An Extended Vector Product Format Profile for Modeling and Simulation

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April 5, 1996

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The Vector Product Format (VPF) has been advancing, through prototype development, the Defense Mapping Agency's (DMA) transition from paper products to geographic information system environments. Indeed, that was VPF's main intent. Lately, however, the DMA has recognized that the VPF prototypes have not been meeting the requirements of a particular group, the Modelling and Simulation (M&S) community. Through support from the Terrain Modeling Project Office and the Defense Modeling and Simulation Office, the Digital Mapping, Charting, and Geodesy Analysis Program (DMAP) has been tasked to extend VPF to satisfy M&S Requirements. What follows is DMAP's initial profile of the Extended VPF and its first prototype. While by no means a completed standard, the EVPF profile is described by DMAP as a promising VPF alternative for the M&S community.
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An Extended Vector Product Format (EVPF) Profile
for Modeling and Simulation

1.0 Introduction

1.1 Products in the Vector Product Format (VPF), a georelational database format, have made great strides at effectively representing what was once a "paper only" environment. The Digital Nautical Chart (DNC), Vector Smart Map (VMap), and Tactical Terrain Data are but a few such databases currently under development which, when completed, should provide excellent digital substitutes for harbor, approach, coastal, and general charts, as well as various culture datasets. In fact, VPF's strength can be observed in its digital representation of charts. It allows the collapsing of a three-dimensional (3-D) environment into two-dimensional (2-D) thematic layers, under rigorous geometric and topological guidelines.

1.2 Unfortunately, for today's modeling and simulation (M&S) community, VPF's representation of an environment is deficient in several regards. The ability to represent culture, terrain, and models in three dimensions is an absolute necessity in most M&S scenarios. While VPF allows for storage of feature height information in various attributes, VPF and its application software VPFView are essentially two dimensional.

1.3 Rich attribution of features is also desirable to the M&S community to accurately portray models in 3-D. Extensive M&S requirements analyses [1,2] have proven VPF's inadequate attribution in most of its databases.

1.4 Finally, VPF's construction of logically separate thematic layers can pose problems, especially in the format's elimination of topology (connectivity) between coverages.

2.0 Spatial Dimensions

2.1 VPF's geometrical limits extend from zero-dimensional nodes to one-dimensional edges and two-dimensional faces. These are represented in VPF as primitive tables. To naturally extend VPF into three dimensions, an additional data structure has been proposed, the Triangulated Irregular Network (TIN).

2.2 Terrain has been shown to be effectively represented and utilized for analysis as a TIN, whereby terrain is represented as network of irregularly shaped triangles. A current literature search and discussions with M&S programs have shown that TINs have become a widely used structure and can be generated from elevation posts of regular spacing, e.g., Digital Terrain Elevation Data (DTED), a commonly used dataset in M&S.

2.3 The Digital Mapping, Charting, and Geodesy Analysis Program (DMAP) proposes to transform the DTED Level 2, 30-m post spacing, within Extended Vector Product Format (EVPF) as a TIN structure. Since there are multiple representations of TINs in relational
databases, investigations are currently underway to determine the representation best suited for VPF's geometric structure. The anticipated result is a new primitive beyond VPF's current limit of face, together with a corresponding feature table to store appropriate attribution. Moreover, TIN and additional formats of elevation data will comprise a single VPF coverage.

2.4 Appendix B presents DMAP's preliminary observations on the relative difficulty of integrating TINs into VPF. Of the three presented storage formats, DMAP proposes to use the triangle-based data structure. Although new file definitions must be created for this structure, it shows considerable promise in terms of storage requirements, access speed for viewing software, and simplicity.

2.5 With respect to TIN generation, many algorithms exist. Since regular grid data will be input, the current plan is to use the generation algorithm of the commercial geographic information system ARC/INFO, which can complete such transformations with minimal input from the user. For testing purposes, DMAP has successfully generated a TIN from VPF contour lines in Urban Vector Smart Map. The intent is now to apply this concept to a more realistic scenario, namely generating TINs from DTED 2.

