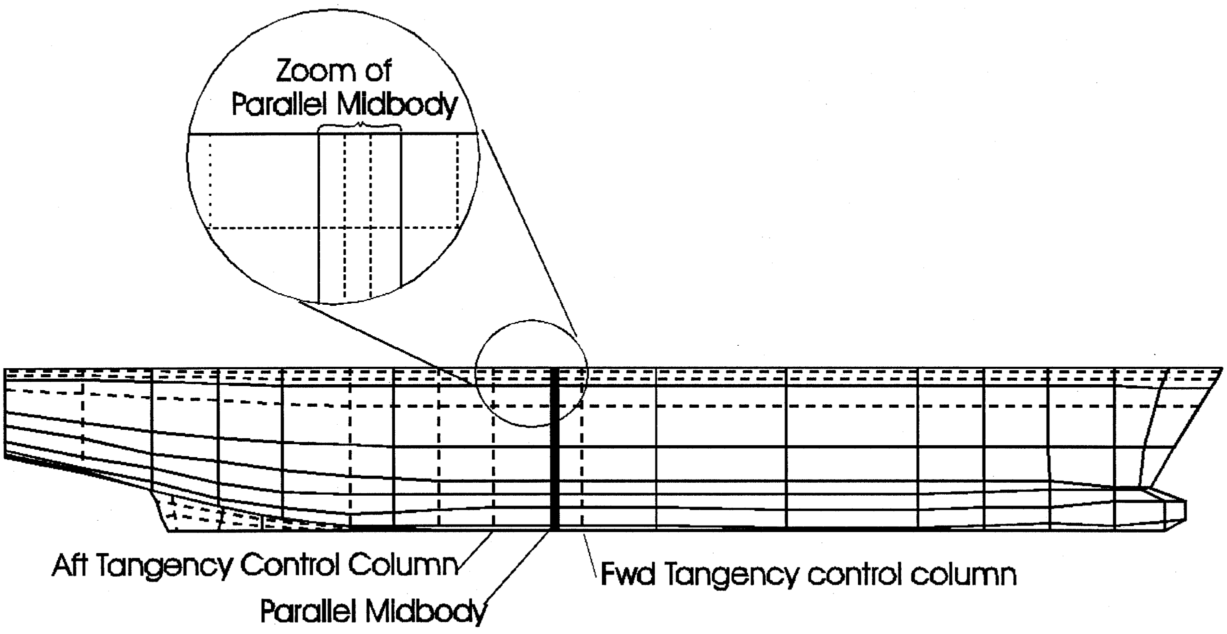

Figure 1: Control Net with a Small Amount of Parallel Midbody

2.4 Criterion #4

The density of the net should be sufficient to permit local control, yet should be coarse enough to maximize the natural fairing characteristics of the NURBS surface.

The density of the net should be as low as possible, while still capturing the details of the ship. This is true of all FastShip models, but is particularly important for parent hulls. The number of inflections in a hull surface is limited by the density of the net. A large amount of net points creates the potential for a wavy or unfair hull, while a coarse net will be more robust.

2.5 Criterion #5

The surface file must conform to standard file names, waterline placement, and coordinate systems.

PMFS has the convention that related files will have the same root name, with different extensions. The use of "pmfs" in the root file name is useful, because it identities the files to be a parent hull form. For example, the AE-36 hull form has the naming convention:

ae36pmfs.srf	AE36 NURBS surface, containing /top/hull/hull and /top/appendages/skeg

ae36pmfs.aux	AE36 auxiliary information
ae36pmfs.pmf	AE36 net topology information for parametric variation macros

Besides file naming conventions, there are conventions for the placement of the coordinate system. The convention is for the positive x-axis to be forward, the positive y-axis to be to port, and for the positive vertical direction to be upwards. The waterline should be at the z=0 value, with positive z values for the main deck and negative z values for the keel.

As a matter of convention, parametric FastShip expects that the parent hull form will consist of either one or two surfaces; the hull, and optionally, the skeg. The surfaces are called /top/hull/hull and /top/appendages/ skeg.

Occasionally, a hull surface is defined by two parts, a forebody and an afterbody. In this case, the forebody.srf and afterbody.srf files need to be merged into one surface file. The following steps should serve as a guide.

- Affirm that the topology of the forebody and afterbody columns are identical. The nets should match in number of rows and in placement of nets and of the knot vectors. If not, nets and knots should be added, deleted, or moved to match across the two parts.

