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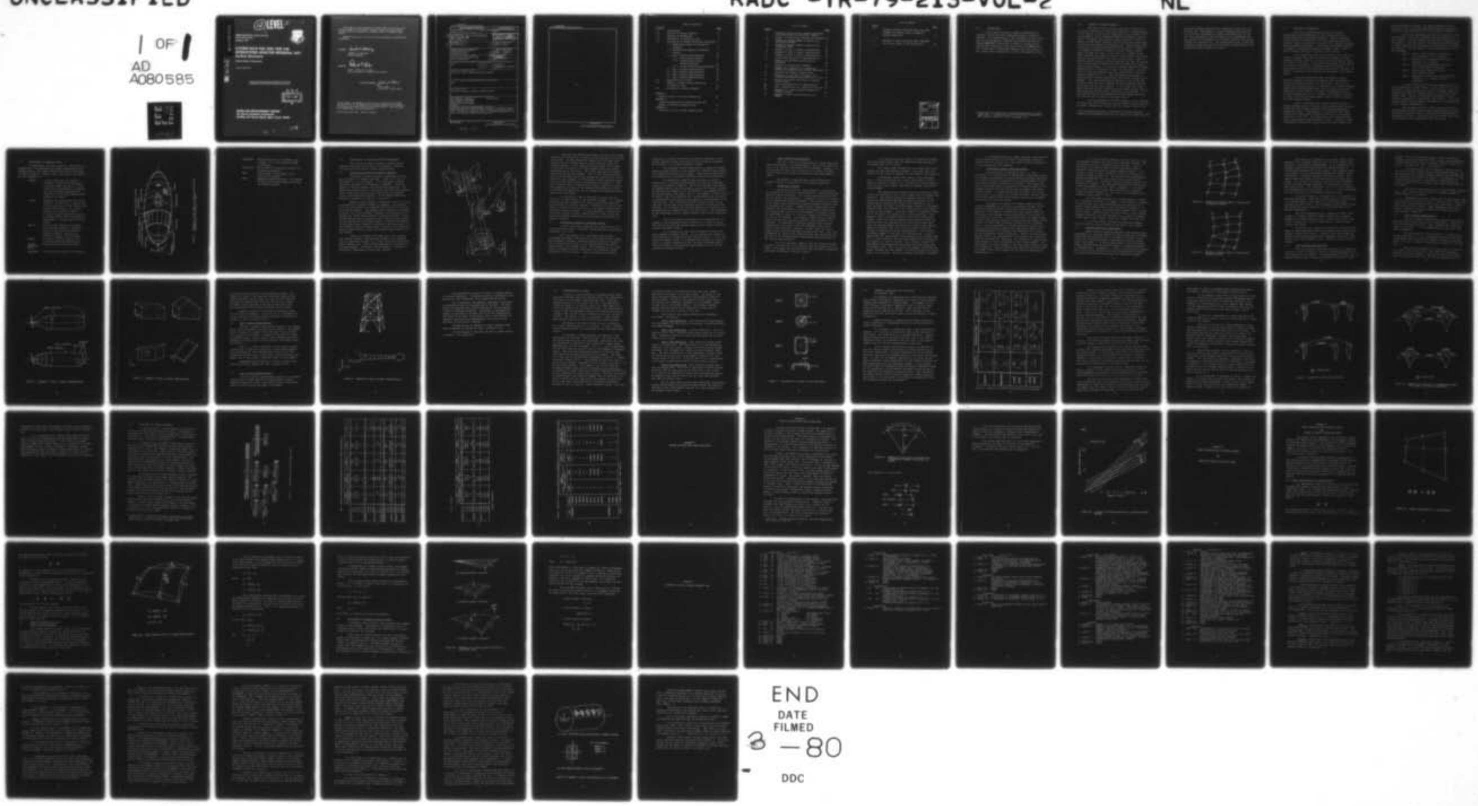

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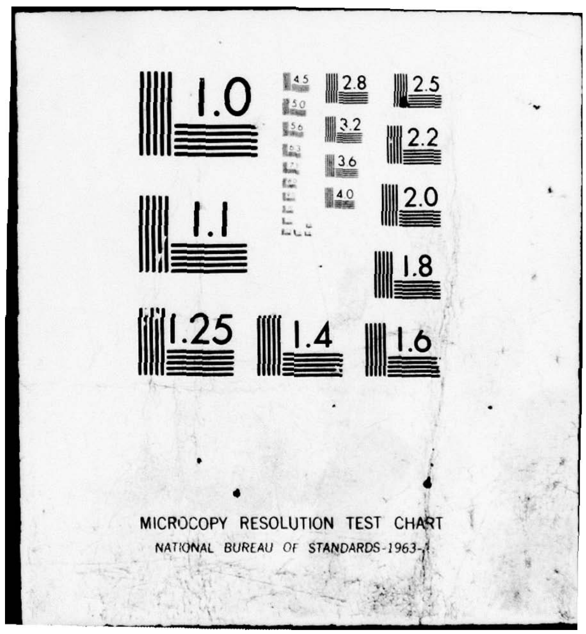
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RADC-TR-79-213, Vol II (of two)
Final Technical Report
December 1979

SYSTEM DATA FILE (SDF) FOR THE INTRASYSTEM ANALYSIS PROGRAM (IAP)
Surface Geometry

Atlantic Research Corporation

Richard Robertson

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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This report describes the Electromagnetic Compatibility/Intrasystem Analysis Program (EMC/IAP) System Data File (SDF) and defines each data entry of the file. This report is intended for use both by personnel building an SDF file and by those wanting to extract data from the file.

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1.0 INTRODUCTION

This report describes a general methodology for digitally storing the three-dimensional shape of geometric surfaces. This methodology has been developed for application with the Electromagnetic Compatibility/Intrasystem Analysis Program (EMC/IAP). Provisions are made for storage of the surface definition data on the System Data File (SDF).[1] The file builder must be thoroughly familiar with the contents of this report before attempting to collect the geometric data.

[1] System Data File (SDF) for the Intrasystem Analysis Program (IAP), Vol. I - Description, Atlantic Research Corporation, RADC Contract F30602-77-C-0126, December 1979.

2.0 PURPOSE OF SURFACE GEOMETRY

EMC analyses often involve conducting surfaces that are part of the physical system being analyzed. A common example is the exterior of an aircraft which would be an essential part of the analysis of the coupling between two antennas on the aircraft. In general, the surface or some portion of it must be modeled in some manner depending upon the input data requirements of the particular analysis code being used. Some analysis codes require only a simple representation of the surface. IEMCAP,* for example, represents a surface by simple, generic shapes: plane, cylinder, and cone. Other codes - e.g., GEMACS,** and those employing the geometric theory of diffraction - need a more accurate representation of the actual surface shape. With the need for greater accuracy in EMC predictions has come the development of more refined techniques by analysis codes for treating actual surface shapes. As a result, a greater quantity of surface definition data is required for input to these codes. This can place an excessive burden on the user, particularly if he must manually prepare the x-, y-, and z-coordinates of hundreds or even thousands of points which define the surface as input to his program. This can be particularly wasteful to the overall EMC effort if other EMC users studying the same system are also preparing data for the same surfaces. It is evident that a data base containing surface definition data for many systems that are often analyzed could be highly beneficial to EMC analysts. To this end the SDF has been designed to provide needed electrical and physical data for specific systems to users.

In the development of the SDF, however, it was necessary to obtain some type of practical technique which could be used for accurately representing a large class of surfaces. None of the

* Intrasystem Electromagnetic Compatibility Analysis Program.
**General Electromagnetic Model for the Analysis of Complex Systems.

existing techniques appeared to be completely suitable for use with the IAP. Consequently a unique methodology was developed to fulfill the requirements of surface representation for the SDF. The approach has been influenced by the requirement that the data are to be organized in a standard structure for digital storage on a computer file. The design permits easy storage and retrieval of data from the file and allows reconstruction of the surface with known bounds on the error.

3.0 APPROACH TO METHODOLOGY

The class of surfaces which must be accurately represented by the methodology are real surfaces which are found on physically realizable structures. Specific examples of the kinds of structures which are most commonly studied are aircraft, rockets, satellites, ground vehicles, ground structures, frame structures and antennas. In addition, the methodology must be capable of defining any apertures, windows, doors, and dielectric panels which may be located on the surfaces.

It is assumed for real surfaces that, in the limit, the surface is smooth and, except at well-defined edges, is slowly changing in shape. That is, at any point on the surface, except at a corner or an edge, a sufficiently small region of the surface can always be found which is mathematically well behaved. At these points the first and second derivatives exist, and thus, the radius of curvature in any direction on the surface can be determined.

It has been determined that the simplest and most practical method of defining this general class of surfaces is with points placed judiciously on the surface. The error of surface point representation is a function of the distance between points and can be made arbitrarily small by placing the points sufficiently close together. (Accuracy considerations are discussed in Appendices A and B.) Ideally, the distances should be as large as the accuracy requirements allow in order to minimize the total number of points.

For this methodology the maximum distances allowed between adjacent points are based on the allowable error in representing the true surface resulting from linear interpolation between the points. Consequently, it is necessary that these connectivity lines between "adjacent" points also be specified explicitly in the file. The connectivity lines indicate where linear interpolation between points is valid. In general, linear interpolation between two surface points for which connectivity is not specified in invalid. The general method for interpolating to any point between the defined surface points must follow the strict guidelines which are outlined in Appendix B.

The overall methodology provides five types of surface representation. The point representation described above is Type 1 which is the most general type and can be applied to all the surfaces. The other types of representations are designed to greatly simplify the definitions of special types of surfaces or structures. The five types of surface representations are the following:

Type 1 - General point definition, applicable to all surfaces. (e.g., aircraft)

Type 2 - Applicable to cylindrical and conical surfaces. (e.g, missile)

Type 3 - Applicable to plane-faced structures. (e.g., rectangular antenna hut)

Type 4 - Applicable to framed structures. (e.g., antenna tower)

Type 5 - Applicable to spherical or hemispherical surfaces. (e.g., storage tank on a satellite.)

In order for any type of surface representation to be easily applied to a surface within a given system, it is first necessary to subdivide the system into an arbitrary number of elements such that each element contains a distinctive kind of surface shape. Second, a rectangular coordinate system of arbitrary orientation is defined for each element. Third, the surface shape of each element is then defined by an appropriate type of surface representation.

The following sections of this report describe the implementation of each type of surface representation in detail. Particular attention is given to describing the general point representation (Type 1) since this will be the most widely used and is also the most complicated of the five types.

4.0 DEFINITIONS OF GEOMETRIC TERMS

The definitions of several geometric terms which are fundamental to the methodology of surface representation are presented below. An example illustrating each of these terms is shown in Figure 1. (Each of these terms may be preceded by the word "geometric.")

Element	- A major subdivision of a system. An element isolates a distinct type of surface shape from the rest of the system for the convenience of applying one type of surface representation. Each point on the system surfaces must belong to an element.
Contour	- Generally the intersection line of two surfaces. In most cases a contour will be the intersection of the surface of an element with a plane, i.e., a cross-section cut through the element. A contour may not include the parts of an element surface which are defined by subcontours. A contour may be open or closed.
Section	- A part of the surface of an element. For an element defined by contours, a section is the surface between two adjacent contours. Sections are bounded by segments and/or contours.
Segment	- A straight line which connects two specified surface definition points.
Surface Definition Point	- A point lying on the true surface.
Subelement	- A portion of the surface of an element.

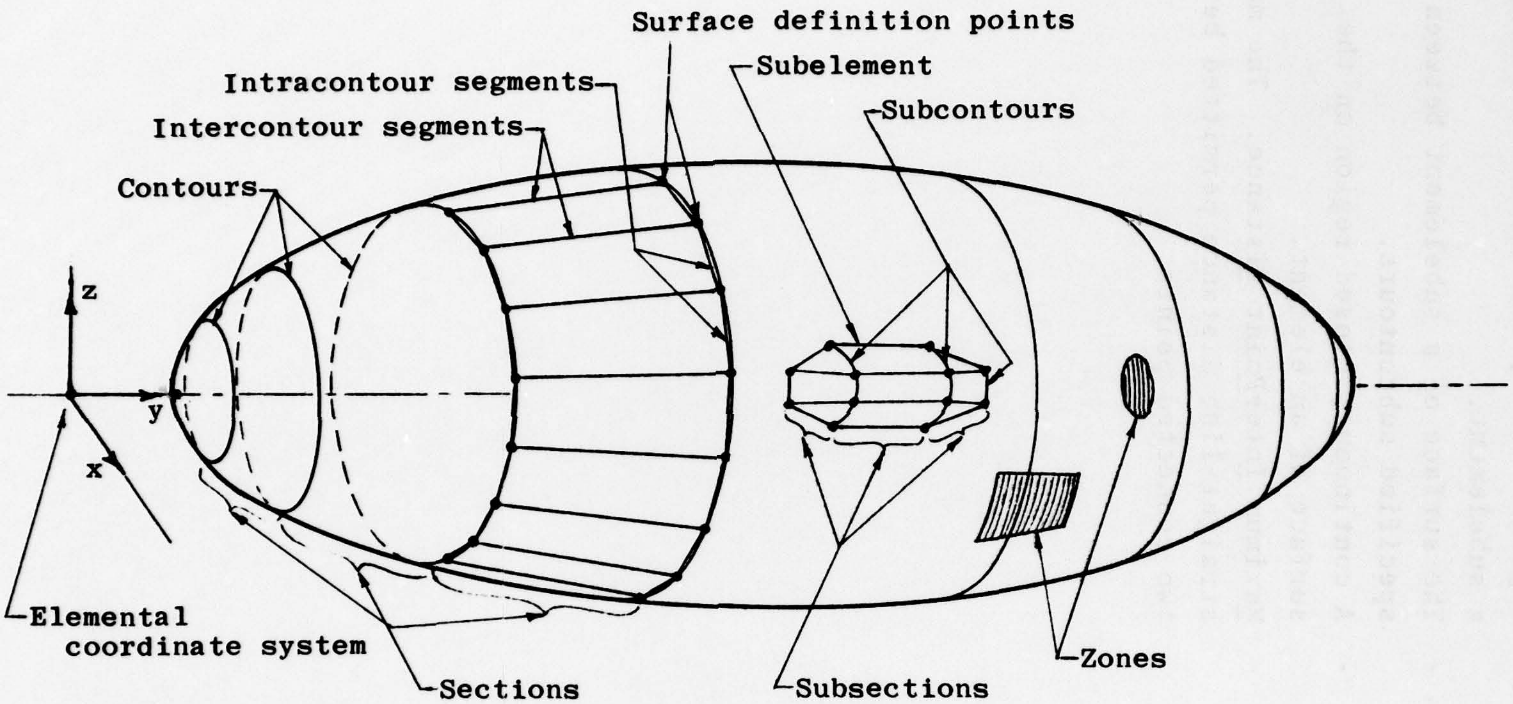


Figure 1. Examples of terms used in surface representation methodology of a geometric element.

Subcontour - The intersection of a subelement with a plane - i.e., cross-section through a subelement.

Subsection - The surface of a subelement between two specified subcontours.

Zone - A continuous, closed region on the surface of an element.

MIPD - Maximum InterPoint Distance. The maximum straight-line distance permitted between two connected points.

5.0 DESCRIPTION OF SURFACE DEFINITION TECHNIQUES

This section discusses geometric elements and the Elemental Coordinate System (ECS), and presents a detailed description of each type of surface representation.

5.1 Subdividing System into Geometric Elements

The manner in which a system is subdivided into geometric elements is somewhat arbitrary. There is no limit to the number or sizes of elements. It is principally surface shape that determines the boundaries of elements. Since the purpose of forming elements is primarily for convenience, the subdivision should be done to the extent that the system surfaces can be relatively easily defined using any of the available surface representation techniques. The following guidelines, however, can generally be applied to any system.

Normally, each separate or unconnected body in a system is assigned to a different element or elements. The distinct parts of a system which are connected should usually be assigned as different elements. The boundary of an element can be defined along any line on the surfaces. Normally, the boundaries of an element will follow natural break or intersection lines. Since the methodology does not permit the use of more than one type of surface representation technique within an element, the boundary of an element should normally be defined at the intersection of two different kinds of surface shape. Generally, the subdivision process should attempt to form a cylindrical-shaped surface for each element.

Figure 2 illustrates the subdivision of an airplane into various elements. The principal element is the fuselage with all appendages removed, i.e., wings, horizontal stabilizers, rudder, engines, etc. Each of these appendages is assigned to a different element. The surface of each element is defined or represented independently of the other elements.