3.0 Feature and Attribution Content

3.1 For an object to be modeled successfully, sufficient attribution must be supplied. The required amount of attribution, of course, depends on those programs modeling the object. Once sufficient and appropriate attribution is available in a given form, successful modeling can take place within a program's own system/simulation.

3.2 To that end, DMAP has based the feature and attribute content on the most up-to-date requirements analyses of 38 Army programs and 110 Navy/Marine Corps programs involved with M&S [1,2]. Additionally, feature and attribute content of the prototype VPF product will contain features and attributes made available in all current VPF prototypes (DNC, Digital Topographic Data, World Vector Shoreline, VMap 0, VMap 1, VMap 2, UVMap), with redundant features eliminated.

3.3 Additionally, Digital Feature Analysis Data (DFAD), a product which is currently used by many M&S programs as a source of cultural information, will be analyzed and incorporated into the extended VPF prototype. (As an aside note, much of DFAD has been integrated into VMap Level 1.) Compared with several current VPF products, DFAD seems limited in feature content. However, its rich attribution satisfies many M&S requirements. No difficulties are anticipated with incorporating such attribution.

3.4 The following section introduces DMAP's initial coverage and feature profile separated into logical thematic groupings that will evolve into VPF thematic coverages. All available Feature and Attribute Coding Catalog (FACC) codes are represented, and those with no code are not yet available in FACC. Once codes are established, all features should be stored in VPF's relational format with equal ease.
4.0 Proposed EVPF Profile

4.1 Appendix C describes required features, grouped into the proposed 12 EVPF coverages *Aeronautical Information, Beach, Data Quality, Demarcation, Elevation, Hydrography, Industry, Physical Geography, Population, Transportation, Utilities, and Vegetation*, with some temporary subheadings for clarity. References to geometry (area, line, and point) are minimized so as to avoid future conflicts with scale. Blanks indicate FACC codes to be developed, and "**" indicates "not a currently identified requirement." DMAP recommends the latter features for inclusion on the basis of future requirement indications. Approximately 20 new FACC features are proposed here, and many other codes required by Navy and Army M&S programs exist in the FACC, but not in any current VPF product.

4.2 Attribution is "to be determined" and will fulfill all requirements without causing multiple representation of entities, as stipulated by VPF. New attribution, including physical measurements relating to infrared properties, emissive properties, reflective properties, and thermal conductivity, will be integrated with standard attribution to satisfy remaining requirements. Some new attribution codes will obviously be needed to supplement the FACC, which may present future technical challenges. Once completed, however, the resulting profile of features and attributes should surpass content of any given VPF product to date.

5.0 Thematic Coverages

5.1 VPF allows similar data objects to be grouped into coverages for the purpose of defining topology. VPF stipulates that topology, by definition, does not extend between coverages. A simple example illustrates the impact of such a restriction: If roads are in coverage Transportation and bridges are in coverage Hydrography, no information about connectedness between road and bridge can be inferred. Careful requirements analyses and mission requirements have been studied to determine coverage content for the existing VPF products.

5.2 Coverages must exist not only for topological reasons but for topography preservation as well. For example, a lake area exists in a land area. Since both area features cannot geometrically exist within a single VPF coverage, separate coverages are required.

5.3 Perhaps the most ambitious (and time consuming) extension to VPF would be to "connect" information between coverages. Clearly, separate coverages reinforce logical separation of data and data manageability. On the other hand, connection between coverages could allow for more enhanced operations, such as thinning, an important concept in M&S. DFAD allows for a way of "stacking" features, thereby in a sense, introducing topography information into the 2-D representations of features. EVPF should have similar capability. However, for the initial prototype, the separate, individually connected coverages of section 4.0 will be the extent of connectedness.
6.0 Software Considerations

6.1 In creating a preliminary prototypical EVPF database for M&S, software must be developed not only to generate TINs, as discussed in Section 2.0, but also to form tables of features from existing VPF products. Since the current products do not normally cover the same geographic area, some data must also be simulated. Software tools are needed to generate VPF tables in all cases.