- Leave or shell out of FastShip and load the afterbody.srf file into a text editor

- Append the forebody.srf file onto the end of the afterbody.srf file. Because FastShip treats the lower left hand corner as the net origin, the afterbody needs to come before the forebody.

- Correct the afterbody header to reflect the new hull form. This typically means changing three rows in the file:

  1. Change the title to reflect the new modifications.
  2. Change the number of columns to include the forebody. The number of rows is constant.

  3. Change the knot vector along the rows to include the forebody.

  As an example, if the afterbody row knot vector looks like:
  (0, 0, 0, 0, .33, 1, 2, 3, 4, 4.67, 5, 5, 5, 5)

  and the forebody knot row vector looks like:
  (0, 0, 0, 0, .33, 1, 2, 3, 3.67, 4, 4, 4, 4)

  then the knot vector would be:
  (0, 0, 0, 0, .33, 1, 2, 3, 4, 4.67, 5, 5.33, 6, 7, 8, 8.67, 9, 9, 9, 9).

  The new knot vector is made by deleting 3 of the "5's," at the end of the afterbody knot vector. The four "0's" at the start of the forebody knot vector are also deleted. Finally, 5 is added to the values in the forebody knot vector, and appended to the afterbody knot vector.

- At the seam where the two parts join, there are two collocated columns. One of the two columns should be deleted from the surface file. The first column of net points, after the forebody header, needs to be deleted. If "m" is the number of rows in the forebody net, then this will be the first "m" lines after the forebody header. @ically, they will be at one x location.

- Finally, the forebody header lines need to be deleted.

3 *.PMF FILE STRUCTURE

The *.pmf file relates local features of the ship to PMFS. For PMFS to modify the net in an intelligent way, the code needs for the user to divide the ship into coherent patches of the net. In the *.pmf file, the user defines these patches. Examples of patches are the stem, the parallel midbody, and the bilge radius. Without guidance from the user, PMFS does not understand these nautical terms. Therefore, the stem, the parallel midbody, and the bilge radius must be delimited according to rows and columns of the net.

Consistent transformations of the hull can be accomplished in many ways, so three examples have been given to help define the approach that was taken in writing PMFS. The three examples are complicated non-linear transformations which scale user defined patches in different ways. The three examples are meant to demonstrate the nomenclature, to show the techniques used to modify the hull form, and to convey the thought-process underlying the programming of PMFS.

3.1 Parallel Midbody Transformations

To illustrate the proper use of a *.pmf file, let's consider one of the more complicated transformations, an increase in the parallel midbody length.

Splitting the ship into two parts and adding a section of parallel midbody is a simple transformation, called jumboizing by shipyards. However, a parametric family of ships should have the same length, despite different lengths of parallel midbody. In PMFS, the length of the ship is preserved by compensating for growth in the parallel midbody with shrinkage of the bow and stern sections. The transformation follows the procedures laid out by Robert McNaull[1], in his extension of Lackenby's work[2]. The longitudinal position of sections is shifted to modify the prismatic coefficient, the longitudinal center of buoyancy, and the parallel midbody of the parent hull. To preserve length, the stations at the forward and aft perpendiculars are fixed in the McNaull transformations. In a transformation that increases the parallel midbody, the afterbody stations are shifted towards the stern, and the forebody stations are shifted towards the bow. For PMFS to understand how to do these transformations, the user must identify the columns that

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[1] 1. McNaull, Robert. "Generating New Ship Lines from a Parent Hull Using Section Area Curve Variation." NSRP #0007 Paper #14, Maritime Administration, Washington, D.C.

[2] 2. Lackenby, H. "On the Systematic Geometrical Variation of Ship Forms," RINA Vol. 92, 1950.

mark the beginning and the end of the parallel midbody, nmidfwd and nmidaft. In addition, for the slopes to match across the parallel midbody, the user identifies the columns adjacent to the beginning and the end of the parallel midbody, maxncxrnid and minncxmid. The parent hull in Figure 2 is the NURBS control net for the AE-36. The child hull has more parallel midbody than the parent does.