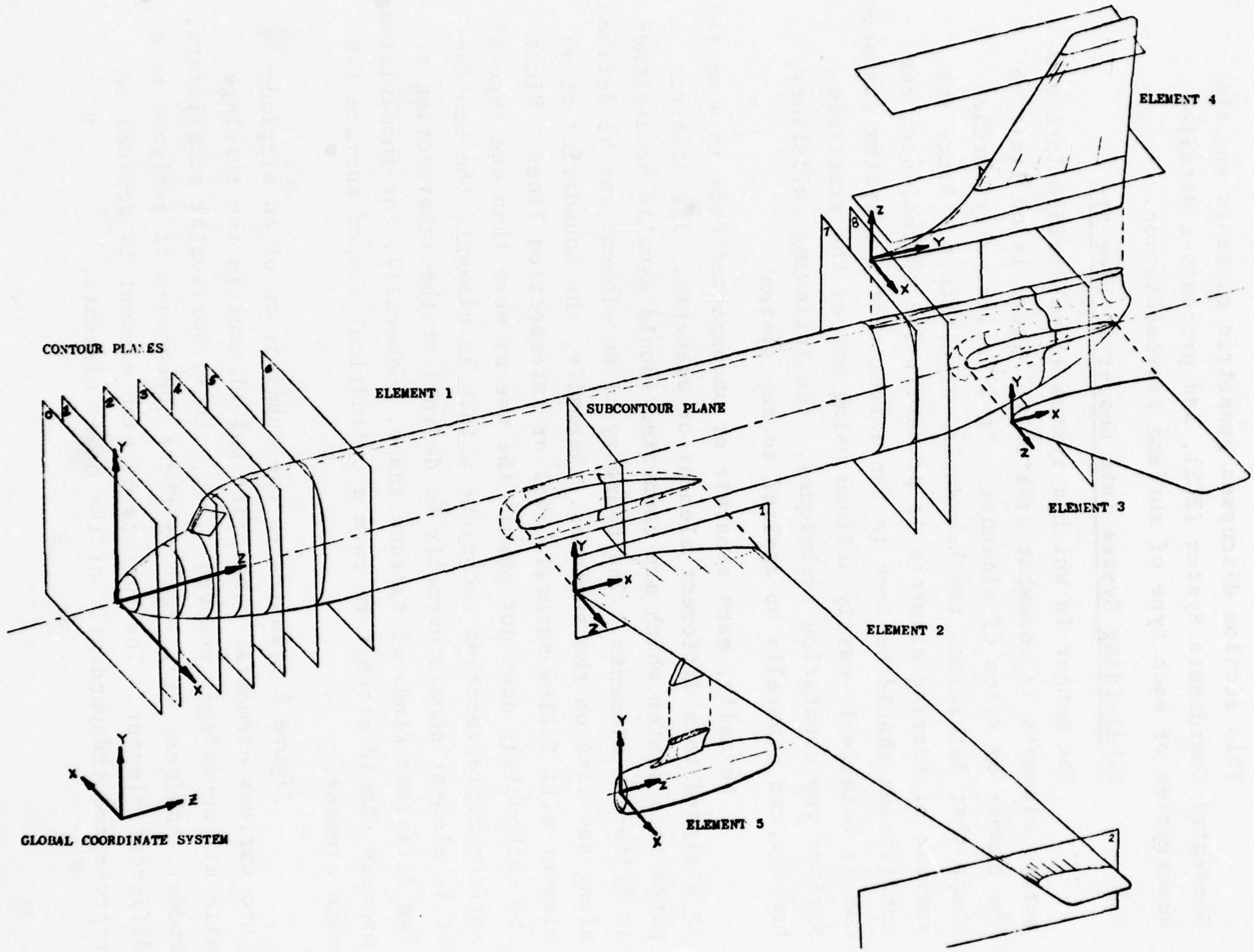


Figure 2. Example of subdividing a system into elements.

Note that the intersection between the wing and fuselage elements is a plane which is placed at the beginning of the uniform wing surface. In this manner the complexity of the wing fillet merging with the fuselage shape is placed entirely within the fuselage element. If the intersection were placed in the center of the fillet transition, then both elements would have surface complexity due to the fillet. This would complicate the surface definition for the wing element. Also, if the intersection were made on the fuselage proper thus placing the entire fillet surface within the wing element, the intersecting surface generally would not be a plane, thus making the definition more difficult. Normally, the best choice of intersection between elements is a plane cut parallel to two axes of the elemental coordinates for one of the elements and which does not cut through the transition surface between the two elements.

In some cases it may be desirable to assign the two halves of a closed surface to two different elements. For example, the upper and lower surfaces of a wing or horizontal stabilizer may be defined as separate elements. Similarly, the interior and exterior surfaces of an air duct (e.g., jet engine nacelle) may be defined as separate elements. The classification of surfaces in this manner permits distinct identification of each surface part which can eliminate ambiguities during surface reconstruction by computer software.

5.2 Establishing Elemental Coordinate Systems

A global coordinate system must be established for the overall physical system. The global system must be a right-handed, orthogonal set of axes.

After the elements of a system have been defined a rectangular coordinate system must be established for each element. Each elemental coordinate system can have any arbitrary location and orientation with respect to the element and can be either a right-handed or left-handed system. The coordinates of all points within an element are to be specified by the coordinate system established for that element. Since each elemental coordinate system must be defined relative to the global coordinates of the overall geometric system, each point in the system can ultimately be referenced to the global coordinate system.

The coordinate system established for a geometric element should be placed relative to the element in a position which simplifies surface definition of the element. Some general guidelines for the selection of an elemental coordinate system are provided below.

For symmetrical elements requiring Type 1 or Type 2 definition, it is generally advantageous to place the coordinate origin on the plane of symmetry. One of the coordinate axes should be aligned parallel with the principal axis of the element, keeping in mind that the elemental axis will generally be perpendicular to the contour planes (for Types 1 and 2). For example, it can be seen in Figure 2 that the coordinate axis established for the wing axis is not parallel to the edges of the wing but is perpendicular to the fuselage axis. This orientation provides contour planes for the wing that are parallel to the presumed direction of wind flow over the wing. It is assumed that the wing profiles as provided by the manufacturers are normally defined in these planes. The orientation of the coordinate system as shown simplifies the surface representation.

The use of negative coordinates can be minimized for an element if the coordinate system is placed at a corner or tip of the element such that the maximum amount of the element surface has positive coordinate values.

It is possible for two or more elements to utilize the same elemental coordinate system. In the extreme, all elements of the system may be referenced to one coordinate system -- e.g., the global coordinate system. If a manufacturer defines his system in terms of a global coordinate system, the same coordinates may be used in the SDF by specifying no transformation for each of the elemental coordinate systems.

5.3 Type 1 Surface Representation

The Type 1 surface representation is a point definition method applicable to all surface shapes. There is no theoretical limit to the accuracy associated with this method. However, it is not practical to apply Type 1 definition to a frame structure (Type 4) unless the surface description of each frame member is needed.

The methods of applying Type 1 point definition to element surfaces is described in the following subsections.

5.3.1 Establishing Contours

The primary purpose of using contours is to facilitate the organization of surface definition points. Contours represent paths of surface definition. All surface definition points must lie on contours (or subcontours). In general, a series of contours must be established along the element. The contours may be chosen in any manner which provides the simplest and most practical means of describing the surface. Element contours should usually be formed by the intersection of a series of parallel planes which are perpendicular to an axis of the elemental coordinate system, as illustrated in Figure 2. This axis should also be the principal axis of the element. For a general doubly-curved surface, such as an aircraft, the use of parallel plane contours is recommended. The advantage of defining parallel plane contours perpendicular to an axis is that one coordinate value of all points on each contour is constant. In most cases, this will simplify data collection and data storage on the file. Also, this arrangement of contours will simplify future data extraction from the file of the required points defining any specified region of the surface being analyzed.

It is not essential, however, that the planes be perpendicular to an axis, nor is it essential that each contour lie in a plane. For example, the intersection of two cylinders is generally non-planar but defines a distinct contour.

It is expected that the choice of a particular contour will also depend largely upon the geometrical data available by the manufacturer of the system.

The single points defining the two extreme ends of an element are also considered as contours - they being the first and last in the series of contours for the element. (See Figure 1)

A designated contour must consist of one continuous curve. If the intersection of a contour plane with a surface forms two disjoint contours (e.g., interior and exterior surfaces of an air duct) each contour line must be assigned a different contour number.

The spacing between contours must be sufficiently small so that the curvature of the surface between them is defined satisfactorily. The spacing between two adjacent contours cannot exceed the minimum MIPD (maximum interpoint distance) for the surface section between the contours (see Appendix B). For a given accuracy criterion, the MIPD between contours is determined from the radius of curvature of the surface along a path perpendicular to the contours. Since the curvature is generally different at all points on a surface (for a given direction), there generally exists a different MIPD for each point along either contour. Since the contour spacing cannot exceed any MIPD (as defined above), the spacing must not exceed the minimum MIPD. Thus, the spacing between two contours is based on the smallest radius of curvature that exists for the surface between the contours (as measured on a path perpendicular to the contours). An extreme example is the case of an aircraft wing. Since it appears that the wing surface can be generated by a straight-line (i.e., a ruled surface), the principal surface can be defined by two contours, as seen in Figure 2. Each contour contains the same number of defining points which are connected respectively by straight lines. Thus, as long as the segments connecting the points represent the true surface, the spacing between the contour planes is not limited. For this situation, the MIPD is infinite.

In the determination of element contours, those portions of the element which will be defined by subcontours should be excluded from the surface (i.e., the surface should be treated as if the subelement(s) were removed).

5.3.2 Establishing Surface Definition Points

The surface must be defined by the x-, y- and z-coordinates of a discrete set of ordered points along each contour. The straight-line distance or spacing between adjacent points must not exceed the MIPD as determined by the minimum radius of curvature along the contour between the two points. The consecutive order of the points must be preserved in the data storage, as the ordering of points for each contour helps to minimize the amount of data storage. A contour may be open or closed. For an open contour there is no connectivity between the first and last points. For a closed contour there is an assumed connectivity or segment between the first and last points.

The selection of points on a contour cannot be made entirely independent of the points on adjacent contours, as the connectivity between points of adjacent contours must also be specified. The length of a connectivity line cannot exceed the MIPD based on the minimum radius of curvature of the surface in the direction of the line. A connectivity line or segment perpendicular to two adjacent contours is valid since the spacing of the contours was based upon satisfying the MIPD for this condition. Thus, if in the development of surface definition, points can be selected along adjacent contours such that their connectivities are perpendicular to the contours, the connectivities are valid and no verification should be necessary. However, an intercontour segment which is not perpendicular to the contours may exceed the MIPD for its direction. Generally, the diagonal of a quadrilateral patch formed by four valid segments is not a valid segment. The significance of a valid segment is that the distance from any point on the segment to the true surface lies within the specified accuracy bounds. Thus, valid segments may be used for interpolation between points.

It is not necessary, however, that there be one-to-one correspondence between the points of two adjacent contours. The two contours may have an unequal number of points. Figure 3 illustrates two possible means of specifying connectivities between two contours having an unequal number of points. It is valid for a point to have connectivity with only one adjacent contour as shown in Figure 3a. This preserves the quadrilateral patches provided there is valid connectivity between points 2 and 4 of contour C2. It would be invalid to permit patch A to be defined by 5 segments. The interpolation within the interior of a patch having more than four sides is undefined. It is valid for a point to connect to more than one point on an adjacent contour as shown in Figure 3b. The result is the formation of a triangular patch, which is valid.

The first defining point on a contour should be located at a convenient reference. For example, if the element is symmetrical and requires only one-half definition, the first and last points of each contour should lie on the plane of symmetry. In general, the first point of an open contour should lie at one end of the contour. Where possible, the first point of every contour should be located at the same reference (e.g., plane of symmetry, leading edge of open contour, centerline, highest position, etc.)

If a surface contour contains straight-line segments, definition points should be placed at the ends of each segment.

5.3.3 Surface Definition of Subelements

Smooth surfaces requiring definition often possess minor protuberances or localized regions of complex shape which, although intentional and definitely part of the physical surface, tend to disrupt the simplistic method of representing the major surface shape. (See Figure 1) To define these details within the general surface representation would often result in a significant amount of redundant data. Consequently, in order to alleviate this problem and to increase the flexibility of this representation technique, the concept of subcontours and subsections has been developed.

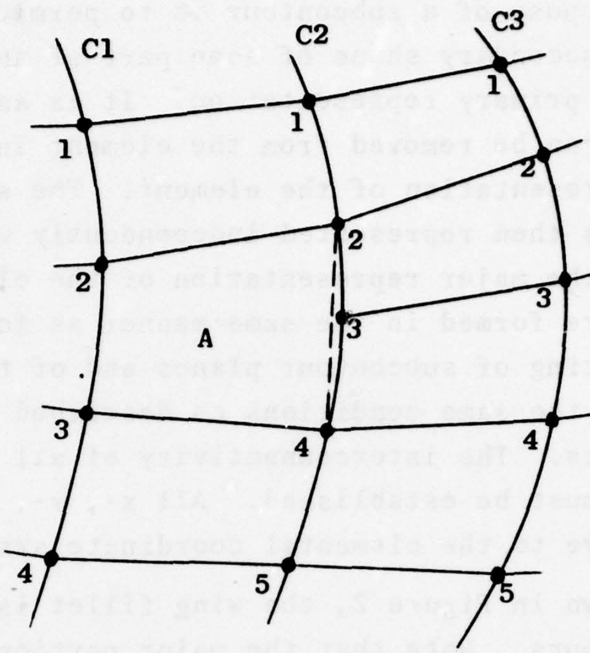


Figure 3a. Example of unequal number of points with rectangular patches.

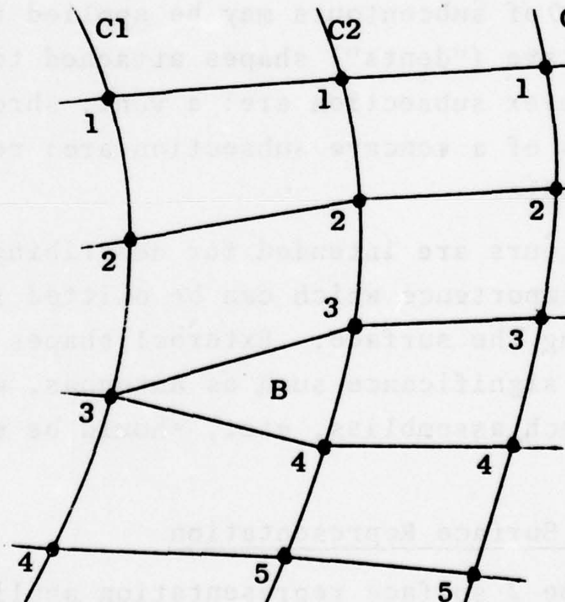


Figure 3b. Example of unequal number of points with triangular patch.

The purpose of a subcontour is to permit surface point definition of a secondary shape of some part of an element independently of the primary representation. It is assumed that the secondary shape can be removed from the element in order to simplify the representation of the element. The secondary shape, or subelement, is then represented independently without direct connectivity to the major representation of the element. Subcontour planes are formed in the same manner as for the contour planes. The spacing of subcontour planes and of the subcontour points must meet the same conditions as described for contours and contour points. The interconnectivity of all points defined on a subelement must be established. All x-, y-, and z-coordinates are given relative to the elemental coordinate system.

As shown in Figure 2, the wing fillet is an example of applying subcontours. Note that the major portion of the fuselage is a constant shape (cylindrical) and is defined by widely-separated contours 6 and 7. This cylindrical shape cannot include the wing fillet shape; therefore, the wing fillet details are defined independently.

The use of subcontours may be applied to either convex ("bumps") or concave ("dents") shapes attached to an element. Examples of a convex subsection are: a vent, shroud, hinge, wing fillet. Examples of a concave subsection are: recessed light, recessed door handle.

Subcontours are intended for describing relatively small shapes of minor importance which can be omitted from some types of analyses involving the surface. External shapes which represent objects of major significance such as antennas, wing braces, aerodynamic fins, winch assemblies, etc., should be assigned separate elements.

5.4 Type 2 Surface Representation

The Type 2 surface representation applies to elements in which all contours defined by a series of planes perpendicular to the element axis are circular. The representation for this type of element requires only the center coordinates and radius of each contour. This type of representation is ideal for defining cylinders, cones, and rods and, thus, is particularly applicable to describing surface shapes of rockets, missiles, pipes, gun barrels, straight wires, etc. See Figure 4.