6.2 A collection of "C" routines is currently being written to manipulate VPF tables. These functions allow the user to read, write, display, delete, and copy elements or rows in VPF tables, thereby allowing DMAP to prototype an M&S VPF prototype which conforms to the basic tenets of the VPF standard and the extensions. Once software engineering is complete, DMAP will have the mechanism to merge diverse database coverage information into the M&S prototype.

6.3 In particular, VPF software tools (collectively called VPFTool), previously used to create a point coverage for the Naval Search and Rescue routine, are being refined and extended to develop these capabilities. Recent additions to VPFTool include:

- **Attribute table merging routines.** A source table row is mapped to a new attribute table, transferring any identical column entries and providing the appropriate null values for columns not found in the source row.

- **Database creation tools.** A set of functions that build the required database header, geographic extent, and library header tables using a template file, sensible default values, and a limited amount of user input, making the construction of a skeleton EVPF database structure quick and easy to accomplish.

- **Point and text feature primitive constructors.** These routines provide a method of sorting text and entity node data by geographic extent and tile, providing a means of migrating existing data to a new database. These functions also provide a way to store selected VPF data in VPF format using the additional database creation functions outlined above. No anticipated difficulties are expected for the line and area primitives.

6.4 Algorithms for constructing the initial EVPF prototype have also been developed. For example, the steps for migrating a coverage to a new database are defined as follows:

1) Create a set of extents, tiled or untiled, that define the new library.

2) Create a new attribute table in which to store the existing coverage attribute data.
3) Transfer the existing data. The software will map the existing attribute rows to the new table and create a table in which to insert any associated primitives that fall within the extents of the new library. If that table already exists, the primitives are appended to that table.

6.5 For displaying the prototype extended VPF, a 3-D software viewing package, PolyView version 3.1, will be used. This public domain package shall enable DMAP to display a terrain skin along with 3-D objects and have a "fly-through" capability. The relationship among the 3-D objects cannot be varied, but sequential images can be used to simulate the relative motion of objects. Documentation unfortunately extends only through version 2.0, so some difficulty is expected to be encountered.

7.0 Issues for Future Consideration

7.1 Unlimited extensions to VPF could be performed. As mentioned in an earlier section, connections between coverages has yet to be resolved.

7.2 Another issue is that of the temporal data. Many features have attribution that extends well beyond that of a "single instance in time." Forward Looking Infrared, for instance, is highly sensitive to time. Efficiently storing such information in a relational database is certainly a topic of concern which lies beyond the scope of the problem at hand.

7.3 Resolution and level of detail are additional topics of interest in M&S. VPF fixes a scale at product development time. WVS, for example, has five separate libraries corresponding to five distinct scales. A hierarchical TIN data structure has been developed to address the concept of storing terrain at various scales (see Appendix B for a brief introduction). Representing scaled data in EVPF, to the benefit of the M&S community, could very well be a separate project unto itself.

8.0 Conclusions

8.1 Results to date have been substantial and promising. The major extension to VPF, the incorporation of 3-D terrain data, has been carefully planned: The popular TIN data structure has been selected, the method of storage of TINs has been selected, and research into TIN generation from regular grids such as DTED is underway. Moreover, all current and future M&S requirements have been compiled. Software is currently being designed, and attempts at using completed software have been successful.

8.2 Anticipated difficulties are in the form of display software, and modeling 3-D objects described by the attribution of EVPF. Limited geographic extent of existing VPF products may pose a problem to EVPF prototype generation, particularly since each product has its own unique extent.
9.0 Acknowledgments

9.1 This effort was sponsored by the Defense Mapping Agency’s Terrain Modeling Program Office and the Defense Modeling and Simulation Office, under Program Element 630603832D, with Mr. Jerry Lenczowski as program manager.