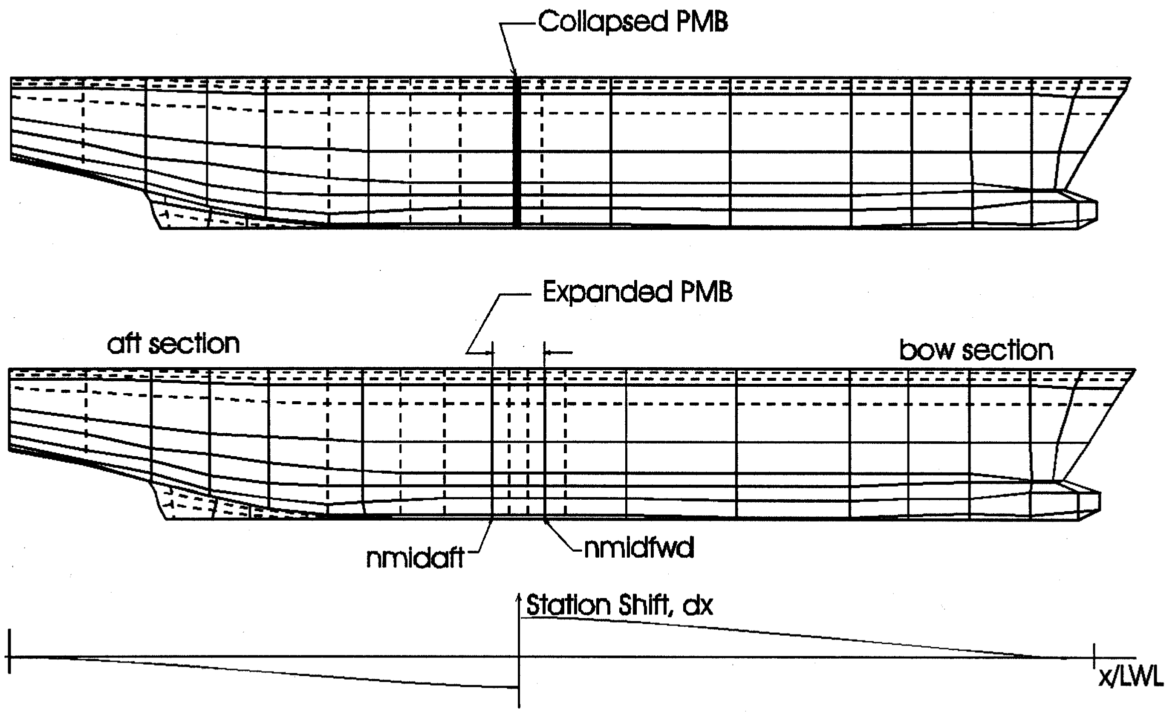

Figure 2: Changes in the Length of the Parallel Midbody

3.2 Midship Section Coefficient Transformations

An increase in the midship section coefficient is accomplished in much the same way as an increase in the parallel midbody. The bilge radius through the parallel midbody is scaled to create the new midship section shape. The changes in the bilge radius are smoothly faded away through transition zones. To accomplish this, the hull is divided into a five by five matrix of fixed zones, transition zones, and at the center of the matrix, the parallel midbody bilge radius patch, as shown in Figure 3.

aft sheer	aft trans. sheer	pmb sheer	fwd trans. sheer	bow sheer
aft upper trans.	aft trans. upper trans.	pmb upper trans.	fwd trans. upper trans.	bow upper trans.
aft bilge keel	aft trans. bilge keel	pmb bilge keel	fwd trans. bilge keel	bow bilge keel
aft lower trans.	aft trans. lower trans.	pmb lower trans.	fwd trans. lower trans.	bow lower trans.
aft keel	aft trans. keel	pmb keel	fwd trans. keel	bow keel

Figure 3: 5x5 Matrix of Patches, for midbody coefficient changes.

Along the girth of the vessel, that is to say, "up" the chart on Figure 3, the hull is divided into five sections, separated by rows. The center patch consists of the rows that pass through the bilge radius. Flanking the bilge radius are two transition regions. The final two areas are the fixed areas at the keel and at the sheer. In the longitudinal direction, that is to say "across" the chart on Figure 3, the hull is divided into five sections, the parallel midbody, the forward and the aft transition sections, and the fixed bow and stern sections. The five girth areas and the five longitudinal areas create a 5x5 matrix of patches. Figure 3 is shown as a square, to simplify the presentation. In reality, this pattern is wrapped around the ship's surface.

The 5x5 matrix is defined by eight variables in the *.PMF file. The four row variables that divide the ship into sets of rows are *minmcx*, *mbilgelo*, *mbilgehi*, and *maxmcx*. The four column variables along the length of the ship are *minncx*, *nmidaft*, *nmidfwd*, and *maxncx*. These variables are shown in Figure 3 and in Figure 4.