The contour planes must be spaced so that the curvature of the surface between them is satisfactorily defined. The spacing between two adjacent contours cannot exceed the MIPD for the surface section between the contours. (See Appendix B) For a given accuracy criterion, the MIPD is determined from the radius of curvature of the surface along a path perpendicular to the contours.

For cases in which there is no curvature between contours (e.g., cone, right circular cylinder) the spacing between the contour planes is not limited.

Subelements on a Type 2 surface may be represented using point definition as defined for Type 1 (Section 5.3.3). Again, the subcontours should be applied only to minor appendages or depressions on the circular surface. Major appendages such as fins should be defined as separate elements and defined with Type 1 representation. (Figure 4)

5.5 Type 3 Surface Representation

The Type 3 surface representation applies to an element having surfaces consisting entirely of plane faces. Examples of this type of element are boxes, sheds, equipment huts and solar panels. See Figure 5. It is assumed that all plane faces have linear boundaries.

The representation of these surfaces is accomplished by a) specifying the x-, y-, and z-coordinates of every vertex and corner point, and b) defining the boundary segments of each face. A face of a Type 3 surface is considered as a section in the data file.

Only the outer boundaries of a face need to be defined. If a closed, interior region of a face intersects with other surfaces, it is not necessary to specify the intersection boundaries in the data for the face. The intersection data will be

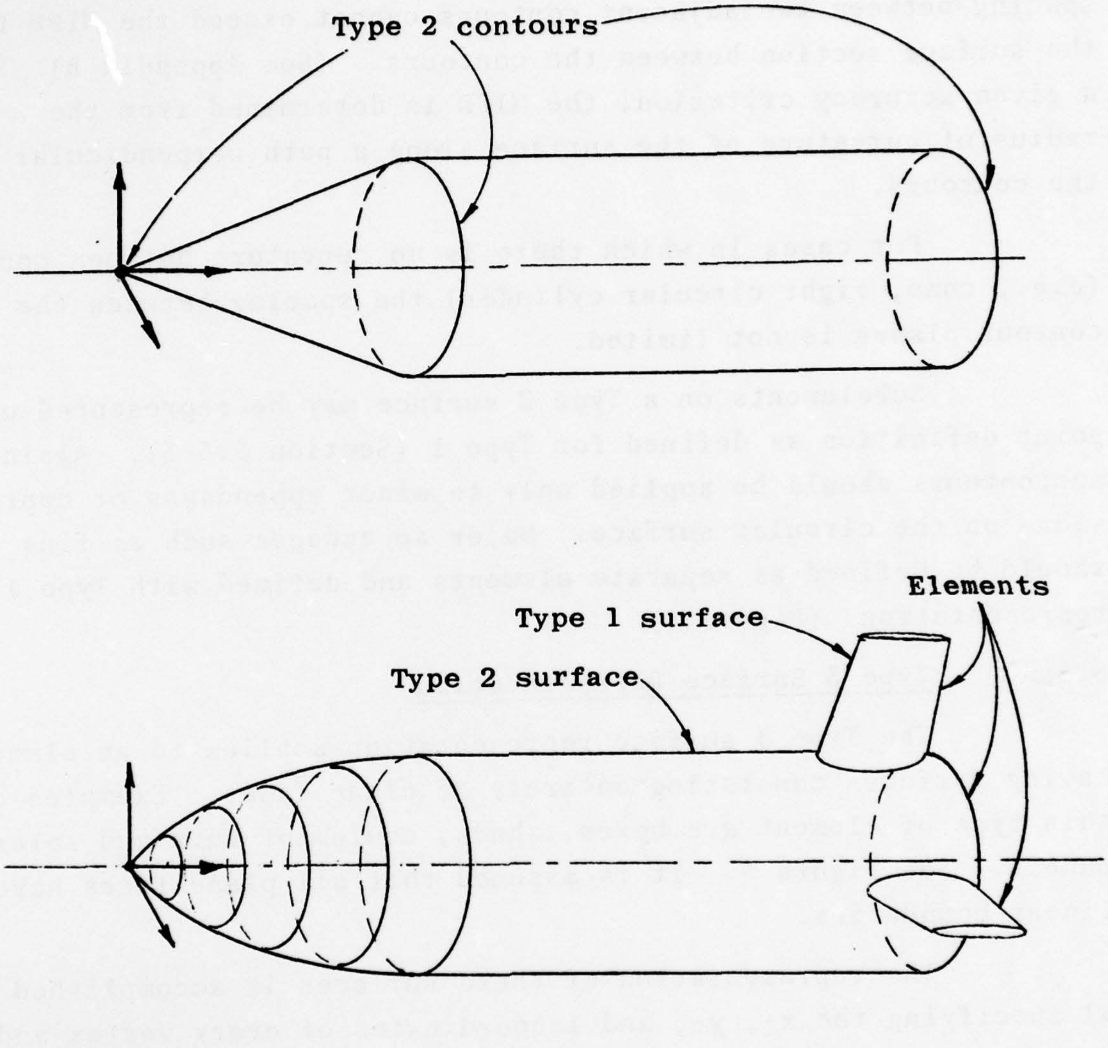


Figure 4. Examples of Type 2 surface representation.

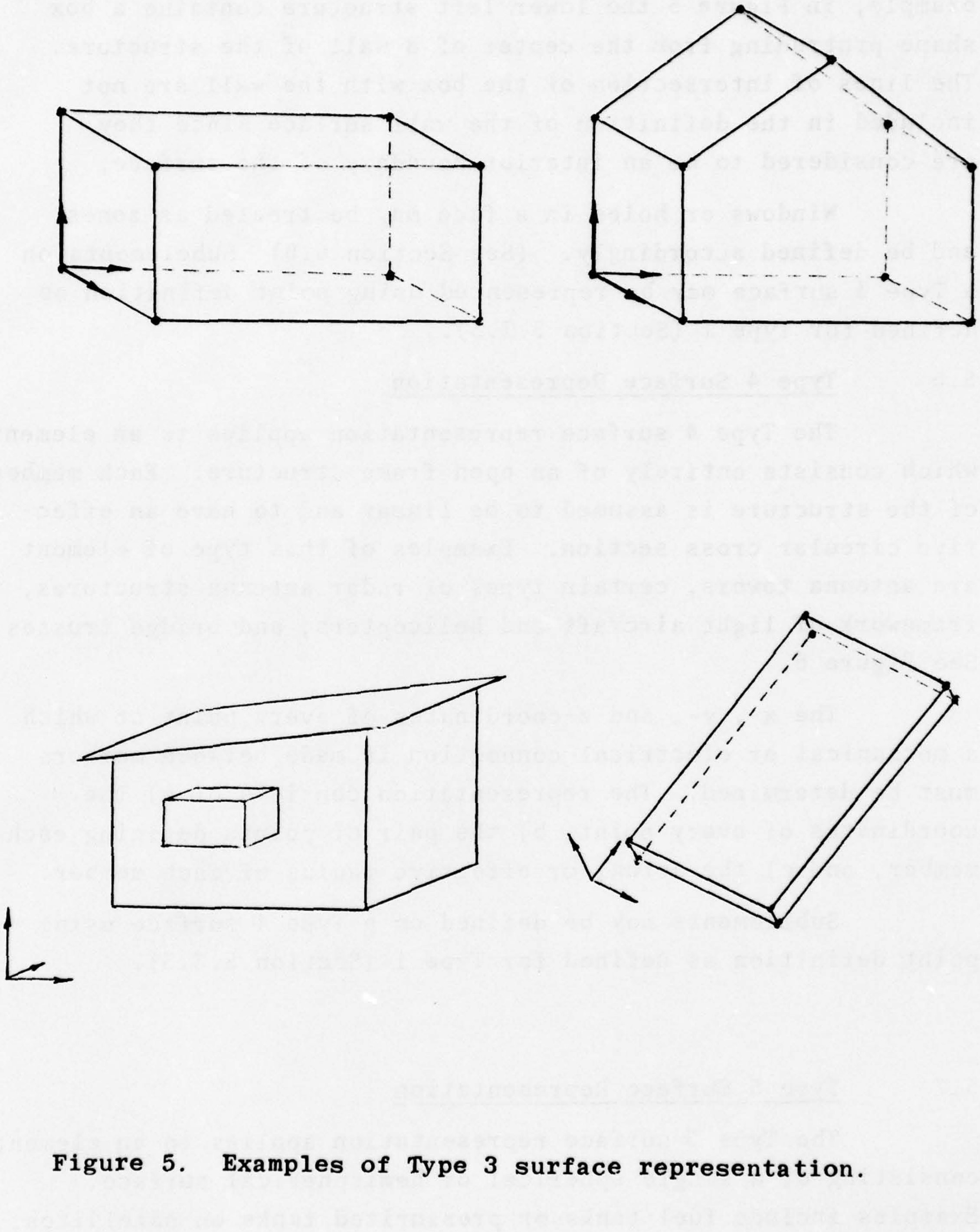


Figure 5. Examples of Type 3 surface representation.

specified with the data for the intersecting surface. For example, in Figure 5 the lower left structure contains a box shape protruding from the center of a wall of the structure. The lines of intersection of the box with the wall are not included in the definition of the wall surface since they are considered to be an interior boundary of the surface.

Windows or holes in a face may be treated as zones and be defined accordingly. (See Section 6.0) Subelements on a Type 3 surface may be represented using point definition as defined for Type 1 (Section 5.3.3).

5.6 Type 4 Surface Representation

The Type 4 surface representation applies to an element which consists entirely of an open frame structure. Each member of the structure is assumed to be linear and to have an effective circular cross section. Examples of this type of element are antenna towers, certain types of radar antenna structures, framework of light aircraft and helicopters, and bridge trusses. See Figure 6.

The x-, y-, and z-coordinates of every point at which a mechanical or electrical connection is made between members must be determined. The representation consists of a) the coordinates of every point, b) the pair of points defining each member, and c) the actual or effective radius of each member.

Subelements may be defined on a Type 4 surface using point definition as defined for Type 1 (Section 5.3.3).

5.7 Type 5 Surface Representation

The Type 5 surface representation applies to an element consisting of a single spherical or hemispherical surface. Examples include fuel tanks or pressurized tanks on satellites, ends of certain missiles and bombs, and radomes.

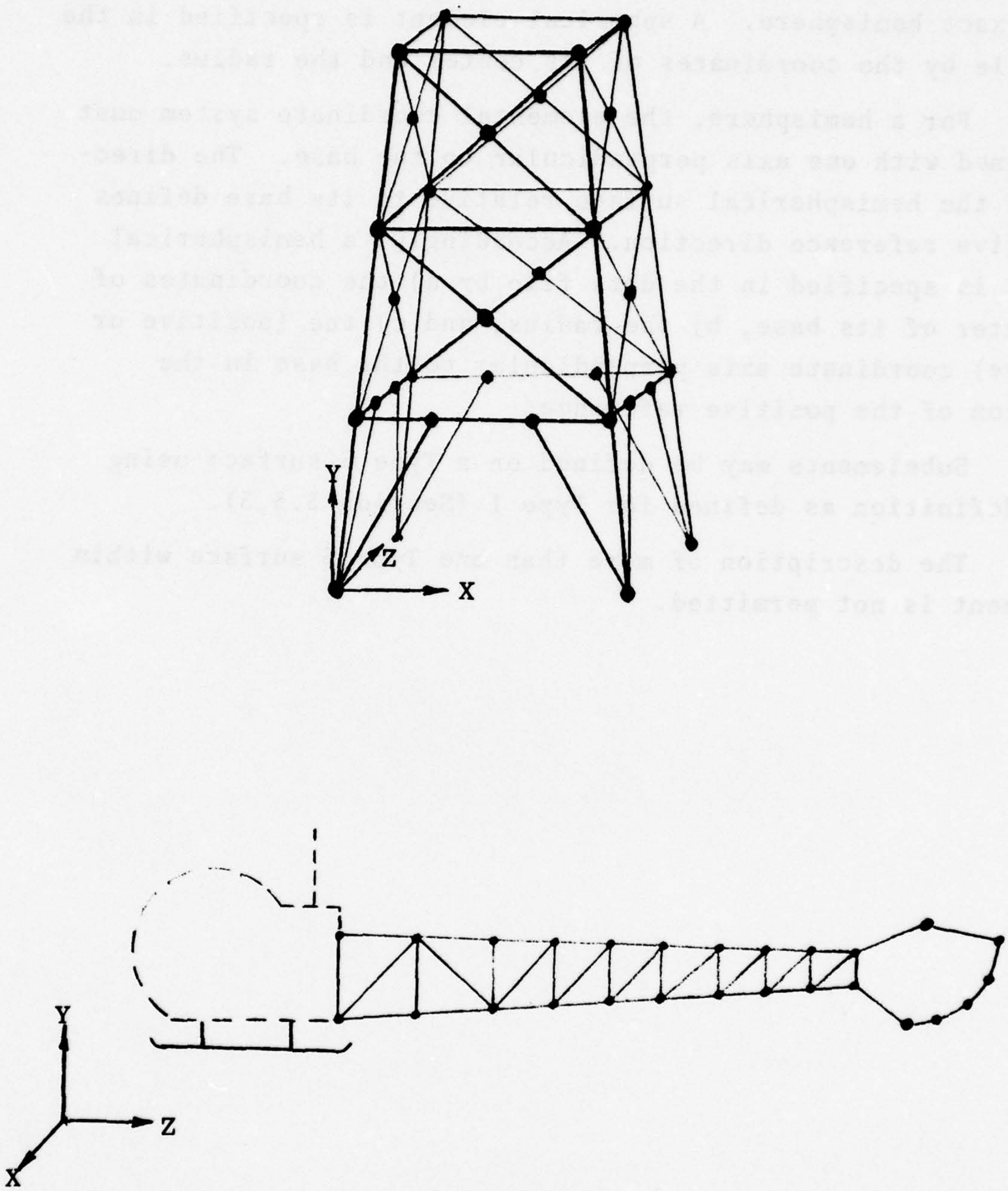


Figure 6. Examples of Type 4 surface representation.

The representation allows for either a complete sphere or an exact hemisphere. A spherical element is specified in the data file by the coordinates of its center and the radius.

For a hemisphere, the elemental coordinate system must be defined with one axis perpendicular to the base. The direction of the hemispherical surface relative to its base defines a positive reference direction. Accordingly, a hemispherical element is specified in the data file by a) the coordinates of the center of its base, b) the radius, and c) the (positive or negative) coordinate axis perpendicular to the base in the direction of the positive reference.

Subelements may be defined on a Type 5 surface using point definition as defined for Type 1 (Section 5.3.3).

The description of more than one Type 5 surface within an element is not permitted.

6.0 REPRESENTATION OF ZONES

A zone is a closed portion of a defined surface which possesses different electrical characteristics than defined for the surface of the element containing the zone. Typically, windows and holes in the surface are zones. More generally, dielectric panels in a metallic surface (or, metal panels in a dielectric surface) are considered as zones. The importance of a zone is that electromagnetic energy can penetrate the surface through a zone (in the case of a dielectric zone in a metallic surface). For IEMCAP, a zone is an aperture. Zones include open doorways and non-rf-tight cracks around closed doorways.

The shape of the surface within a zone is defined by the surface representation for the element. A zone is defined by its boundaries which are superimposed on the existing defined surface.

For purposes of representation, two classes of zone definitions are available: fixed and local. All zones can be described using the fixed zone definition. Generally, the fixed zone definition is applied to zones which have a unique shape appearing only once on an element. All x-, y-, and z-coordinates for the fixed zone are given in terms of the elemental coordinate system. The local zone definition applies to a specific zone shape which has multiple occurrences on an element. The shape of a local zone is defined by an independent or Local x, y (plane) Coordinate System (L.C.S.). The location of each local zone is given by the elemental coordinates of the origin of the zone L.C.S. on the element surface. For example, a row of 100 identical passenger windows on the side of a fuselage can be represented by defining the window shape once in local coordinates and specifying the coordinates of each window location. The local zone method of representing a zone should be applied only to zones which are small in relation to the curvature of the surface on which they lie in order that their shape can be defined with reasonable accuracy in the x-y plane of a local coordinate system. The local coordinate system is two-dimensional only and, thus, cannot describe any curvature of the zone surface. The origin of the local coordinates should be placed at the geometric center of the zone shape. Therefore, the location of each local zone is specified by the elemental coordinates of the geometric center of each zone on the element surface. The surface curvature defined for the element at the location of a local zone is assumed to define the curvature in the zone.

Four types of zone shape definitions are available, as follows. See Figure 7.

Type 1 Zone Definition. Point definition along boundary. This type applies to zones having a continuous, closed area within the defined boundary.