10.0 References


Appendix A. Acronym List.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-D</td>
<td>Two Dimensional</td>
</tr>
<tr>
<td>3-D</td>
<td>Three Dimensional</td>
</tr>
<tr>
<td>ARC/INFO</td>
<td>commercial geographic information system</td>
</tr>
<tr>
<td>DFAD</td>
<td>Digital Feature Analysis Data</td>
</tr>
<tr>
<td>DMAP</td>
<td>Digital Mapping, Charting, and Geodesy Analysis Program</td>
</tr>
<tr>
<td>DNC</td>
<td>Digital Nautical Chart</td>
</tr>
<tr>
<td>DTED</td>
<td>Digital Terrain Elevation Data</td>
</tr>
<tr>
<td>EVPF</td>
<td>Extended Vector Product Format</td>
</tr>
<tr>
<td>FACC</td>
<td>Feature and Attribute Coding Catalog</td>
</tr>
<tr>
<td>M&amp;S</td>
<td>Modeling and Simulation</td>
</tr>
<tr>
<td>TIN</td>
<td>Triangulated Irregular Network</td>
</tr>
<tr>
<td>VMap</td>
<td>Vector Smart Map</td>
</tr>
<tr>
<td>VPF</td>
<td>Vector Product Format</td>
</tr>
<tr>
<td>VPFTool</td>
<td>VPF software tools</td>
</tr>
<tr>
<td>VPFView</td>
<td>VPF viewing software</td>
</tr>
<tr>
<td>WVS</td>
<td>World Vector Shoreline</td>
</tr>
</tbody>
</table>
Appendix B. TIN Data Structures.

DATA STRUCTURE FOR TINs

PRELIMINARY THOUGHTS

- Storing TINs by adding a third dimension to VPF's vertices
- Storing TINs using a triangle-based data structure
- Storing TINs using a vertex-based data structure
Sample Triangular Network

- \(e_1, e_2, e_3, \ldots\) edges
- 1, 2, 3, \ldots vertices
- \(a, b, c, \ldots\) triangles

Connected Node Table:

<table>
<thead>
<tr>
<th>ID</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(x_1)</td>
<td>(y_1)</td>
<td>(z_1)</td>
</tr>
<tr>
<td>2</td>
<td>(x_2)</td>
<td>(y_2)</td>
<td>(z_2)</td>
</tr>
<tr>
<td>\ldots</td>
<td>\ldots</td>
<td>\ldots</td>
<td>\ldots</td>
</tr>
</tbody>
</table>
Edge Table (level 3 - LFT_ID not included):

<table>
<thead>
<tr>
<th>ID</th>
<th>start_node</th>
<th>end_node</th>
<th>right_edge</th>
<th>left_edge</th>
<th>right_face</th>
<th>left_face</th>
<th>coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>e₁</td>
<td>4</td>
<td>10</td>
<td>e₃</td>
<td>e₃</td>
<td>e</td>
<td>d</td>
<td>x₁y₁z₁ x₂y₂z₂</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Face Table (a face is any triangle that does not contain an edge inside - AFT_ID not included):

<table>
<thead>
<tr>
<th>ID</th>
<th>Ring_pointer</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>d</td>
<td>9</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Ring Table:

<table>
<thead>
<tr>
<th>ID</th>
<th>Face</th>
<th>Starting_edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>9</td>
<td>d</td>
<td>e₁</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Storage Requirement = (54N - 18B - 49) storage units

- N = number of TIN vertices
- B = number of TIN vertices that belong to the convex hull
- storage unit = amount of storage needed to store either a pointer or one coordinate

Basic Queries:

- Point Location: requires reading several VPF tables
- Edge Neighbor finding: needs only the edge table
- Vertex Neighbor finding: difficult to perform

Advantages:

- Visualization software available?
- Minimum change to VPF
- Allows for area, line, and point features

Disadvantages:

- Storage requirement
- Complex data structure that was not meant for TINs
Triangle-Based Data Structure

Connected Node Table:

<table>
<thead>
<tr>
<th>ID</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x₁</td>
<td>y₁</td>
<td>z₁</td>
</tr>
<tr>
<td>2</td>
<td>x₂</td>
<td>y₂</td>
<td>z₂</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Face Table (stores triangles):