Figure 4 illustrates an increase in the midship area coefficient. The first control net is for the parent AE36 hull form. The child control net has a greater midship coefficient and a smaller bilge radius than the parent hull. The transition zones are adjacent to the bilge keel parallel midbody. The forward half of the bow, the aft third of the stern, and the shear patch are fixed. The five fixed patches along the keel have collapsed to the keel-centerline in this example, because minmcx=0.

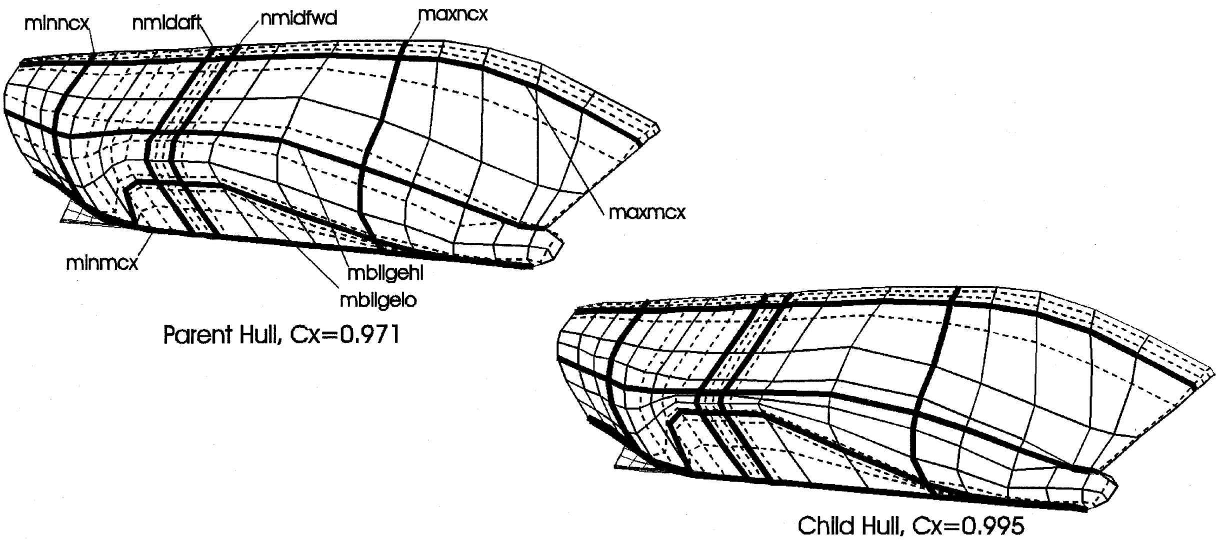

Figure 4: Midship Coefficient Changes

3.3 Depth/Draft Transformations:

The final example is a change in the depth of the vessel. Scaling the depth can be more complicated than scaling the ship's length because the draft can be scaled independently from the depth. PMFS handles this case by dividing the hull form into two parts, with a boundary defined by the variable *depth/draft* ratio in the *.pmf file. To the degree that the depth and draft are scaled together, both patches can be multiplied by the same scaling factor. To the degree that the depth and draft scale factors differ, the upper patch is scaled by an additional quadratic scaling factor, which makes up the difference. A quadratic function in height was used, so that there would be slope continuity at the joint.

For example, it might be desirable to keep the same underwater hull shape as the parent hull, perhaps to use the parent hull resistance tests. In this example, however, the decks are being redesigned, to better meet the new design criteria. To meet the new space requirements, the depth is to be 4 feet larger than before. In this example, a simple scaling of the z-offsets would destroy the similarity of the underwater hull. PMFS has been developed to handle this situation by scaling draft and depth independently. The draft scaling would be linear, while the quadratic depth scaling would increase the depth by 4 feet.

The process is illustrated below, in Figure 5. In figure 5, the draft is increased from 27 feet to 28 feet, an increase of 3.7%. The depth is increased from 60 feet to 64 feet, an increase of 6.7%. The two scale factors are contradictory; the hull can not be scaled by a single factor to match both the draft and depth criteria. First, the entire net is scaled by 103.7% in the z-direction. Next, the upper patch of the hull, as defined by depth/draft-ratio, is scaled in a quadratic fashion to make up the difference between the draft scaling and the depth scaling. In this way, the depth can be scaled independently of the draft scaling.