Type 2 Zone Definition. Circular definition. This is a special case of Type 1 definition which applies only to a circular zone. Definition consists of specifying the radius and the coordinates of the center.

Type 3 Zone Definition. Point definition along centerline of a closed strip. This type applies to a zone having the shape of a strip that forms a single, closed loop on the surface. An example is a continuous RF opening or crack around a closed door. The zone is defined by a) the coordinates of points along the centerline of the strip on the element surface and b) the average width of the strip. Since the zone strip is closed there is an assumed connectivity between the first and last points.

Type 4 Zone Definition. Point definition along centerline of an open strip. This type is identical to Type 3 with the exception that the centerline of the zone strip is not closed-i.e., there is no connectivity between the first and last points. An example of this type of zone is an RF crack which extends only part way around a door.

For all zones which require point definition, the spacing between points should not exceed the MIPD based on the radius of curvature of the zone boundary measured in a plane tangential to the surface of the element.

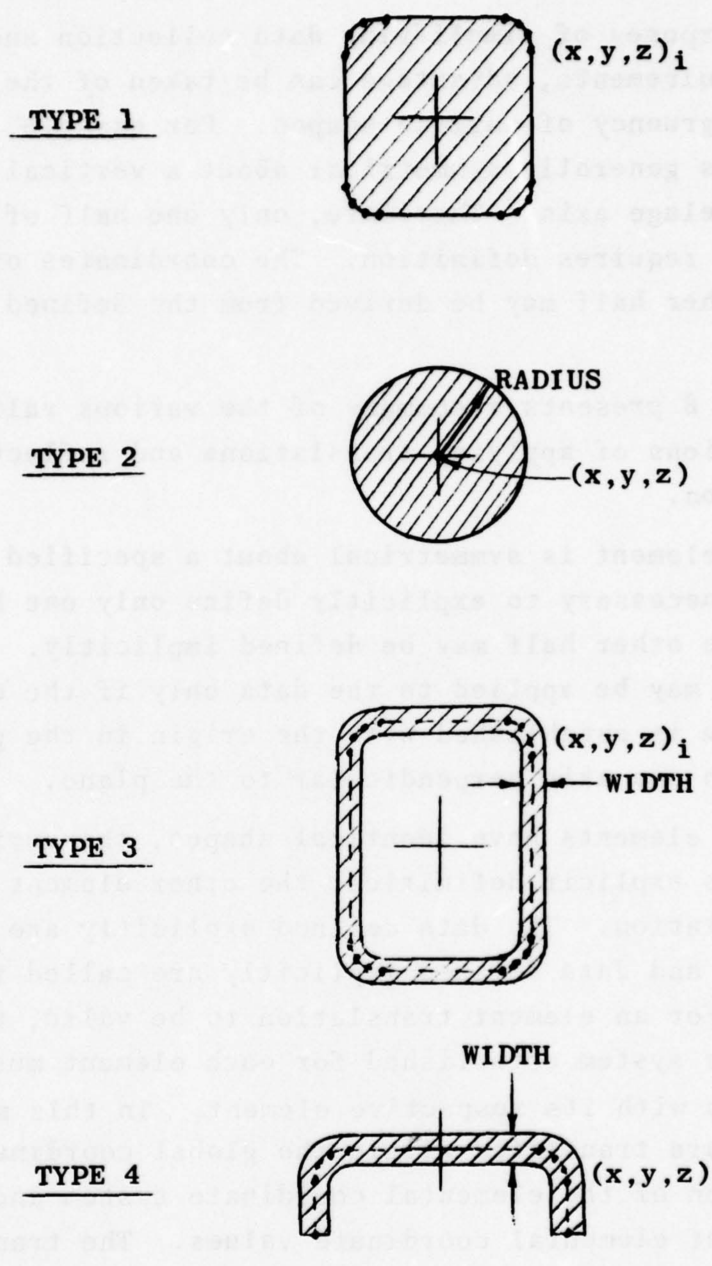


Figure 7. Illustration of types of zone definition.

7.0 SYMMETRY, TRANSLATION AND REFLECTION OF GEOMETRIC DATA

For purposes of simplifying data collection and reducing data storage requirements, advantage can be taken of the possible symmetry and congruency of surface shapes. For example, an aircraft fuselage is generally symmetrical about a vertical plane lying on the fuselage axis. Therefore, only one half of the fuselage surface requires definition. The coordinates of all points on the other half may be derived from the defined or source coordinates.

Figure 8 presents a summary of the various valid and invalid combinations of applying translations and reflections to surface definition.

If an element is symmetrical about a specified plane of symmetry, it is necessary to explicitly define only one half of the surface. The other half may be defined implicitly. However, implied symmetry may be applied to the data only if the element coordinate system is established with the origin in the plane of symmetry and with one axis perpendicular to the plane.

If two elements have identical shapes, the surface of only one requires explicit definition; the other element may be derived by translation. The data defined explicitly are called the source data, and data defined implicitly are called the derived data. In order for an element translation to be valid, the elemental coordinate system established for each element must have the same relationship with its respective element. In this manner the source data are translated within the global coordinate system by the translation of the elemental coordinate system and not by the translation of elemental coordinate values. The translation of element surface data to another element may include rotation since there is no restriction on the relative orientations of the two coordinate systems for the elements.

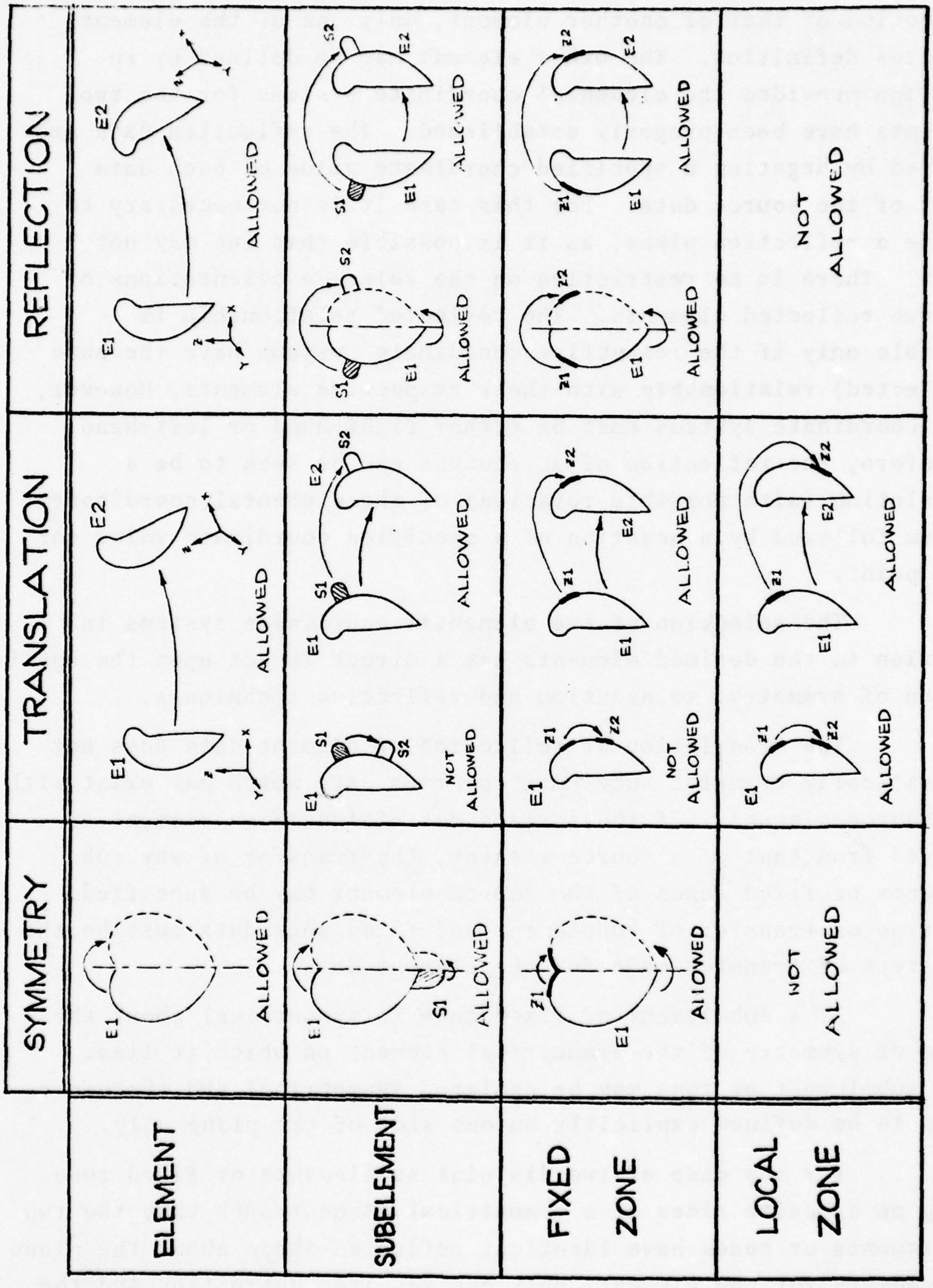


Figure 8. Summary of Translation and Reflection Techniques.

Finally, if the surface shape of an element is an exact reflection of that of another element, only one of the elements requires definition. The other element may be defined by reflection provided the elemental coordinate systems for the two elements have been properly established. The reflection data are derived by negating a specified coordinate value of each data point of the source data. For this case it is not necessary to define a reflection plane, as it is possible that one may not exist. There is no restriction on the relative orientations of the two reflected elements. The reflected relationship is possible only if the respective coordinate systems have the same (reflected) relationship with their respective elements. However, both coordinate systems must be either right-hand or left-hand. Therefore, the reflection of an element can be seen to be a translation (with possible rotation) of the elemental coordinate system followed by a negation of a specified coordinate value for each point.

The selection of the elemental coordinate systems in relation to the defined elements has a direct impact upon the application of symmetry, translation and reflection techniques.

The translation or reflection of element data does not automatically transfer subelement or zone data which may exist with the source element. If the surface definition of an element is derived from that of a source element, the transfer of any subelements or fixed zones of the source element may be specified. The type of transfer of subelement and fixed zone data must be the same type of transfer made for the element data.

If a subelement or fixed zone is symmetrical about the plane of symmetry of the symmetrical element on which it lies, such subelement or zone may be declared symmetrical and therefore needs to be defined explicitly on one side of the plane only.

For the case of two disjoint subelements or fixed zones lying on opposite sides of a symmetrical element such that the two subelements or zones have identical reflected shape about the plane of symmetry for the element, only one requires definition and the other may be derived by reflection. It is necessary that the subelements or zones be assigned unique identification names. See Figure 8, Reflection of Subelement and Fixed zones.

If two elements which relate through reflection (with possible translation and rotation) contain subelements and/or fixed zones which also relate by reflection between the two elements, as illustrated in the second examples under Reflection of Subelements and Fixed Zones in Figure 8, only the subelements and/or fixed zones on the source element require definition.

The data for a subelement or a fixed zone may not be translated within an element, but may be translated with a translation of the element.

There are no provisions in the methodology to apply symmetry techniques to a local zone having a symmetrical shape. The zone shape must be defined explicitly in its entirety. Also, the methodology does not allow for a local zone shape to be derived from the reflection of another local zone shape. A defined local zone shape may, however, be translated or applied to any other point on the surface of the system, provided the radius of curvature at the point is suitable and valid reference axes can be defined.

Chained data transfers are not permitted. That is, only one level of source data is permitted for a given surface. A specified source element cannot also be derived from another element. This rule applies to elements, subelements, and zones. For example, a translation followed by a reflection, illustrated in Figure 9a, is not allowed since the source element of E3 is E2 which is not the ultimate defining source. Elements E2 and E3 can both be derived from E1 which is the defining source, as shown in Figure 9b.

It is permissible to translate or reflect a symmetrical element, as illustrated in Figure 10a; however, the transfer of symmetrically placed subelements or zones on the source element cannot be fully transferred with the transferred element. A solution, shown in Figure 10b, is to explicitly redefine the

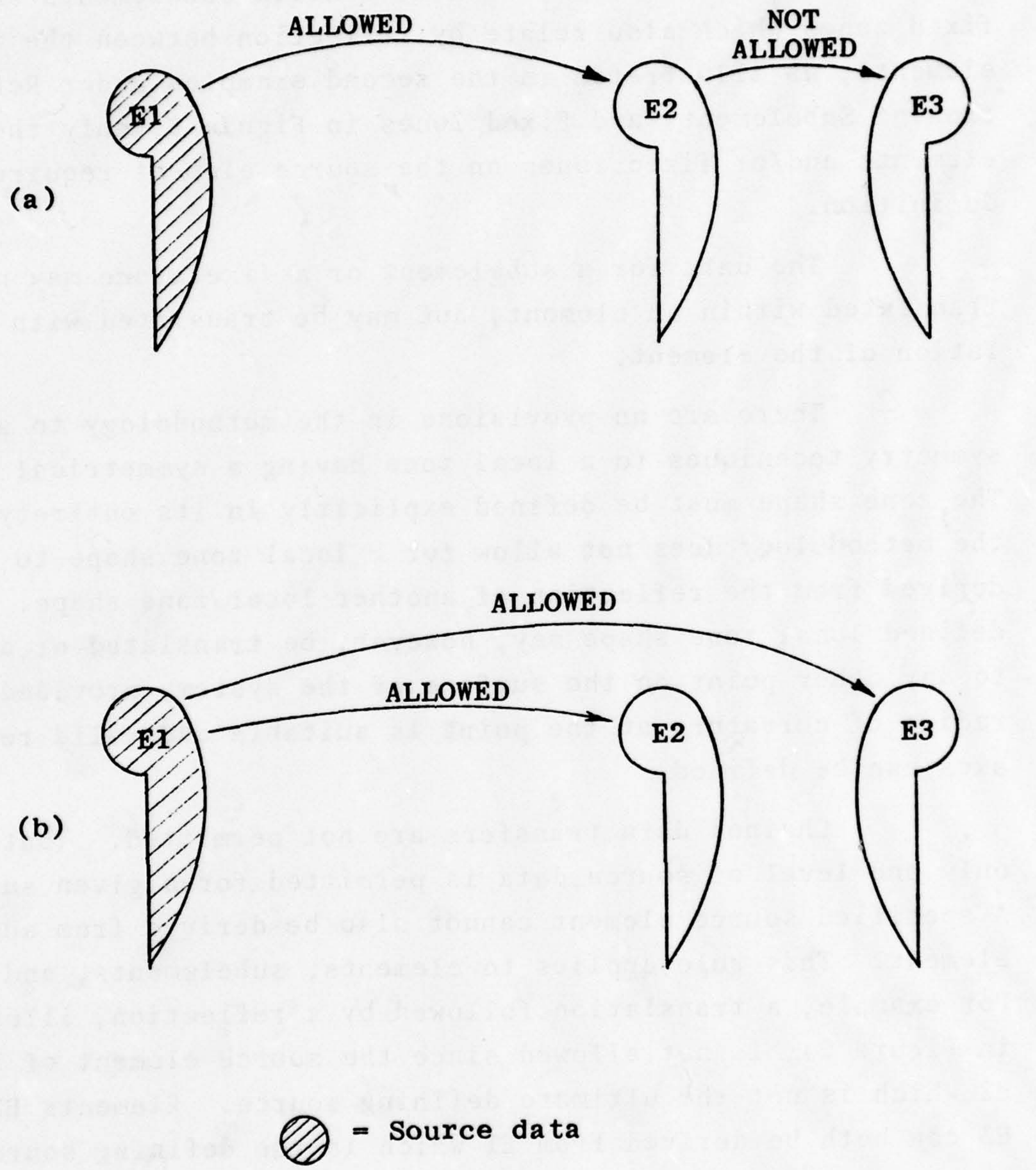
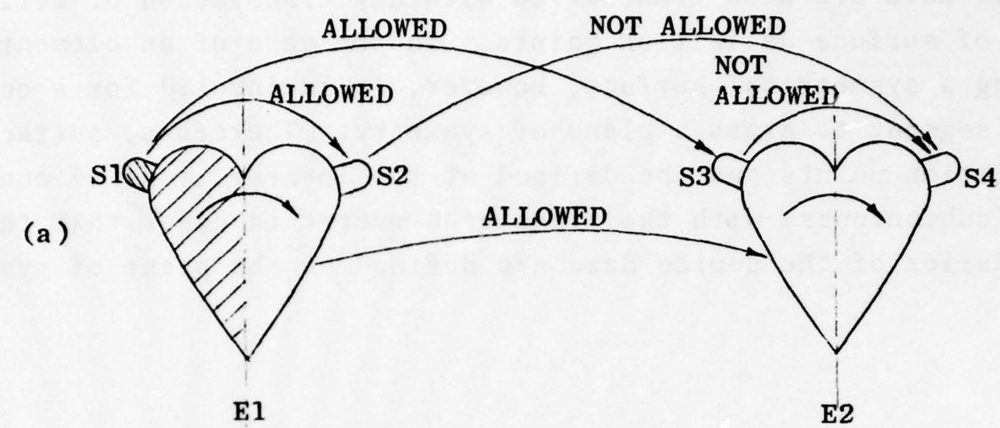


Figure 9. Example of chained data transfers.