<table>
<thead>
<tr>
<th>ID</th>
<th>V₁</th>
<th>V₂</th>
<th>V₃</th>
<th>T₁</th>
<th>T₂</th>
<th>T₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>null</td>
<td>b</td>
<td>e</td>
</tr>
<tr>
<td>b</td>
<td>2</td>
<td>11</td>
<td>10</td>
<td>f</td>
<td>c</td>
<td>a</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B-5
Storage requirement = 18N - 7B - 14 storage units

Basic Queries:

- Point Location: simpler than VPF data structure
- Edge Neighbor finding: simpler than VPF data structure
- Vertex Neighbor finding: simpler than VPF data structure

Advantages:

- Less storage than VPF (about three times less)
- Data format similar to that of ARC/INFO

Disadvantages:

- Will require substantial changes to VPF
- No edge table (but line features can easily be expressed in terms of a list of pointers to TIN vertices)
Vertex-Based Data Structure

Coordinates:

<table>
<thead>
<tr>
<th>ID</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>Neighbors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x₁</td>
<td>y₁</td>
<td>z₁</td>
<td>2 10 4</td>
</tr>
<tr>
<td>2</td>
<td>x₂</td>
<td>y₂</td>
<td>z₂</td>
<td>3 15 12 11 10 1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Storage requirement = 10N - 2B - 6 storage units

Basic Queries:

- Point Location: about same complexity as triangle-based data structure
- Edge Neighbor finding: complex compared to triangle-based data structure
- Vertex Neighbor finding: simple

Advantages:

- Less storage than the triangle-based data format

Disadvantages:

- Will require substantial changes to VPF
- Does not allow for area features
- Does not allow for line features
DATA STRUCTURE FOR TINs

Goal:

- Extend VPF to allow for the efficient storage of TIN-based elevation data
- Integrate terrain elevation data with ground surface features (point, line, and area features)

Methodology: Add an optional primitive TIN-face. A TIN-face will be stored using a triangle-based data structure

Extended Primitive Directory
Structure of a TIN-Face Table

<table>
<thead>
<tr>
<th>TIN-Face Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangle Identifier</td>
</tr>
<tr>
<td>Vertex 1 Identifier</td>
</tr>
<tr>
<td>Vertex 2 Identifier</td>
</tr>
<tr>
<td>Vertex 3 Identifier</td>
</tr>
<tr>
<td>Adjacent Triangle 1 Identifier</td>
</tr>
<tr>
<td>Adjacent Triangle 2 Identifier</td>
</tr>
<tr>
<td>Adjacent Triangle 3 Identifier</td>
</tr>
</tbody>
</table>
HIERARCHICAL TINs

Hierarchical (multiresolution) TINs:

- Describe a terrain model at different levels of resolution.

- Each level corresponds to a particular surface elevation error. The root level is composed of all the TIN-triangles needed to reconstruct the surface with the largest error (the lowest level of resolution). The next level in the hierarchy contains TIN-triangles that when added to those of the root level yield a surface representation that has a higher resolution than that of the root level. Therefore, each level provides additional TIN-triangles that when combined with the existing ones bring the resolution of the surface to that of the corresponding level.

- Enables the compression of elevation data according to an accuracy level criterion.

- Features can be manipulated at different levels of accuracy.

Algorithms for the Generation of Hierarchical TINs:

Algorithms for the generation of hierarchical TINs can be classified into two broad categories:

- Recursive subdivision of enclosing triangles

  *Ternary triangulation*
  
  + simple
  
  - may lead to triangles with elongated shape (result in inaccuracies in numerical interpolation)

  *Quaternary triangulation*
  
  + avoids the generation of elongated triangles
  
  - may lead to discontinuous surfaces

  *Cartographic coherence preservation*
  
  + preserves cartographic coherence (features - such as ridges - of the surface to be approximated are preserved)
  
  - complex algorithm

- Retriangulation of the added points and their region of influence
  
  + avoids the generation of elongated triangles
  
  - complex
Data Structures for Hierarchical TINs:

All hierarchical TIN implementations can use essentially the same data structures.