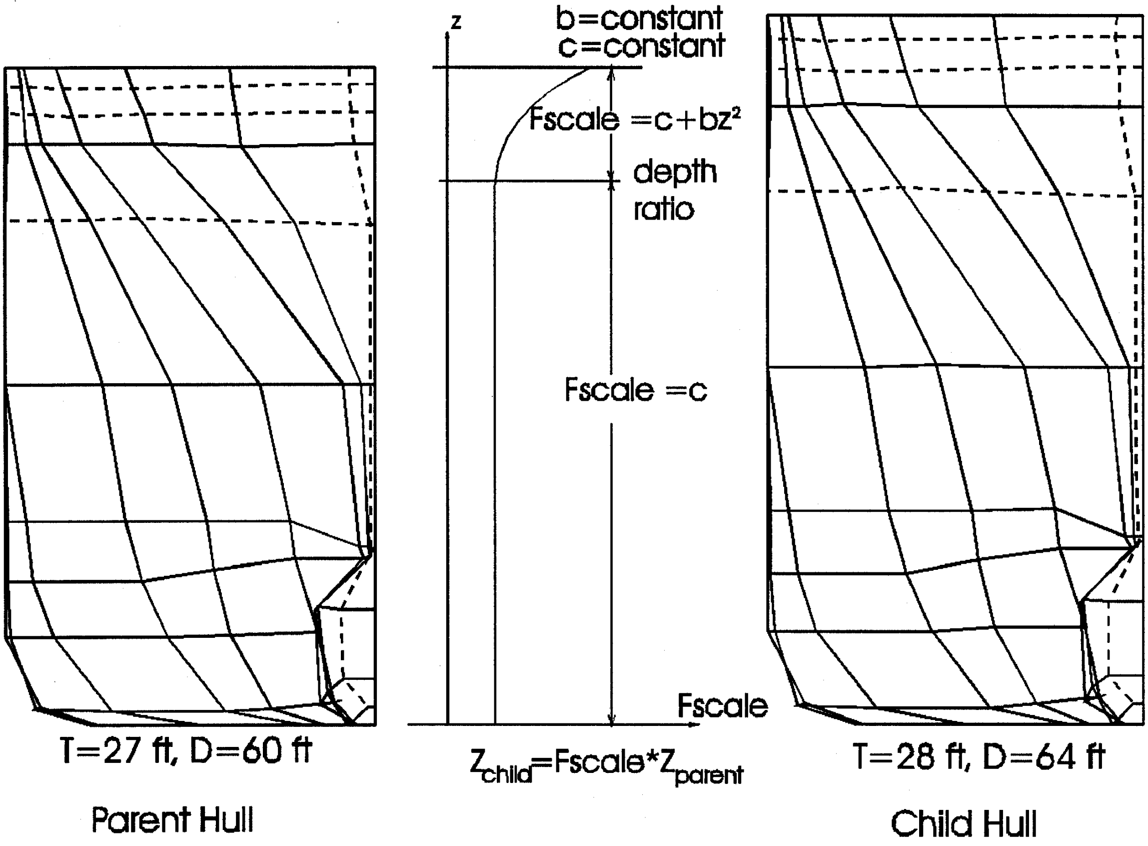

Figure 5: Changes in the Depth and the Draft

4 Example *.pmf File

An example *.pmf file for the AE-36 is listed below. Figure 6 illustrates some of the variables that are listed below. *Notes are* added *in italics*.

****
GENERAL NET TOPOLOGY
****

Maximum net column index in hull, maxn = 22 *Number of columns in the /top/hull/hull net*

Maximum net row index in hull, max = 14 *Number of rows in the /top/hull/hull net*
Maximum net column index in skeg, maxskeg = 6 *Number of columns and rows in the*
Maximum net row index in skeg, maxskegm = 6 */top/hull/hull net*
Set maxskegn and niaxskegm to (0,O) if no skeg surface exists

Aft column index of parallel midbody, nmidaft = 9 *Aft extent of the parallel midbody*
Fwd column index of parallel midbody, nmidfwd = 12 *Forward extent of the parallel midbody*
****
NET TOPOLOGY RELATING TO CX INFLUENCE
This section defines regions of transition around the midship section.
****