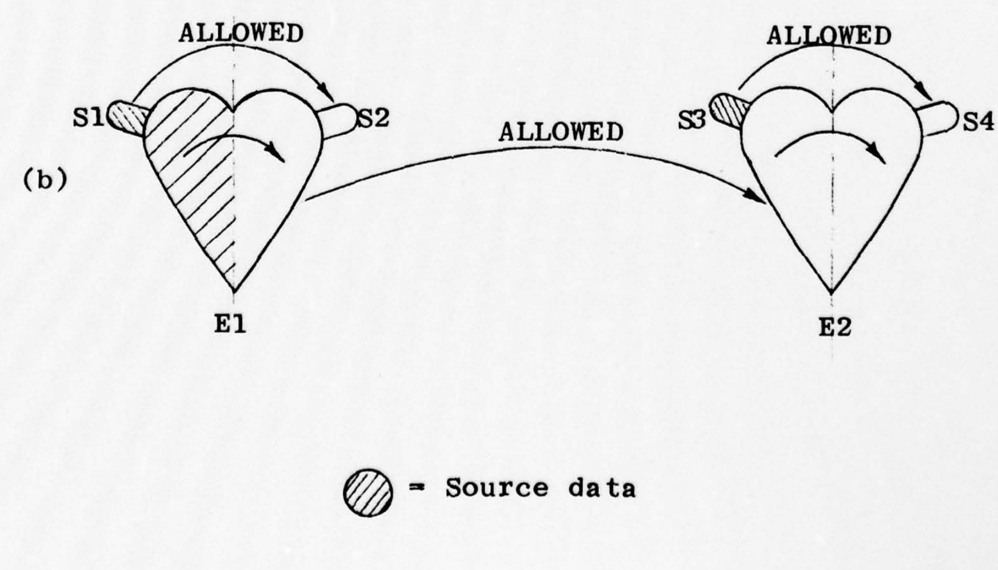


Figure 10. Example of a transfer of a symmetrical element with symmetrically-placed subelements.

subelement on the transferred element and reflect this subelement source to the other side. Both elements must be declared symmetrical.

It is assumed that all connectivities specified in the source data are also transferred with any translation or reflection of surface definition points. In the case of an element having a symmetrical surface, however, it is invalid for a connecting segment to cross a plane of symmetry. Therefore, surface definition points must be defined at the intersections of contours (and subcontours) with the plane of symmetry in order that the boundaries of the source data are defined on the plane of symmetry.

8.0 SUBSCHEMA FOR SURFACE GEOMETRY

All surface geometry definition data are intended to be stored in the IAP System Data File (SDF). Accordingly, a subschema for these data has been designed and is described in this section. The reader is assumed to have a thorough understanding of the System Data File (SDF).[1]

A diagram of the subschema is presented in Figure 11. The leading set GEOMELEMENT contains the data defining each element of the system. The elemental coordinate system (E.C.S.) is defined by 12 attributes. Under this set are four branches. The branch containing set SURFCONTOUR defines each element contour and stores the coordinates of every contour point. The subelement data are stored in the second branch. The third branch with set SURFSECTION defines the connectivities or segments between contours and subcontours and includes data specifying the intersections with other elements. Finally, all zone data for the element are stored in the fourth branch, SURFZONE.

An attribute list for the subschema, given in Appendix C, shows the attributes ordered under their respective sets. Following each attribute name is the field size (where C = alphanumeric character, R = real number, I = integer) and the definition. Additional descriptions of various attributes are provided in the Notes referred to in the attribute list. The subschema (Figure 11) and the attribute list are also presented in the report describing the system data file.[1]

Tables 1 and 2 provide a summary of the optional values permitted for some of the attributes of the surface geometry schema. In these tables, where an attribute is not applicable, a zero value is shown (without optional values); however, if all attributes in a set are non-applicable, dashes are entered to indicate that the set is empty.

[1] System Data File (SDF) for the Intrasystem Analysis Program (IAP), Vol. I - Description, Atlantic Research Corporation, RADC Contract F30602-77-C-0126, December 1979.

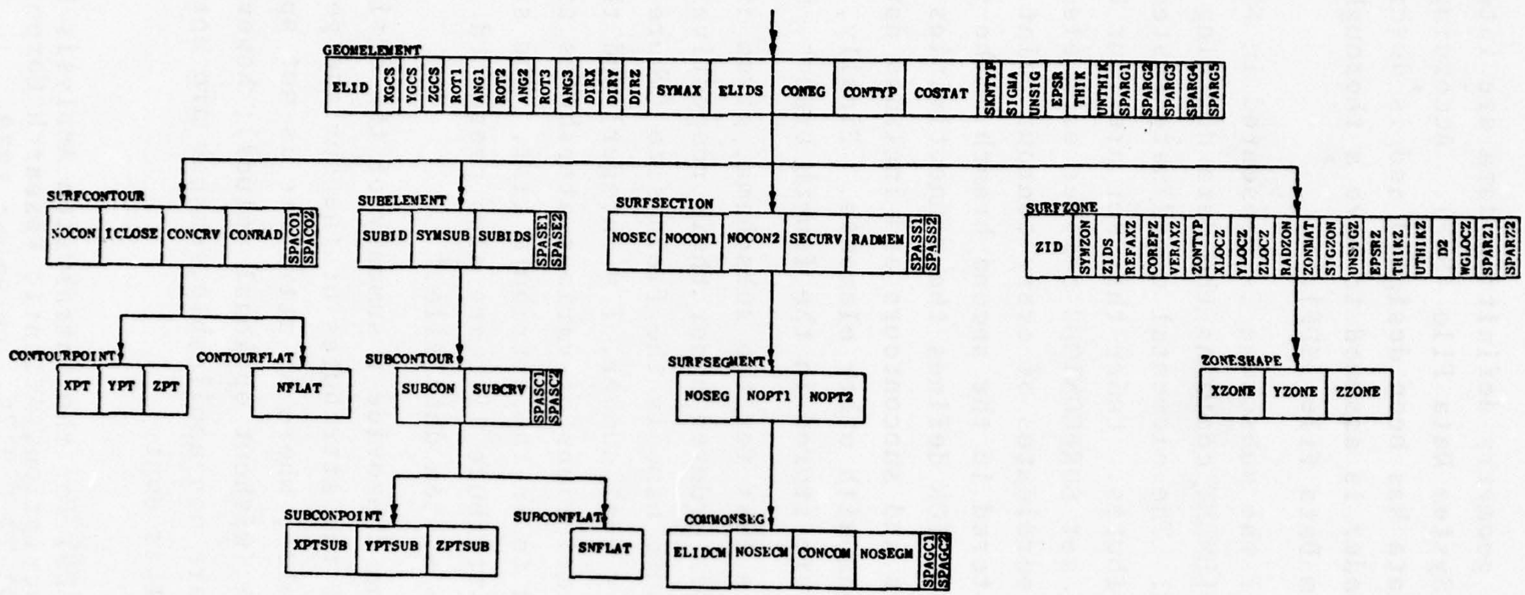


Figure 11. Subschema for Surface Geometry Data

TABLE 1. OPTIONS OF VALUES PERMITTED UNDER SET GEOMELEMENT FOR VARIOUS TYPES OF GEOMETRIC SURFACE DEFINITION.

		TYPE 1 General point definition using parallel plane contours.	TYPE 2 Circular contours in parallel planes.	TYPE 3 Plane-faced surfaces.	TYPE 4 Frame structure.	TYPE 5 Sphere / Hemisphere
GEOMELEMENT	ELID	$ELID_i$	$ELID_i$	$ELID_i$	$ELID_i$	$ELID_i$
	SYMAX	0,1,2,3	0,1,2,3	0,1,2,3	0,1,2,3	0
	ELIDS	0, $ELID_i$, $ELID_j$	0, $ELID_i$, $ELID_j$	0, $ELID_i$, $ELID_j$	0, $ELID_i$, $ELID_j$	0, $ELID_i$, $ELID_j$
	CONEG	0,1,2,3	0,1,2,3	0,1,2,3	0,1,2,3	0
	CONTYP	1	2	3	4	5
	COSTAT	1,2,3	1,2,3	0	0	0
SURFCONTOUR	NOCON	1,2,3,...,C_i,...	1,2,3,...,C_i,...	0	0	0
	ICLOSE	0,1	0	0	0	1 (Sphere) / 0 (Hemisphere)
	CONCRV	0,1,2	0	0	0	0 (Sphere) / ±1,±2,±3 (Hemisphere)
	CONRAD	0	RADIUS	0	0	RADIUS
CONTOURPOINT	XPT	x	x(CEN)	x	x	x(CEN)
	YPT	y } P_i	y(CEN)	y } P_i	y } P_i	y(CEN)
	ZPT	z	z(CEN)	z	z	z(CEN)
CONTOURFLAT	NFLAT	-, SG_i	-	-	-	-
SUBELEMENT	SUBID	$SUBID_i$	$SUBID_i$	$SUBID_i$	$SUBID_i$	$SUBID_i$
	SYMSUB	0,1	0,1	0,1	0,1	0,1
	SUBIDS	0, $SUBID_i$, $SUBID_j$	0, $SUBID_i$, $SUBID_j$	0, $SUBID_i$, $SUBID_j$	0, $SUBID_i$, $SUBID_j$	0, $SUBID_i$, $SUBID_j$
SUBCONTOUR	SUBCON	1,2,3,...,SC_i,...	1,2,3,...,SC_i,...	1,2,3,...,SC_i,...	1,2,3,...,SC_i,...	1,2,3,...,SC_i,...
	SUBCRV	0,1,2	0,1,2	0,1,2	0,1,2	0,1,2
SUBCONPOINT	XPTSUB	x	x	x	x	x
	YPTSUB	y } P_i	y } P_i	y } P_i	y } P_i	y } P_i
	ZPTSUB	z	z	z	z	z
SUBCONFLAT	SNFLAT	-, SG_i	-, SG_i	-, SG_i	-, SG_i	-, SG_i

TABLE 1. (CONTINUED)

		TYPE 1 General point definition using parallel plane contours.	TYPE 2 Circular contours in parallel planes.	TYPE 3 Plane-faced surfaces.	TYPE 4* Frame structure.	TYPE 5 Sphere / Hemisphere
SURFSECTION	NOSEC	$(\pm)1,2,3,\ldots,S_i,\ldots,0$	$(\pm)1,2,3,\ldots,S_i,\ldots$	$(\pm)1,2,3,\ldots,S_i,\ldots$	$(\pm)1,2,3,\ldots,S_i,\ldots$	$1,2,3,\ldots,S_i^*,\ldots,-$
	NOCON1	$(\pm)C_i,SC_i$	$(\pm)C_i,SC_i$	$(\pm)SUBID_i^*,0$	$(\pm)SUBID_i^*,0$	$SUBID_i^*.-$
	NOCON2	$(\pm)C_j,SC_j$	$(\pm)C_j,SC_j$	$(\pm)SUBID_j^*,0$	$(\pm)SUBID_j^*,0$	$SUBID_j^*.-$
	SECURV	0,1	0,1	0	0	0,-
	RADMEM	0	0	0	RADIUS	0,-
SURFSEGMENT	NOSEG	$(\pm)1,2,3,\ldots,SG_i,\ldots$	$(\pm)1,2,3,\ldots SG_i^*,\ldots,-$	$(\pm)1,2,3,\ldots,SG_i,\ldots$	$(\pm)1,2,3,\ldots,SG_i,\ldots$	$1,2,3,\ldots,SG_i^*,\ldots,-$
	NOPT1	$(\pm)P_i$	$(\pm)P_i^*,-$	$(\pm)P_i$	$(\pm)P_i$	$P_i^*,-$
	NOPT2	$(\pm)P_j$	$(\pm)P_j^*,-$	$(\pm)P_j$	$(\pm)P_j$	$P_j^*,-$
COMMONSEG	ELIDCM	$ELID_i,-$	$ELID_i,-$	$ELID_i,-$	$ELID_i,-$	$ELID_i,-$
	NOSECM	$0,(\pm)S_i,-$	$0,(\pm)S_i,-$	$0,(\pm)S_i,-$	$0,(\pm)S_i,-$	$0,(\pm)S_i.-$
	CONCOM	$(\pm)C_i,0,-$	$(\pm)C_i,0,-$	$(\pm)C_i,0,-$	$(\pm)C_i,0,-$	$(\pm)C_i,0,-$
	NOSEGM	$(\pm)SG_i,0,-$	$(\pm)SG_i,0,-$	$(\pm)SG_i,0,-$	$(\pm)SG_i,0,-$	$(\pm)SG_i,0,-$

*Applies to subelement only.

Table 2. Options of values permitted under SURFZONE for various types of zone definitions.

		TYPE 1 General point definition around boundary.		TYPE 2 Circular	TYPE 3 OR 4* Slit defined by points along centerline.	
SET	ATTRIB.	FIXED	LOCAL	FIXED	FIXED	LOCAL
SURFZONE	SYMZON	0,1	0	0,1	0,1	0
	REFAXZ	0	1,2	0	0	1,2
	COREFZ	0	1,2,3	0	0	1,2,3
	VERAXZ	0	1,2	0	0	1,2
	ZONTYP	1	1	2	3,4	3,4
	XLOCZ	0	X(CEN)	X(CEN)	0	X(CEN)
	YLOCZ	0	Y(CEN)	Y(CEN)	0	Y(CEN)
	ZLOCZ	0	Z(CEN)	Z(CEN)	0	Z(CEN)
	RADZON	0	0	RADIUS	WIDTH	WIDTH
ZONESHAPE	XZONE	X	X	--	X	X
	YZONE	Y	Y	--	Y	Y
	ZZONE	Z	0	--	Z	0

*Type 3 - closed contour, Type 4 - open contour.

APPENDIX A
SURFACE ACCURACY WITH POINT DEFINITION

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SURFACE ACCURACY WITH POINT DEFINITION

The major concern with point definition is the quantity of points required to define a large surface. The quantity is directly related to the accuracy with which the surface needs to be described between points. The given points are assumed to lie exactly on the surface and, thus, are "perfectly" accurate. The surface is not defined between the given definition points; consequently, any interpolation process will generally provide an estimate of the surface. It is important to know the accuracy or the tolerance limits of points calculated by interpolation.

Clearly, the higher the accuracy requirements the closer the defining points must lie in both dimensions on the surface. As an example, the total surface area of a Boeing 747 aircraft is approximately 28,000 square feet. Since the craft is symmetrical, only 14,000 square feet requires definition. If the average spacing of the definition points is one per square foot, then 14,000 points are required. If the spacing is only 6 inches between points or one-fourth square foot per point, the total number of points is quadrupled to 56,000. The surface, however, does not require uniform definition. Typically, much of the large area sections of an aircraft are relatively smooth and capable of being represented by straight lines. Thus, a cylindrical type of sectioning can usually be applied to fuselages, and general conical sectioning can define wing shapes.[1] Fortunately, these sectioning methods require a minimal number points to define the largest areas of the craft.

Consider the significance of the accuracy resulting from straight-line interpolation between points. Figure A1 shows a straight-line drawn between two points on a circular arc of radius R. The arc length between the points is s, and the mid-point difference between the chord and the arc is d which represents the maximum error. We wish to determine the distance s between the points as a function of R and d.

1 Lidbro, N., "Modern Aircraft Geometry," Aircraft Engineering, Nov. 1956, pp. 388-394.

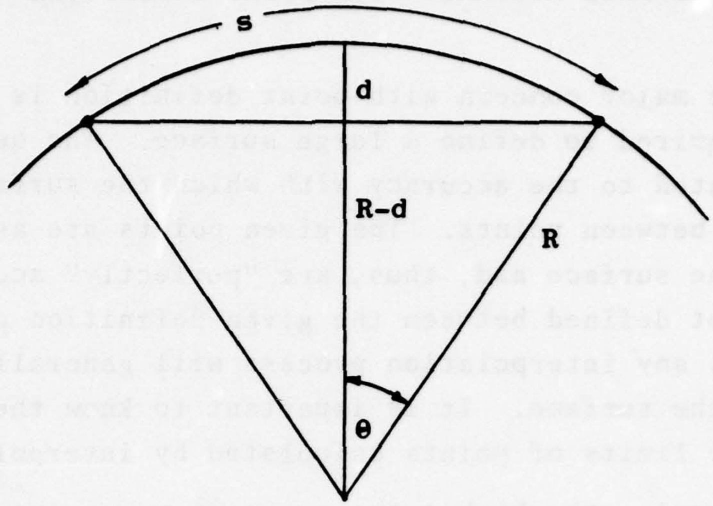


Figure A1. Geometry of error due to straight-line interpolation between two points on a circle.