**Level Table**

<table>
<thead>
<tr>
<th>Level Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level ID</td>
</tr>
<tr>
<td>Max Error</td>
</tr>
<tr>
<td>Num. Triangle</td>
</tr>
<tr>
<td>Num. Points</td>
</tr>
<tr>
<td>Triangle List</td>
</tr>
</tbody>
</table>

**Triangle Table**

<table>
<thead>
<tr>
<th>Triangle Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
</tr>
<tr>
<td>Max Error</td>
</tr>
<tr>
<td>Type (internal, external, boundary)</td>
</tr>
<tr>
<td>child list</td>
</tr>
<tr>
<td>Internal</td>
</tr>
<tr>
<td>Vertex 1</td>
</tr>
<tr>
<td>Vertex 2</td>
</tr>
<tr>
<td>Vertex 3</td>
</tr>
<tr>
<td>Adjacent 1</td>
</tr>
<tr>
<td>Adjacent 2</td>
</tr>
<tr>
<td>Adjacent 3</td>
</tr>
</tbody>
</table>
Appendix C. Feature Classes and Features.

1. AERONAUTICAL INFORMATION

Air Routes
- GA005  Airspace
- GA010  ATS Route Segment/Leg
- GA015  Special Use Airspace
- GA020  Airspace Boundary Sector
- GA025  Special Use Airspace Segment
- GA030  Off Route Radial/Bearing
- GA035  NAVAIDS (Aeronautical)
- GA045  Route (Air)
- GA055  Waypoint/Reporting-Calling in Point
- ZD020  Void Collection Area

2. BEACH
- BA050  Beach
- ZD020  Void Collection Area

3. DATA QUALITY
- ZD020  Void Collection Area

4. DEMARCATION

Boundaries/Limits/Zones (Topographic)
- FA000  Administrative Boundary
- FA001  Administrative Area
- FA005  Access Zone
- FA015  Firing Range/Gunnery Range
- FA020  Armistice Line
- FA030  Cease-Fire Line
- FA040  Claim Line
- *FA041  Contact Zone
- FA050  Mandate Line/Convention Line
- FA060  Defacto Boundary
- FA070  Demilitarized Zone
- FA090  Geophysical Prospecting Grid
- FA110  International Date Line
- FA165  Training Area
- FA170  Zone of Occupation

Boundaries/Limits/Zones (Hydrographic)
- FC021  Maritime Limit Boundary
- FC031  Maritime Area
*FC035   Pond Partition
FC036   Restricted Area
FC040   Traffic Separation Scheme System
*FC041   Traffic Separation Scheme (TSS)
FC100   Measured Distance Line
FC130   Radar Reference Line
FC165   Route (Maritime)
*FC166   Deep Water Route
*FC167   Defined Water
*FC168   Canal Route
FC170   Safety Fairway
*FC177   Swept Area

**Miscellaneous**
AL025   Cairn
AL070   Fence
AL260   Wall
ZD020   Void Collection Area

**Other**
- Sensitivity Areas
- Low Intensity Conflict Areas
- Key Tracking Areas

**5. ELEVATION**
CA010   Contour Line (Land)
CA020   Ridge Line
CA025   Valley Bottom Line
CA026   Breakline (*useful in TIN generation*)
CA030   Spot Elevation
CA035   Inland Water Elevation
CA040   Contour Polygon (Land) (*probable attribution: irregular triangle for TIN*)