Fwd column index for Cx influence, maxncx = 16 *Fwd extent of transition region*

Aft column index for Cx influence, minncx =3 *Aft extent of transition region*
Lower row index for Cx influence, minmcx =0 *Lower extent of transition region*
Upper row index for Cx influence, maxmcx = 11 *Upper extent of transition region*
Lower row index defining bilge radius, mbilgelo = 3 *Definition of lo7ver row bilge radius*
Upper row index defining bilge radius, rnbilgehi = 7 *Definition of upper row bilge radius*
Because of tangency control at the edges of the parallel midbody, the columns just outside the parallel midbody need to match the parallel midbody as defined by maxncxmid and minncxmid.
Fwd column index for parallel Cx influence, maxncxmid = 14 *For tangency control, nmidfwdd+l*
Aft column index for parallel Cx influence, minncxmid = 8 *For tangency control, nmidaft-1*

****
NET TOPOLOGY RELATING TO VERTICAL SCALING FOR DEPTH AND DRAFT
In order to scale depth and draft independently, the ship needs to be divided into two patches.
****
Upper row # for DWL influence, maxmdwl *= 11 Preserves the main deck, when modifying the Design WaterLine*
Depth/draft ratio for z-scaling interface,depth-ratio = 1.2 *Divides the ship into two patches, to scale depth and draft independently*
****
NET TOPOLOGY DEFINING FLAT OF BOTTOM FOR DWL MANIPULATION
****
Row defining FOB, fobrow =3 *The row defining the flat of bottom*
Aft column defining FOB, aftfobcol =6 *Aft edge of FOB*
Fwd column defining FOB, fwdfobcol = 18 *Fwd edge of FOB*

****
NET TOPOLOGY DEFINING FIXED VERTICES AND STRAIGHT PATCHES *There can be as many or as few straight patches and points as necessary.*
****
Fixed point indices in Cx region, fixpt = 4,1 *The point (4,I) is fixed.*[3]
Fixed point indices in Cx region, fixpt = 4,2
Fixed point indices in Cx region, fixpt = 4,3
Fixed point indices in Cx region,fixpt = 5,1
Fixed point indices in Cx region, fixpt = 5,2
Fixed point indices in Cx region, fixpt = 5,3
Fixed point indices in Cx region, fixpt = 6,1
Fixed point indices in Cx region, fixpt = 6,2
Fixed point indices in Cx region, fixpt = 6,3
Lower row of stem patch, stemmirun = 7 *The identification of the stem patch*
Aft column of stem patch, stenuninn = 20
Lower row of stem patch, stenurtinm = 0 *The identification of the stern patch*

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[3] *Tlie points werefixed to make the parent hall eye robust during Cx treinslbrniations. lit this hall, tlle.flat fif bottomjijtie,s awa@. quickly aft of the parallel ntidbotly. The net rows that pass through the bilge radius are. ver@, close to the centerline lit this area. When the inidships section is shrunk-, the netitist cifi of the pmb can cross the c,entertine. Bvfixing these points, the tr(in@vforination is more r@ibitst. These points ai-efrte to inoi,e in all transfon@tions except the Cx modification.*

Stem boundary Condition, stembc = mirror*The options are mirror or natural. Mirrored boundaries along the stem are forced to be normal to the centerplane, like elliptical waterline. Natural boundaries along the stem are not forced to be normal to the center-plane.*

Straight patch, str_patch =0,11,19,14,col *The columns in the patch from (0,11) to (19,14) are collinear. This particular straight patch is the shell plating just below the sheer line.*

Straight patch, str_patch = 22,7,22,14,col *The columns in the patch from (22,7) to (22,14) are collinear. This patch is the stem, above the bulbous bow.*

Straight patch, str-patch = 0,10,15,12,col

Straight patch, str-patch = 5,0,5,14,row

Assumes hull is one surface with (0,0) at aft inboard end.