From Figure A1 it is seen that

$$\cos\theta = \frac{R-d}{R} = 1 - \frac{d}{R}$$

$$\text{also,}\quad \theta = \frac{s}{2R} \text{ (radians)}$$

$$\text{Thus,}\quad \cos\left(\frac{s}{2R}\right) = 1 - \frac{d}{R}$$

$$\text{For } \theta \text{ small,}\quad \cos\theta \approx 1 - \frac{\theta^2}{2}.$$

$$\text{Then,}\quad 1 - \tfrac{1}{2}\left(\frac{s}{2R}\right)^2 \approx 1 - \frac{d}{R}$$

$$s \approx \sqrt{8dR}$$

$$\text{or}\quad s \approx R\sqrt{8\frac{d}{R}}$$

The first expression for s gives the maximum spacing between points on a surface of radius R which will result in a midpoint error not exceeding d (straight line interpolation assumed). The calculations for errors of 1/8", 1/4", 1/2", and 1" are shown by the solid lines in Figure A2.

The second expression for s is in a form convenient to express the error in terms of a fraction of the radius of curvature. The spacing for error ratios d/R of .01, .02, .05 and .10 are shown by the dashed lines in Figure A2.

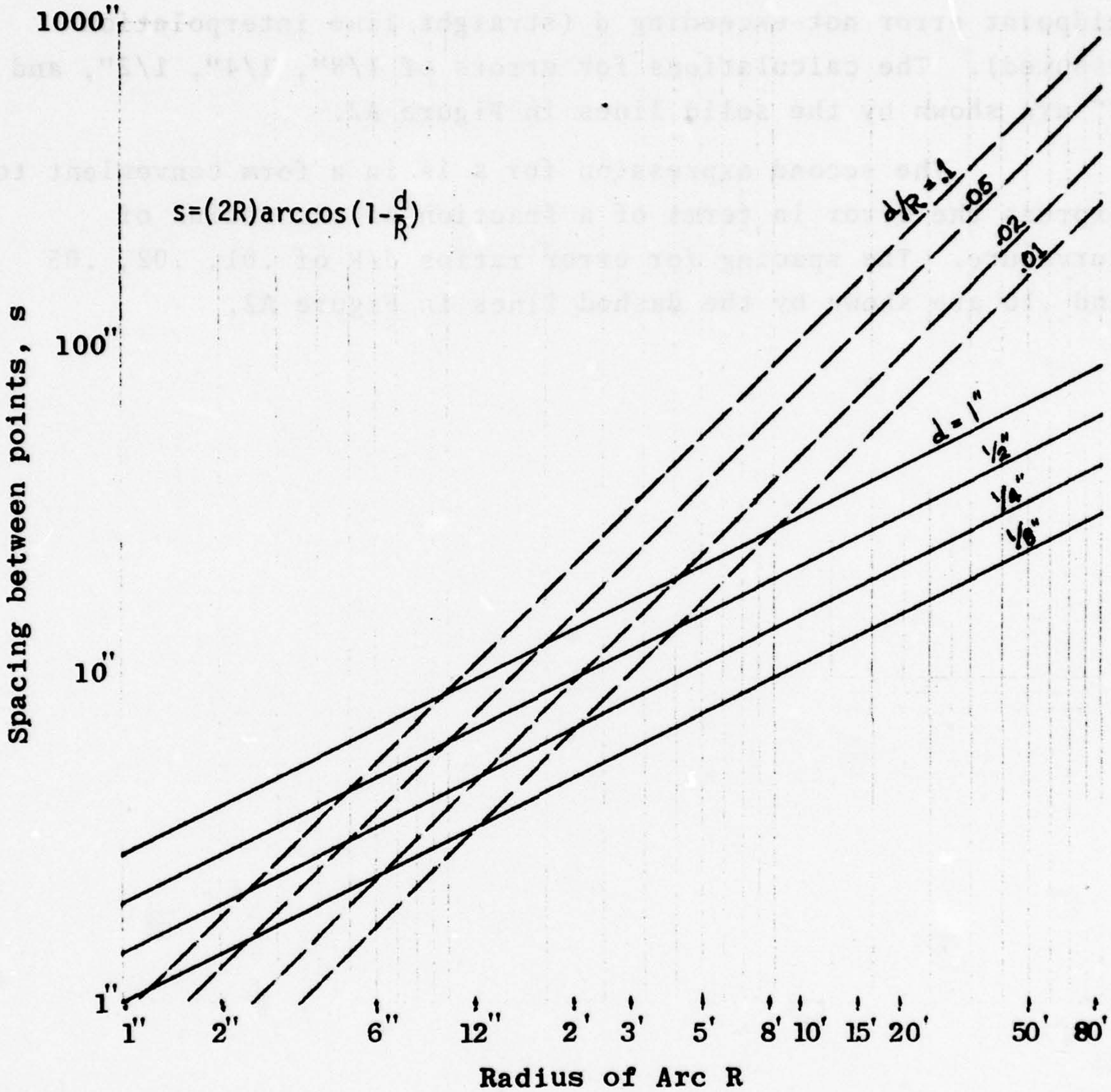


Figure A2. Accuracy of surface definition vs spacing between points.

APPENDIX B

LINEAR INTERPOLATION IN SURFACE PATCHES

AND

BOUNDS ON SURFACE ESTIMATION ERROR

APPENDIX B
LINEAR INTERPOLATION IN SURFACE PATCHES AND BOUNDS ON SURFACE ESTIMATION ERROR

The purpose of this Appendix is to provide user guidelines in the application of quadrilateral and triangular patches to represent curved surfaces. The vertices of a patch are points lying on the given surface, and the boundaries are straight line segments specified by connectivities between the points. Particular attention is given to quadrilateral patches, since they are generally nonplanar.

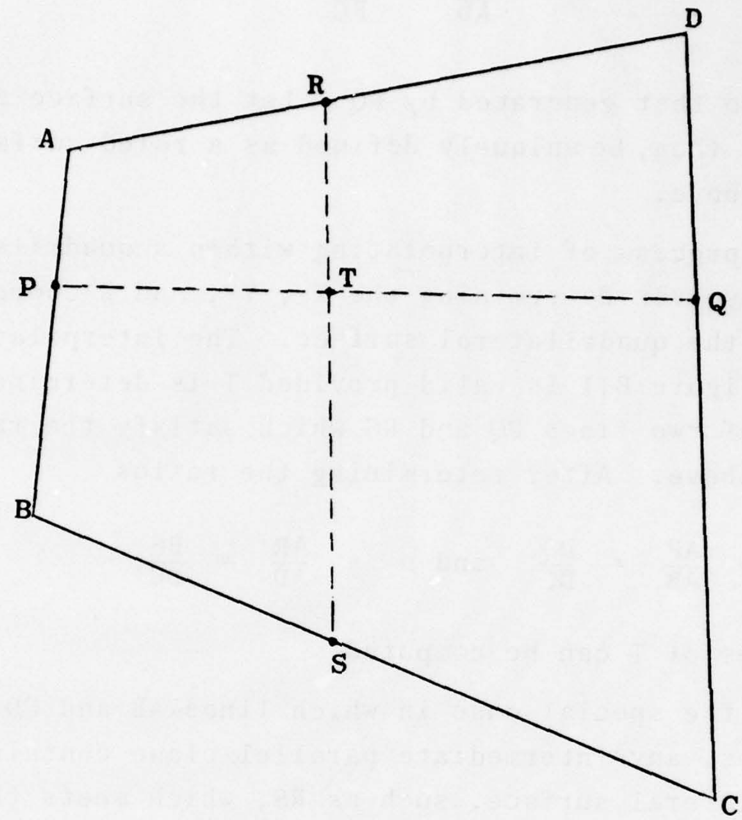
A practical and consistent method of interpolation to any interior point of a quadrilateral is needed in order that the person defining a given surface within specified limits of accuracy can provide proper spacing of the data points. Further, a user who is reconstructing the surface from the data file can then be assured that all points determined by interpolation will meet the specified accuracy requirements for estimating the true surface.

B1. Linear Interpolation in a Quadrilateral.

Let quadrilateral ABCD (see Figure B1) be defined by four straight-line segments connecting the given points in three-dimensional space. Let straight-line segment PQ intersect opposite sides of the quadrilateral such that the points of intersection have the same fractional distance along their respective sides. That is,

$$\frac{AP}{AB} = \frac{DQ}{DC}.$$

The surface generated by PQ sweeping from AD to BC while always maintaining the above ratio is a ruled surface. It is not difficult



$$\frac{AP}{AB} = \frac{DQ}{DC} \quad \text{and} \quad \frac{AR}{AD} = \frac{BS}{BC}$$

Figure B1. Linear interpolation in a quadrilateral.

to prove that the ruled surface similarly generated by sweeping RS from AB to DC such that

$$\frac{AR}{AD} = \frac{BS}{BC}$$

is identical to that generated by PQ. Let the surface of the quadrilateral, then, be uniquely defined as a ruled surface generated as described above.

The process of interpolating within a quadrilateral essentially involves determining the X-, Y-, and Z-coordinates of a point on the quadrilateral surface. The interpolation of a point T (see Figure B1) is valid provided T is determined as the intersection of two lines PQ and RS which satisfy the ratio requirements stated above. After determining the ratios

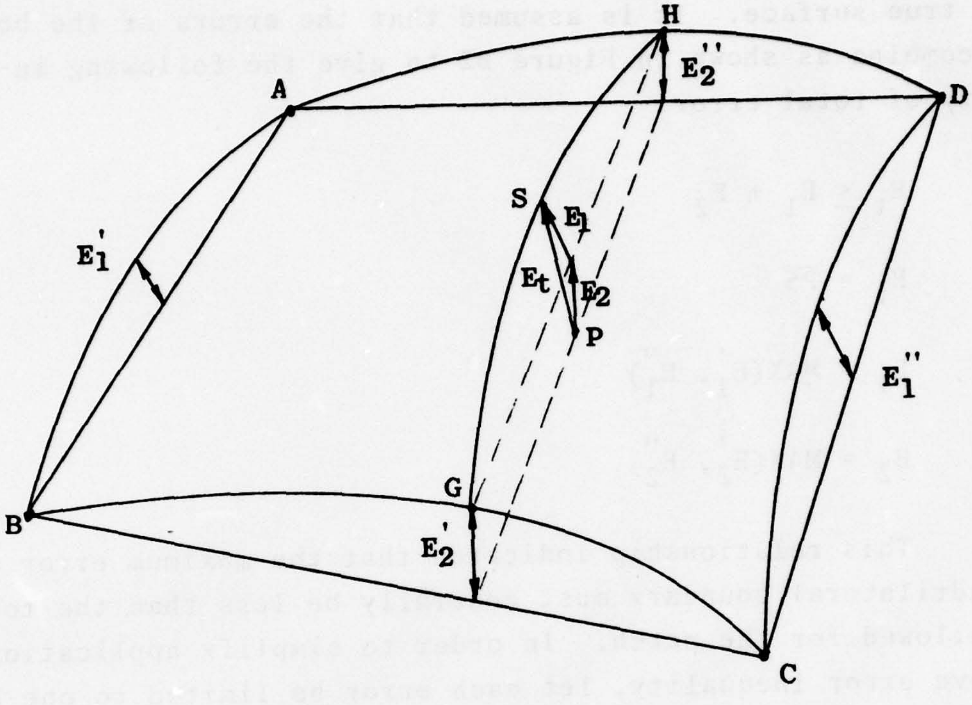
$$m = \frac{AP}{AB} = \frac{DQ}{DC} \quad \text{and} \quad n = \frac{AR}{AD} = \frac{BS}{BC},$$

the coordinates of T can be computed.

For the special case in which lines AB and CD lie in parallel planes, any intermediate parallel plane contains a line on the quadrilateral surface, such as RS, which meets the equal-ratio criterion. The value of the ratio equals the corresponding ratio of plane spacings.

B2. Bounds of Surface Error for Quadrilateral Estimation

Let a small region of a doubly-curved surface be defined by surface points ABCD (see Figure B2). Let E_1' represent the maximum error between any point on line AB and the nearest point on the true surface. Similarly, E_1'' represents the maximum error on segment CD, E_2' the maximum error on BC, and E_2'' the maximum error on AD. With these maximum errors known along the boundaries of a quadrilateral patch, it is necessary to determine a bound on the maximum error for the interior of the patch.



$$E_1 = MAX(E_1^{'} , E_1^{''})$$

$$E_2 = MAX(E_2^{'} , E_2^{''})$$

$$E_t \leqq E_1 + E_2$$

Figure B2. Total surface error of a quadrilateral patch.

Let PS represent the maximum error of the patch, where P is a point lying on the quadrilateral surface, and S is a point on the true surface. It is assumed that the errors of the boundaries combine as shown in Figure B2 to give the following inequality of total error:

$$E_t \leq E_1 + E_2$$

where $E_t = \overline{PS}$

$$E_1 = \mathrm{MAX}(E_1', E_1'')$$

$$E_2 = \mathrm{MAX}(E_2', E_2'').$$

This relationship indicates that the maximum error along any quadrilateral boundary must generally be less than the total error allowed for the patch. In order to simplify application of the above error inequality, let each error be limited to one-half the maximum allowable error. Thus, if E = maximum allowable error specified for the system then,

$$E_1 \leq \frac{E}{2} \text{ and } E_2 \leq \frac{E}{2}.$$

in this way we have,

$$E_1 = \mathrm{MAX}(E_1', E_1'') \leq \frac{E}{2}$$

$$E_2 = \mathrm{MAX}(E_2', E_2'') \leq \frac{E}{2}$$

then

$$E_t \leq E_1 + E_2$$

$$\leq \frac{E}{2} + \frac{E}{2}$$

$$\leq E.$$

Thus, the point spacing must provide at least twice the specified system accuracy between the defined points in order to ensure system accuracy at all interpolated points.

Consequently for a doubly-curved surface, the maximum interpoint distance (MIPD) needed during development of surface definition, and given by the curves in Appendix A, is to be based upon one-half the specified surface accuracy required for the system.

For a singly-curved surface defined by a quadrilateral patch, e.g., a cylinder, airplane wing, there is no curvature in one direction. In this case,

$$E_1' = E_1'' = E_1 = 0$$

and the total error is given by

$$E_2 = MAX(E_2', E_2'').$$

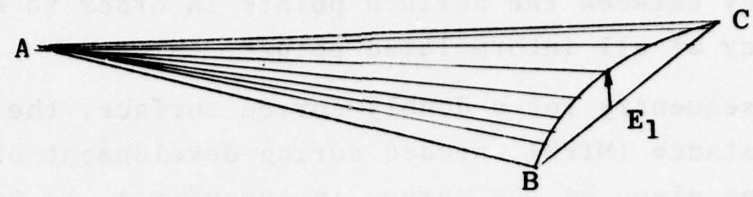
Thus, $E_2 \leq E$

will result in meeting the accuracy requirements.

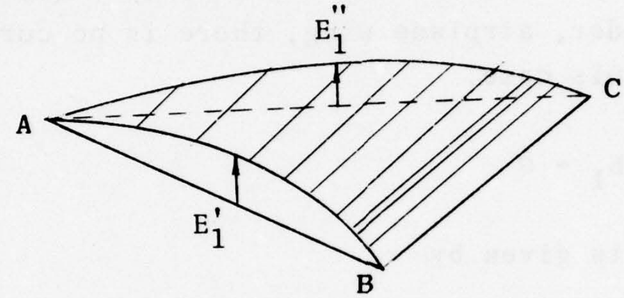
B3. Discussion of Triangular Surface Patches

A triangular patch formed by three straight-line segments defines a plane surface. Consequently, interpolation within a triangular patch involves determining the coordinates of a point lying in the plane of the triangle.