**Other**
SA050   Slope Polygon
ZD020   Void Collection Area
- Berm/Barricade

**6. HYDROGRAPHY**

**Coastal Hydrography**
BA010   Coastline/Shoreline
BA020   Foreshore
BA030   Island
BA040   Water (Except Inland)
*BA051   Dyke Crown
- Surf
Ports and Harbors
BB005 Harbor
*BB006 Harbor Complex
*BB007 Channel Edge
BB010 Anchorage
*BB012 Anchor Berth
BB019 Anchor
BB020 Berth
*BB021 Mooring Trot
BB022 Basin
*BB030 Bollard
BB040 Breakwater/Groyne
*BB042 Mole
BB050 Calling-In Point
BB079 Mooring/Warping Facility
BB080 Dolphin
BB081 Shoreline Construction
BB090 Drydock
*BB100 Fish Stakes
BB105 Fishing Harbor
BB110 Fish Traps/Fish Weirs
BB111 Tunny (Tuna) Nets Area
BB115 Gridiron
BB140 Jetty
BB150 Landing Place
BB151 Landing Stairs
BB160 Mooring Ring
BB170 Offshore Loading Facility
*BB180 Oyster Bed/Mussel Bed
BB190 Pier/Wharf/Quay
BB199 Floating Dock
BB200 Pump Out Facility
BB201 Small Craft Facility
BB220 Ramp (Maritime)
BB230 Seawall
BB240 Slipway/Patent Slip
BB250 Watering Place
SU003 Port Facility

NAVAIDs
BC010 Beacon
BC020 Buoy
BC030 Leading Light(s)
BC031 Navigation Line
BC032 Radar Line
BC033 Radar Range
BC035  Lights in Line
BC040  Light
BC050  Lighthouse
BC055  Marker
BC060  Light Sector
BC070  Light Vessel/Lightship
BC080  Perches/Stakes
BC100  Leading Line
BC101  Fog Signal

Dangers/Hazards
BD000  Underwater-Danger/Hazard
BD001  Mine
BD005  Miscellaneous Underwater Feature
BD010  Breakers
BD020  Crib
BD030  Discolored Water
BD040  Eddies
BD050  Foul Ground
BD060  Kelp/Seaweed
BD070  Obstruction (Nautical)
BD071  Log Boom/Booming Ground
BD072  Pontoon
BD073  Oil Barrier
BD074  Chain/Wire
BD079  Fishing Facility
BD080  Overfalls/Tide Rips
BD100  Pile/Piling/Post
BD110  Platform
BD111  Offshore Platform Site (cleared)
BD112  Production Installation
BD119  Ledge
BD120  Reef
*BD121  Pingo
BD130  Rock
BD140  Snags/Stumps
BD180  Wreck
BD181  Hulk
       Spoil/Disposal Area
       Mine-Like Objects
       Seamount

Depth Information
BE010  Depth Curve
BE015  Depth Contour
*BE019  Depth Area
BE020  Sounding
BE021  Drying Line, Low Water Line-LWL
BE022  Sand Line
BE023  Mud Line
BE029  Bottom Return
BE030  Track Swath
BE040  Track Line

**Bottom Features**
- BF010  Bottom Characteristics
- BF011  Bottom Feature
  - Bottom Type (acoustic)
  - False Acoustic Targets
  - Underwater Canyon
  - Shelf

**Tide and Current Information**
- BG010  Current Flow
- BG011  Tideway
- BG012  Water Turbulence
- BG020  Tide Gauge
- BG030  Tide Data Point
- BG040  Current Diagram
  - Sound Speed Profiles

**Inland Water**
- BH000  Inland Water
- BH010  Aqueduct
- BH015  Bog
- BH020  Canal
- BH030  Ditch
- BH040  Filtration Beds/Aeration Beds
- BH050  Fish Hatchery/Fish Farm/Marine Farm
- BH060  Flume
- BH070  Ford
- BH075  Fountain
- BH077  Hummock
- BH080  Lake/Pond
- BH090  Land Subject to Inundation
- *BH091  Flooded Area
- BH095  Marsh/Swamp
- BH100  Moat
- BH110  Penstock
- *BH115  Underground Water/Phreatic Water
- BH120  Rapids
- BH130  Reservoir
- BH135  Rice Field
- BH140  River/Stream
- BH141  River Bank
BH145 River Stream Vanishing Point
BH150 Salt Pan
BH155 Salt Evaporator
BH160 Sebkha
BH165 Spillway
BH170 Spring/Water-Hole
BH175 Trough
BH180 Waterfall
BH190 Lagoon/Reef Pool
BH200 Miscellaneous Surface Drainage Feature
BH210 Inland Shoreline
BH501 River Navigation Route