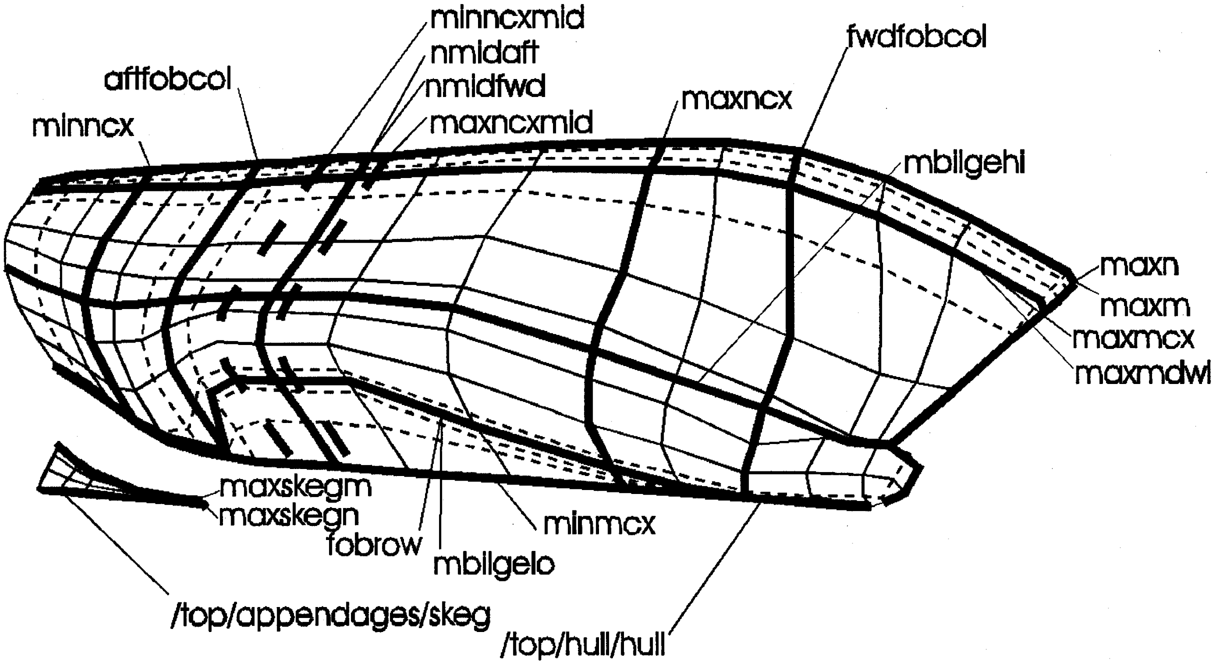

Figure 6: Nomenclature for the AE36pmfs.pmf file

5 Recommended Procedures

This section is meant to summarize the advice in one concise example, the development of a Navy Auxiliary parent hull form. The choice of hull form, the development of the net, and the development of the *.pmf file will be shown for the AE36 parent hull form. Along the way, advice and recommendations will be made about the best procedures in developing a parent hull.

5.1 Choice and Topology of the AE-36 Parent Hun

The parent hull is shown in Figure 7. The hull meets the five criteria laid out earlier in the beginning of Appendix A. The AE-36 has very favorable resistance and stability characteristics, and has served as the baseline for two new Naval Auxiliary designs. The AE-36 hull form qualifies as a good parent, because she possesses these outstanding qualities, in accordance with criterion # 1. The hull is similar in section shape and general characteristics to new Navy auxiliary designs, satisfying the "similar in general characteristics" guidance of criterion #2. The children hull forms are expected to have a bulbous bow, and a buttock flow transom, fulfilling the "same local features" clause of criterion #3. The density of the net is appropriate for capturing the details of a bulbous bow, without being excessive, which fulfills criterion #4. The hull form is represented by two surfaces, called /top/hull/ hull and /top/appendages/skeg. A small length of parallel midbody is included in the net, though the hull does not have any parallel midbody.