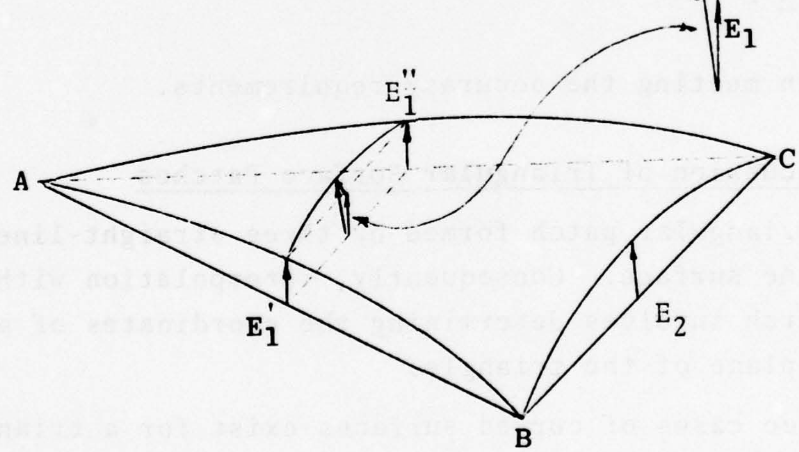
Three cases of curved surfaces exist for a triangular patch, as illustrated in Figure B3. For single boundary curvature (Figure B3a) the maximum error between the plane and the true surface is assumed to be E_1. For double boundary curvature (Figure B3b) the maximum error for the patch is considered to be the maximum of E_1' and E_1'' measured at the boundaries. Finally, the maximum error E_t of triple boundary curvature may be expressed by



(a) Single boundary curvature.



(b) Double boundary curvature.



(c) Triple boundary curvature.

Figure B3. Examples of a curved surface defined by a triangular patch.

$$E_t \leq E_1 + E_2$$

where $E_1 = MAX(E_1', E_1'')$.

This relationship is illustrated in Figure B3c, where the boundary errors E_1' and E_1'' are shown with segments AB and AC, respectively. The selection of the two boundary errors to maximize in the above equation for a given triangle is somewhat arbitrary and does, in general, affect the estimate of total error. As a practical criterion, let E_1' and E_1'' be the two boundary errors which are most nearly similar for the triangle.

For a maximum allowable error E specified for a system, the limit criteria for boundary errors of a triangular patch may be summarized for the three cases as follows (See Figure B3):

1. Single boundary curvature.

$$E_1 \leq E$$

2. Double boundary curvature.

$$MAX(E_1', E_1'') \leq E$$

e. Triple boundary curvature.

$$MAX(E_1', E_1'') \leq \frac{E}{2}, \text{ where } E_1' \simeq E_1''$$
$$E_2 \leq \frac{E}{2}.$$

APPENDIX C

ATTRIBUTE LIST FOR SURFACE GEOMETRY DATA

GEOMELEMENT (SEE NOTE 1)

1.	ELID	C5	ELEMENT ID.
2.	XGCS	R15	GLOBAL X-COORDINATE OF ELEMENTAL ORIGIN.
3.	YGCS	R15	GLOBAL Y-COORDINATE OF ELEMENTAL ORIGIN.
4.	ZGCS	R15	GLOBAL Z-COORDINATE OF ELEMENTAL ORIGIN.
5.	ROT1	I1	FIRST AXIS OF ROTATION FOR ELEMENT C.S. IN DEGREES (0=NO ROTATION, 1=X-AXIS, 2=Y-AXIS, 3=Z-AXIS)
6.	ANG1	R8	FIRST ROTATION ANGLE FOR ELEMENT C.S.
7.	ROT2	I1	SECOND AXIS OF ROTATION FOR ELEMENT C.S. IN DEGREES (0=NO ROTATION, 1=X-AXIS, 2=Y-AXIS, 3=Z-AXIS)
8.	ANG2	R8	SECOND ROTATION ANGLE FOR ELEMENT C.S.
9.	ROT3	I1	THIRD AXIS OF ROTATION FOR ELEMENT C.S. IN DEGREES (0=NO ROTATION, 1=X-AXIS, 2=Y-AXIS, 3=Z-AXIS)
10.	ANG3	R8	THIRD ROTATION ANGLE FOR ELEMENT C.S.
11.	DIRX	I2	X-AXIS REDIRECTION FOR ELEMENT C.S. (+ OR - 1,2,3=NEW X,Y OR Z DIRECTION)
12.	DIRY	I2	Y-AXIS REDIRECTION FOR ELEMENT C.S. (+ OR - 1,2,3=NEW X,Y OR Z DIRECTION)
13.	DIRZ	I2	Z-AXIS REDIRECTION FOR ELEMENT C.S. (+ OR - 1,2,3=NEW X,Y OR Z DIRECTION)
14.	SYMAX	I1	ELEMENTAL AXIS PERPENDICULAR TO PLANE OF SYMMETRY OF ELEMENT. (0=NO SYMMETRY OR TYPE 5, 1=X-AXIS, 2=Y-AXIS, 3=Z-AXIS)
15.	ELIDS	C5	ELEMENT ID OF ELEMENT PROVIDING SOURCE DATA. (=0 or ELID IF DATA NOT DERIVED FROM ANOTHER ELEMENT)
16.	CONEG	I1	COORDINATE AXIS OF SOURCE DATA TO BE NEGATED IF REFLECTED. (0=NO REFLECTION OR TYPE 5, 1=X-AXIS, 2=Y-AXIS, 3=Z-AXIS) APPLIES ONLY IF REFLECTION FROM ANOTHER ELEMENT.
17.	CONTYP	I1	TYPE OF CONTOUR SURFACE DEFINITION (=1,2,3,4,5)
18.	COSTAT	I1	ELEMENTAL AXIS PERPENDICULAR TO CONTOUR AND/OR SUBCONTOUR PLANES, (=1, 2, 3). APPLIES TO ELEMENT TYPES 1,2 ONLY. (=0 OTHERWISE).
19.	SKNTYP	C5	TYPE OF SKIN MATERIAL.

AL	ALUMINUM	BE8	BORON-EPOXY, 8-PLY
ST	STEEL	KEV	KEVLAR
CU	COPPER	GL	GLASS
GE	GRAPHITE-EPOXY	PLX	PLEXIGLASS
BE2	BORON-EPOXY, 2-PLY	NO	NO MATERIAL

20.	SIGMA	R12	SURFACE CONDUCTIVITY IN UNITS OF UNSIG.
21.	UNSIG	C5	UNIT OF CONDUCTIVITY. (=RELCU, MHOPM, MHOPC)
22.	EPSR	R9	RELATIVE DIELECTRIC CONSTANT OF SURFACE. (RELATIVE TO FREE SPACE)
23.	THIK	R15	AVERAGE THICKNESS OF SURFACE SKIN IN UNITS OF UNTHIK.
24.	UNTHIK	C2	UNIT OF SKIN THICKNESS. (=FT, IN, ME, CM, MM, ML(MILS))
25.	SPARG1	R15	SPARE.
26.	SPARG2	R15	SPARE.
27.	SPARG3	R15	SPARE.
28.	SPARG4	I5	SPARE.
29.	SPARG5	C6	SPARE.

SURFCONTOUR

1. NOCON I3 CONTOUR NUMBER. APPLIES TO ELEMENT TYPES 1,2 ONLY (=0 OTHERWISE).
2. ICLOSE I1 CONTOUR CLOSURE INDICATOR. (FOR ELEMENT TYPE 1: 0=NO CLOSURE, 1=CLOSURE. FOR ELEMENT TYPE 5: 0=HEMISPHERE, 1=SPHERE, =0 OTHERWISE).
3. CONCRV I2 INDICATOR FOR CURVATURE BETWEEN POINTS ON A CONTOUR. (FOR ELEMENT TYPE 1: 0=CURVATURE, 1=STRAIGHT LINE FOR SEGMENTS SPECIFIED IN SET CONTOURFLAT, 2=STRAIGHT LINE FOR ALL SEGMENTS) (FOR ELEMENT TYPE 5: AXIS THROUGH HEMISPHERE ZENITH= +OR- 1,2,3, =0 OTHERWISE)
4. CONRAD R15 RADIUS OF CIRCULAR CONTOUR (ELEMENT TYPE 2) OR SPHERE/HEMISPHERE (ELEMENT TYPE 5). (=0 OTHERWISE)
5. SPAC01 R15 SPARE.
6. SPAC02 I3 SPARE.

CONTOURPOINT

1. XPT R15 X-COORDINATE OF SURFACE POINT IN ELEMENTAL C.S. FOR ELEMENT TYPES 1,3,4. (=CENTER COORDINATE FOR ELEMENT TYPES 2,5)
2. YPT R15 Y-COORDINATE OF SURFACE POINT IN ELEMENTAL C.S. FOR ELEMENT TYPES 1,3,4. (=CENTER COORDINATE FOR ELEMENT TYPES 2,5)
3. ZPT R15 Z=COORDINATE OF SURFACE POINT IN ELEMENTAL C.S. FOR ELEMENT TYPES 1,3,4. (=CENTER COORDINATE FOR ELEMENT TYPES 2,5)

CONTOURFLAT

1. NFLAT I3 NUMBER OF SEGMENT ON A CONTOUR HAVING ACTUAL STRAIGHT LINE SHAPE. APPLIED TO ELEMENT TYPE 1 ONLY.

SUBELEMENT (SEE NOTE 2)

1. SUBID C5 SUBELEMENT ID.
2. SYMSUB I1 FLAG TO INDICATE SYMMETRY OF SUBELEMENT ON A SYMMETRICAL ELEMENT WITH COINCIDENT PLANES OF SYMMETRY. (0=NO SYMMETRY, 1=SYMMETRY)
3. SUBIDS C5 SUBELEMENT ID OF SUBELEMENT PROVIDING SOURCE DATA. (=0 OR SUBID IF DATA NOT DERIVED FROM ANOTHER SUBELEMENT.
4. SPASE1 R15 SPARE.
5. SPASE2 I3 SPARE.

SUBCONTOUR

1. SUBCON I3 SUBCONTOUR NUMBER, UNIQUE WITH CONTOUR NUMBERS FOR SYSTEM.
2. SUBCRV I2 INDICATOR FOR CURVATURE BETWEEN POINTS ON A SUBCONTOUR. (0=CURVATURE, 1=STRAIGHT LINE FOR SEGMENTS SPECIFIED IN SET SUBCONFLAT, 2=STRAIGHT LINE FOR ALL SEGMENTS)
3. SPASC1 R15 SPARE.
4. SPASC2 I3 SPARE.

SUBCONPOINT

1. XPTSUB R15 X-COORDINATE OF SUBELEMENT SURFACE POINT IN E.C.S.
2. YPTSUB R15 Y-COORDINATE OF SUBELEMENT SURFACE POINT IN E.C.S.
3. ZPTSUB R15 Z-COORDINATE OF SUBELEMENT SURFACE POINT IN E.C.S.

SUBCONFLAT

1. SNFLAT I3 NUMBER OF SUBCONTOUR SEGMENT HAVING ACTUAL STRAIGHT LINE SHAPE.

SURFSECTION (SEE NOTE 3)

1. NOSEC	I4	SECTION OR SUBSECTION NUMBER. APPLIES TO A SECTION OF ELEMENT TYPES 1,2,3,4 ONLY OR TO A SUBSECTION ON ANY TYPE OF ELEMENT. ENTER NEGATIVE VALUE IF ENTIRE SECTION OR SUBSECTION IS DERIVED BY REFLECTION OF SYMMETRICAL ELEMENT OR SUBELEMENT (=0 INTRACONTOUR SEGMENT FOR TYPE 1).
2. NOCON1	I4	NUMBER OF CONTOUR (ELEMENT TYPES 1,2 ONLY) OR SUBCONTOUR (ANY ELEMENT TYPE) AT FORWARD OR FIRST END OF SECTION OR SUBSECTION. ENTER NEGATIVE VALUE IF ENTIRE CONTOUR (OR SUBCONTOUR) IS DERIVED FROM REFLECTED CONTOUR (OR SUBCONTOUR) OF SYMMETRICAL ELEMENT (OR SUBELEMENT).
3. NOCON2	I4	NUMBER OF CONTOUR (ELEMENT TYPES 1,2 ONLY) OR SUBCONTOUR (ANY ELEMENT TYPE) AT AFT OR SECOND END OF SECTION OR SUBSECTION. ENTER NEGATIVE VALUE AS WITH NOCON1.
4. SECURV	I1	INDICATOR FOR CURVATURE BETWEEN CONTOURS. (0=CURVATURE, 1=STRAIGHT LINE FOR ALL SEGMENTS) APPLIES TO ELEMENT TYPES 1,2 ONLY.
5. RADMEM	R15	AVERAGE OR EFFECTIVE RADIUS OF SEGMENT. APPLIES TO ELEMENT TYPE 4 ONLY.
6. SPASS1	R15	SPARE.
7. SPASS2	I3	SPARE.

SURFSEGMENT

1. NOSEG	I4	SEGMENT NUMBER.
2. NOPT1	I4	POINT NUMBER ON CONTOUR (ELEMENT TYPES 1,3,4 ONLY) OR SUBCONTOUR (ANY ELEMENT TYPE) NOCON1 WHICH DEFINES ONE END OF SEGMENT. ENTER NEGATIVE NUMBER IF POINT IS DERIVED FROM REFLECTION OF SYMMETRICAL ELEMENT (OR SUBELEMENT).
3. NOPT2	I4	POINT NUMBER ON CONTOUR (ELEMENT TYPES 1,3,4 ONLY) OR SUBCONTOUR (ANY ELEMENT TYPE) NOCON2 WHICH DEFINES SECOND END OF SEGMENT. ENTER NEGATIVE NUMBER AS WITH NOPT1.

COMMONSEG

1. ELIDCM	C5	ELEMENT ID OF INTERSECTING ELEMENT.
2. NOSECM	I4	NUMBER OF SECTION OR SUBSECTION OF INTERSECTING ELEMENT CONTAINING SEGMENT. (=0 FOR INTRACONTOUR SEGMENT, THEN CONCOM APPLIES)
3. CONCOM	I4	NUMBER OF CONTOUR (ELEMENT TYPE 1) OR SUBCONTOUR (ANY ELEMENT TYPE) OF INTERSECTING ELEMENT CONTAINING COMMON SEGMENT. (=0 IF NOSECM APPLIES)
4. NOSEGM	I4	SEGMENT NUMBER OF SECTION, SUBSECTION, CONTOUR OR SUBCONTOUR OF INTERSECTING ELEMENT.
5. SPAGC1	R15	SPARE.
6. SPAGC2	I3	SPARE.

SURFZONE (SEE NOTE 4)

```
 1. ZID     C5     ZONE ID.
 2. SYMZON  I1     FLAG TO INDICATE SYMMETRICAL ZONE ON SYMMETRICAL
                   ELEMENT WITH COINCIDENT PLANES OF SYMMETRY.
                   APPLICABLE TO FIXED ZONES ONLY. (0=NO SYMMETRY OR
                   LOCAL ZONE, 1=SYMMETRY)
 3. ZIDS    C5     ZONE ID OF ZONE PROVIDING SOURCE DATA.
                   (IF NO SOURCE ZIDS=0 OR =ZID)
 4. REFAXZ  I1     REFERENCE AXIS OF LOCAL C.S. FOR LOCAL ZONE
                   DEFINITION. (0=FIXED ZONE,1=X-AXIS, 2=Y-AXIS)
 5. COREFZ  I1     AXIS OF ELEMENTAL C.S. PERPENDICULAR TO REFAXZ.
                   FOR LOCAL ZONE DEFINITION ONLY.
                   (0=FIXED ZONE, 1=X-AXIS, 2=Y-AXIS, 3=Z-AXIS)
 6. VERAXZ  I1     AXIS OF LOCAL C.S. HAVING UPWARD COMPONENT.
                   (0=FIXED ZONE, 1=X-AXIS, 2=Y-AXIS)
 7. ZONTYP  I1     TYPE OF ZONE DEFINITION. (=1,2(FIXED ONLY),3,4)
 8. XLOCZ   R15    X-COORDINATE OF ZONE LOCATION IN ELEMENTAL C.S.
                   (=COORDINATE OF CENTER FOR LOCAL ZONE AND TYPE 2
                   FIXED ZONE. =0 FOR FIXED ZONE TYPES 1,3,4.)
 9. YLOCZ   R15    Y-COORDINATE OF ZONE LOCATION IN ELEMENTAL C.S.
                   (=COORDINATE OF CENTER FOR LOCAL ZONE AND TYPE 2
                   FIXED ZONE.  =0 FOR FIXED ZONE TYPES 1,3,4.)
10. ZLOCZ   R15    Z-COORDINATE OF ZONE LOCATION IN ELEMENTAL C.S.
                   (=COORDINATE OF CENTER FOR LOCAL ZONE AND TYPE 2
                   FIXED ZONE. =0 FOR FIXED ZONE TYPES 1,3,4.)
11. RADZON  R15    RADIUS OR WIDTH. (ZONE TYPE1=0, ZONE TYPE2=RADIUS,
                   ZONE TYPES 3,4=WIDTH)
12. ZONMAT  C5     MATERIAL CODE OF ZONE.
                   SEE EXAMPLES FOR ATTRIBUTE SKNTYP(GEOMELEMENT .19)
13. SIGZON  R12    CONDUCTIVITY OF ZONE MATERIAL IN UNITS OF UNSIGZ.
14. UNSIGZ  C5     UNIT OF CONDUCTIVITY.(=RELCU, MHOPM, MHOPC)
15. EPSRZ   R9     RELATIVE DIELECTRIC CONSTANT OF ZONE MATERIAL
                   (RELATIVE TO FREE SPACE).
16. THIKZ   R15    THICKNESS OF ZONE MATERIAL IN UNITS OF UTHIKZ.
17. UTHIKZ  C2     UNIT OF THICKNESS. (=FT, IN, ME, CM, MM, ML(MILS))
18. D2      R15    DISTANCE OF REFLECTING SURFACE FROM ZONE.
                   (PROGRAM APERTURE)
19. WGLOCZ  C6     WING LOCATION OF ZONE (IEMCAP).
                   (=NOW, BOT, TOP, FWDEDG, AFTEDG, TIP)
20. SPARZ1  R15    SPARE.
21. SPARZ2  R15    SPARE.
```

ZONESHAPE

```
 1. XZONE   R15    X-COORDINATE OF ZONE POINT IN E.C.S. FOR FIXED
                   ZONE, OR LOCAL C.S. FOR LOCAL ZONE.
                   APPLIES TO ZONE TYPES 1,3,4 ONLY.
 2. YZONE   R15    Y-COORDINATE OF ZONE POINT IN E.C.S. FOR FIXED
                   ZONE, OR LOCAL C.S. FOR LOCAL ZONE.
                   APPLIES TO ZONE TYPES 1,3,4 ONLY.
 3. ZZONE   R15    Z-COORDINATE OF ZONE POINT IN E.C.S. FOR FIXED
                   ZONE TYPES 1,3,4. (=0 FOR LOCAL ZONE)
```

Note 1. An elemental coordinate system may be defined at any location and orientation relative to a global rectangular coordinate system. A total of 12 parameters is required to define the elemental coordinate system and consists of 3 parameters for translation, 6 for rotations, and 3 for axis redirections.

A right-handed global coordinate system must be defined to serve as an absolute reference, directly or indirectly, for all geometric coordinates specified in the system. The global system must be a right-handed, orthogonal set of axes which may be arbitrarily positioned relative to the geometric system.

Associated with each element defined in the geometric system must be an elemental coordinate system to which all geometric coordinates specified for the element are directly referenced. Each elemental coordinate system must be an orthogonal set of axes which may be right- or left-handed and arbitrarily positioned at any location and orientation relative to its associated geometric element.

Each elemental coordinate system is defined with reference to the global coordinate system in accordance with the following steps. These steps must be followed in the order given.

Step 1. Specify the location of the origin of the elemental system in terms of x, y, z coordinates of the global system. This represents a translation of the global origin to the position of the elemental origin. (Parameters 1, 2, 3)

Step 2A. Specify one of the three axes of the translated global system to be the axis for the first rotation. The rotation angle is defined to be positive if the rotation is clockwise when viewed from a positive point on the rotation axis looking toward the origin. (Parameters 4, 5)

Step 2B. Specify one of the remaining two axes of the rotated coordinate system (after first rotation) to be the axis for the second rotation. The positive sense of rotation is as defined in Step 2A. (Parameters 6, 7)

Step 2C. Specify the remaining axis of the rotated coordinate system (after second rotation) to be the axis for the third rotation. The positive sense of rotation is as defined in Step 2A. (Parameters 8, 9)

Step 3. Where appropriate, specify the redirection of each axis parallel to the x-, y-, or z-axes. Six directions are available, and both right-hand and left-hand coordinate systems are permitted. (Parameters 10, 11, 12)

The direction of each axis is specified by the code:

1 = Directed to +X.
-1 = Directed to -X.
2 = Directed to +Y.
-2 = Directed to -Y.
3 = Directed to +Z.
-3 = Directed to -Z.

The reference coordinate directions are established by the right-hand set which was transformed from the global set to the present point of elemental origin, following Step 2C.

Note: The code numbers 1, 2, 3 specified for the directions of the x, y, z axes, respectively, signify no change or redirection of the axes.

Axis redirection is a technique which offers the user a convenient means of rearranging the x-, y-, and z-coordinates on a given set of three-dimensional axes. Although the redirection of a right-hand system to another right-hand system can be specified (in steps 2A, 2B and 2C) by rotation angles involving appropriate multiples of 90 degrees, it may be difficult to visualize a correct rotation sequence for some arrangements. Hence, axis redirection eliminates the risk of error for these cases. Also, axis redirection provides the means for specifying a left-handed coordinate system.

If the element is not symmetrical, SYMAX = 0. With a symmetrical element for which symmetry techniques are to be applied to the data, it is essential that the origin of the elemental coordinate system lie on the plane of symmetry and that one axis be perpendicular to the plane. In this case SYMAX = 1, 2 or 3 to indicate the perpendicular axis.

If the element is to be derived by translation or reflection from another element whose surface is explicitly defined, the ID name of the source element is entered for ELIDS. Otherwise, ELIDS = 0 or ELID.

If the element is to be derived by translation of a source element, CONEG = 0. If the element is to be derived by reflection of a source element, CONEG = 1, 2 or 3 to indicate the axis for which the source data coordinates require negating.

Note 2. Subelements may be defined with any type of element. A subelement surface must be defined using point definition as described for Type 1 (Section 5.3.3).

If the surface shape of a subelement is not symmetrical, or is symmetrical but does not lie on a symmetrical element, then SYMSUB = 0. However, if a subelement is symmetrical and lies on a symmetrical element, and both lie on a common plane of symmetry, the subelement may be declared symmetrical by setting SYMSUB = 1.

If the surface definition of a subelement is derived by translation or reflection from another subelement which is explicitly defined, the ID name for the source subelement is entered as SUBIDS. Otherwise, SUBIDS = 0 or SUBID.

A subelement may be derived from a source subelement only if the derived subelement lies on an element whose definition is derived from the element containing the source subelement. The type of data transfer (i.e., translation or reflection) between the subelements must be the same as that specified for the respective elements. The reflection of subelement data includes the case where both subelements lie on the same element, provided that the element is symmetrical with the plane of symmetry coincident with the plane of reflection for the two subselements.

Note 3. The SURFSECTION branch of the SDF schema is for data which define the connectivities between surface points and, also, define the common boundaries of intersecting elements.

The surface of an element is divided into sections and subsections. The primary purpose for applying the concept of surface sections is to facilitate the organization of connectivity data in the SDF. The definition of a section depends upon the type of surface representation. For Type 1 and Type 2 surfaces, a section is the surface between two adjacent contours. For a Type 3 surface, each plane face is a section. For a Type 4 surface or frame structure, a section consists of all connecting segments or frame members of the element having the same effective radius. The concept of a surface section does not apply to a Type 5 surface.

A subsection is the surface area between two adjacent subcontours on a subelement, which may exist on any type of surface representation.

Contours (or subcontours) which bound a section (or a subsection) are specified in attributes NOCON1 and NOCON2. In general, each segment belonging to a section or subsection is defined in the repeating set SURFSEGMENT. However, for a Type 1 surface (or a subelement) the segments along a contour (or subcontour) generally do not require definition, since the connectivity of adjacent contour points as listed under set SURFCONTOUR is implied. Only the intercontour segments of these surfaces require explicit definition by set SURFSEGMENT. Attributes NOPT1 and NOPT2 define the end points of a segment; it is this specification which explicitly defines connectivity between surface definition points.

If a segment is common with another element, the data identifying that segment relative to the surface definition of the intersecting element are defined in set COMMONSEG. Note that all intercontour segments in the source data must be specified in the file for purposes of defining connectivity, whether or not they are common with an intersecting element. Intracontour segments in the source data do not require explicit definition of connectivity unless they are common to an intersecting element.

If an intracontour segment (i.e., lying on a contour of a Type 1 surface) is also common with an intersecting element, it is necessary to define this segment in sets SURFSECTION and SURFSEGMENT in order that the intersection data may be entered in set COMMONSEG. Such a segment may be defined with the following special considerations. The section number NOSEC is specified as zero. Since the end points of the segment lie on the same contour, NOCON1 and NOCON2 are both specified with the same contour number. The segment number NOSEG is the count number of the segment along the contour as defined in branch SURFCONTOUR. For example, if the Nth (intracontour) segment of a contour connects the Nth and (N+1)th contour points, NOSEG = NOPT1, and NOPT2 = NOPT1 + 1.

Another situation which requires special consideration of data entry into the SDF involves specifying a common segment lying within the derived half of a symmetrical element. The segment is not defined within the source data of the file, but since the element is declared to be symmetrical (SYMAX ≠ 0), the segment is a reflected image of a source segment. All connectivities specified with the source data are transferred by reflection to the derived data. However, intersection data specified with the source data cannot be transferred by reflection within a symmetrical element, since the source and derived surfaces will generally intersect different elements. In fact, the derived surface may not intersect any element.

When it is necessary to specify a segment of the derived surface of a symmetrical element, negative values of the corresponding section or subsection number (NOSEC), contour or subcontour numbers (NOCON1, NOCON2), segment number (NOSEG) and point numbers (NOPT1, NOPT2) of the image data must be entered in the data file. The negative sign flags the data to indicate that they are surface components derived by reflection.

Consider, for example, that a system data file for an aircraft contains source data defining the right half of a symmetrical fuselage. The segments on the right side of the fuselage which are common with the right wing are defined under SURFSECTION using positive-valued numbers for NOSEC, NOCON1, NOCON2, NOSEG, NOPT1 and NOPT2. For the left side of the fuselage, since all surface definition is derived implicitly by reflection of the source data, no data entries under SURFSECTION are required, except for any segments common to intersecting elements. In this case, the segments which are common with the left wing are defined under SURFSECTION using negative-valued numbers NOSEC, NOCON1, NOCON2, NOSEG, NOPT1 and NOPT2. Note that the data entries for NOSECM, CONCOM and NOSEGM under set COMMONSEG must contain appropriate positive or negative numbers for the common segments as they are defined relative to the surface representation of the intersecting element.

Note 4. Every zone in a system must be assigned a unique ID name (ZID). The shape and location of each zone must be defined either by a fixed or local method of representation. The fixed method, which may be applied to any zone, requires that the zone boundary be defined directly in elemental coordinates. The local method must be applied only to zones that are flat or nearly flat, i.e., the maximum zone dimension is relatively small compared to the radius of curvature of the zone surface. Where there is multiplicity of one zone shape in a system, the use of the local representation, if applicable, simplifies the total representation by requiring the shape to be defined for only one of the zones, which serves as a source zone (ZIDS) for the remaining zones having the same shape. It is not required that a zone (ZID) and its source zone (ZIDS) lie on the same element.

If a fixed zone is not symmetrical, or is symmetrical but does not lie on a symmetrical element, then SYMZON = 0. However, if a fixed zone is symmetrical and lies on a symmetrical element, and both have a common plane of symmetry, the zone may be declared symmetrical by setting SYMZON = 1. Then only half of the zone needs to be described explicitly.

For any local zone definition, SYMZON = 0.

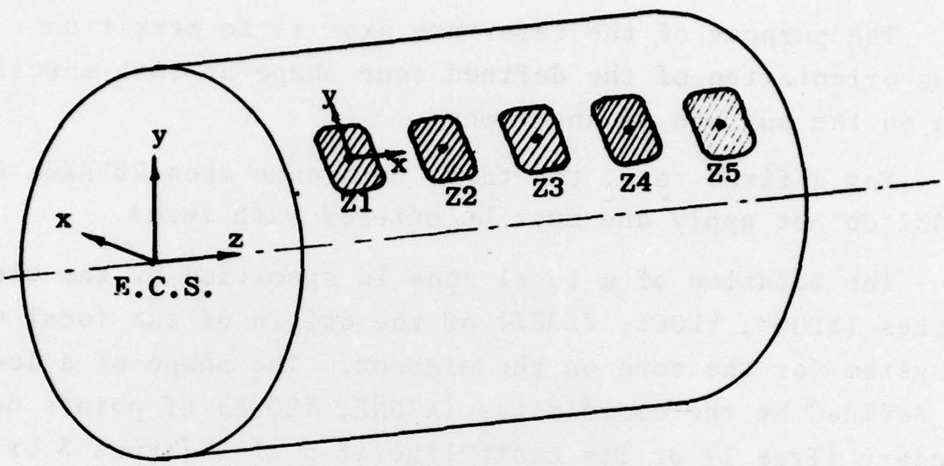
If a fixed zone is derived by translation or reflection from another fixed zone which is explicitly defined, the ID name of the source zone is entered as ZIDS. Otherwise, ZIDS = 0 or ZID.

The transfer of source fixed zone data is valid only if the derived zone lies on an element whose definition is derived (in whole or in part) from the element containing the source zone. The type of data transfer (i.e., translation or reflection) between the zones must be the same as that specified for the respective elements. The reflection of fixed zone data includes the case where both zones lie on the same element, provided that the element is symmetrical with the plane of symmetry coincident with the plane of reflection for the two zones.

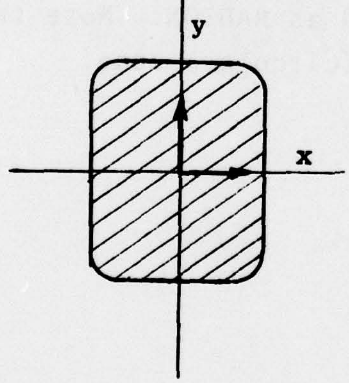
If a zone is defined by the local method, a two-dimensional (X-Y) rectangular coordinate system must be established to define the shape of the zone. The origin of the local coordinates should be established at the geometrical center of the zone shape. The coordinate system must be oriented so that one of the axes can serve as the local reference axis (REFAXZ) for each of the zones referencing the defined shape. With the local coordinate system applied to each zone in place on the surface of the element, the REFAXZ must, in every case, be perpendicular to one of the axes (COREFZ) of the elemental coordinate system.

To illustrate this, Figure C1a shows a section of a fuselage element containing five identical windows. The shape of each window is described by local coordinates as illustrated in Figure C1b. The origin of the local coordinates is defined at the center of each window. The local coordinates are shown applied to the first window. The plane of the local coordinate system is tangent to the element surface at the origin. Since the x-axis lies in a horizontal plane at every window location, this axis is designated as the local reference axis, and REFAXZ = 1. Paired with the REFAXZ is the COREFZ to which REFAXZ is perpendicular. In this example, the y-axis (vertical axis) of the elemental coordinate system is designated as COREFZ.

The required relationship between REFAXZ and COREFZ can, in general, be maintained at essentially all locations of a given (local) zone on an element, provided the zone is installed with one edge of the defined shape always to the top, as is normally the case for aircraft windows. Where the zone cannot meet the local reference conditions the zone must be defined by the fixed method.



a) Local coordinate system positioned on element surface.



For this example:

REFAXZ = 1

COREFZ = 2

VERAXZ = 2

b) Zone shape defined by local coordinates.

Figure C1. Example of local zone definition on an element.

While the REFAXZ/COREFZ reference axes ensure that the zone is applied horizontally, it is further necessary to specify a relative upward direction or top of the zone to ensure that the zone is not applied upside down. In the example of Figure C1, the y-axis of the local coordinates has an upward component, thus, VERAXZ = 2.

The purpose of the reference axes is to permit unambiguous orientation of the defined zone shape at each specified location on the surface of an element.

For a fixed zone, the three reference axes REFAXZ, COREFZ and VERAXZ do not apply and must be entered with zeros.

The location of a local zone is specified by the elemental coordinates (XLOCZ, YLOCZ, ZLOCZ) of the origin of the local coordinate system for the zone on the element. The shape of a local zone is defined by the coordinates (XZONE, YZONE) of points defining its boundary (Type 1) or its centerline if a slit (Types 3 or 4).

Multiple zones having a circular shape (Type 2) are most easily described with the fixed method with ZONTYP = 2. The center of each zone is defined by elemental coordinates (XLOCZ, YLOCZ, ZLOCZ), and the radius is specified as RADZON. Note that the local method does not apply to a Type 2 (circular) zone.