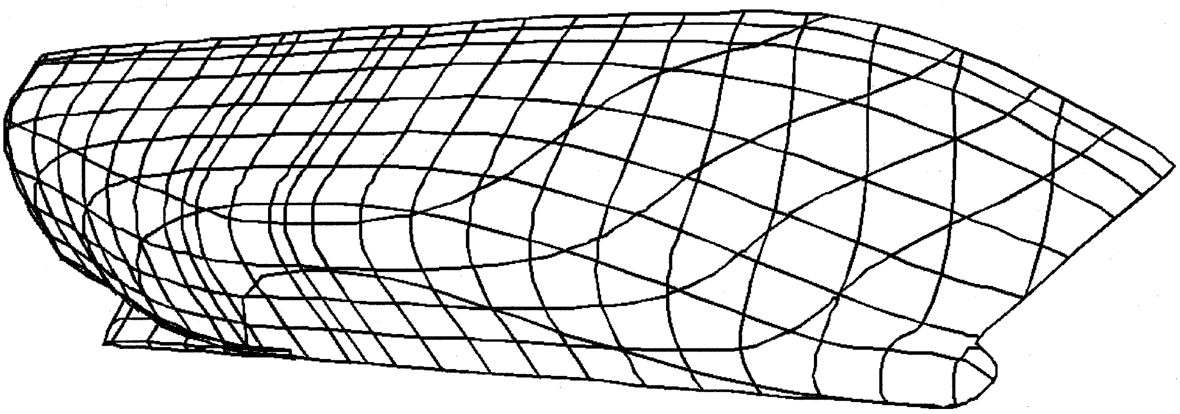

Figure 7: AE-36 Parent Hull Form

5.2 Development of the *.pmf File

The next step in the process is to develop a *.pmf file. The *.pmf file shown in the section "*.PMF File Development, example *.pmf file" is the *.pmf file for the AE-36 shown in Figure 7. The best starting point for developing a *.pmf file is to copy a previous *.pmf file, or to use the sample tile in this Appendix. It is easy to edit the file in a separate window, with both FastShip and the file on the screen. The next step is to use the **select point** command in FastShip to find the indices of a particular net point. The first two lines in the *.pmf file ask for the maximum net column index in the hull, maxn and maxm. In PMFS, the lower left-hand corner of the profile view is usually the net index origin (0,0). The upper right-hand corner of the net is usually at the net index (maxm,maxn). The **select point** command will display the net index of any selected point. Therefore, by selecting the upper right-hand corner, **select point** will display (maxm,maxn) in the dialogue window. In a similar way, **select point** can be used to determine the maximum net column and row index in the skeg, or the extents of the parallel midbody.

Some of the parameters in the *.pmf file are known with certainty, and some of the parameters are a matter of preference. For example, the number of columns and the number of rows, maxn and maxm, in the net are known exactly. However, the extent of the influence of the parallel midbody, nmincx, and nmaxcx is a matter of judgment and experience. For these types of parameters, the best approach is to make a reasonable guess, perhaps based on the AE-36 example. With testing and refinement, the *.pmf tile can be proven to be robust over a wide range of translations. Until such testing has been carried out, the creation of the parent hull form is not complete.

Knuckles in the topology of the net require special consideration in the *.pmf file. Triple knots introduce the potential for discontinuities in slope and curvature; without knowledge of these triple knots, PMFS might create an unfair hullform. For example, let's consider a knuckle in the flare of a bow, shown in Figure 8. The knuckle is represented by a triple knot row in the net. At the bow, the knuckle is prominent, but around amidships, the knuckle fades away into a smooth, continuous surface. Through this aft smooth area, the rows above and below the knuckle are collinear with the knuckle, so that the slopes match. If PMFS does not know about the presence of the knuckle, some of the transformations could misalign the net and create an unintended hard spot. To prevent this, a straight patch should be created. In this case, the straight patch extends across the length of the collinear columns. Because the knuckle is in the row direction, the columns should be kept collinear. In general, PMFS needs information about every knuckle in the net, except the knuckles associated with the parallel midbody and the bilge radius. The parallel midbody and bilge radius knuckles are handled formally through the *.pmf file.

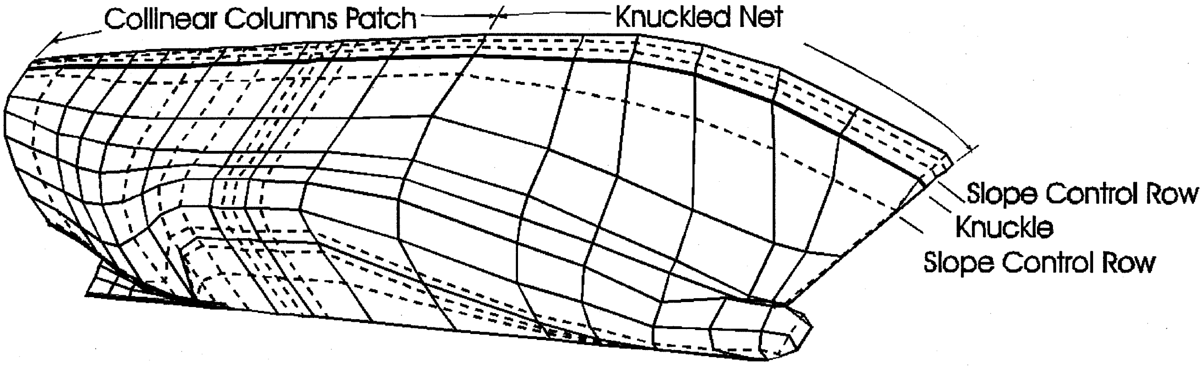

Figure 8: Straight patch centered around a knuckle in the bow flare