Miscellaneous Inland Water
BI005 Boat Lift
BI010 Cistern
BI020 Dam/Weir
BI030 Lock
*BI039 Sluice
BI040 Sluice gate
BI041 Gate (Nautical)
BI042 Caisson
BI043 Flood Barrage
BI050 Water Intake Tower
*BI060 Fish Ladder
BI070 Gauging Station

Snow/Ice
BJ020 Moraine
BJ030 Glacier
BJ040 Ice Cliff
BJ060 Ice Peak/Nunatak
BJ065 Ice Shelf
BJ070 Pack Ice
BJ080 Polar Ice
BJ100 Snow Field/Ice Field
BJ110 Tundra

Other
ZD020 Void Collection Area
SA010 Common Open Water
SA060 Covered Drainage

7. INDUSTRY
Extraction
AA010 Mine
AA011 Quarry/Mine Shear Wall
AA012 Quarry
AA013 Pit
AA040 Rig/Superstructure
AA050 Well
AA051 Wellhead
AA052 Oil/Gas Field

Disposal
AB000 Disposal Site/Waste Pile
AB010 Wrecking Yard/Scrap Yard
*AB020 Burner
*AB021 Diffuser

Processing Industry
AC000 Processing Plant/Treatment Plant
AC010 Blast Furnace
AC020 Catalytic Cracker
AC030 Settling Basin/Sludge Pond
AC040 Oil/Gas Facilities
AC050 Works

Associated Industrial Structures
AF010 Chimney/Smokestack
AF020 Conveyor
AF030 Cooling Tower
AF040 Crane
*AF041 Sheerlegs (Shear Legs)
AF050 Dredge/Powershoevel/Dragline
AF060 Engine Test Cell
AF070 Flare Pipe
AF080 Hopper

Agriculture
AJ010 Circular Irrigation System
*AJ020 Siphon
AJ030 Feed Lot/Stockyard/Holding Pen
AJ050 Windmill
*AJ051 Windmotor

Miscellaneous
AL140 Particle Accelerator
AL240 Tower (Non-Communication)
AL241 Tower (General)

Storage
AM010 Depot (Storage)
AM020 Grain Bin/Silo
AM030 Grain Elevator
AM060 Storage Bunker/Storage Mound
AM070 Tank
AM080 Water Tower
*AM031  Timber Yard
*AM040  Mineral Pile

Other
ZD020  Void Collection Area

8. PHYSICAL GEOGRAPHY
Exposed Surface Materials
DA005  Asphalt Lake
*DA006  Alkali Flats
DA010  Ground Surface Element
DA020  Barren Ground
*DA030  Land Area
*DA031  Land Region
SA020  Disturbed Soil
SA030  Exposed Bedrock

Landforms
DB010  Bluff/Cliff/Escarpment
DB030  Cave
DB031  Hill
DB060  Crevice/Crevasse
DB070  Cut
DB080  Depression
DB090  Embankment/Fill
DB100  Esker
DB110  Fault
DB115  Geothermal Feature
DB145  Miscellaneous Obstacle
DB150  Mountain Pass
DB160  Rock Strata/Rock Formation
DB170  Sand Dune/Sand Hills
DB176  Slope Category
DB180  Volcano
DB190  Volcanic Dike
DB200  Gully/Gorge
DB210  Potential Landslide Area
*DB211  Landslide
DB230  Fan
DB240  Karst
DB500  Bottomline of Cliff
DB501  Topline of Cliff

Other
ZD020  Void Collection Area
SA040  Permanent Snowfield
9. POPULATION

Institutional/Government
AH010 Bastion/Rampart/Fortification
AH020 Trench
AH050 Fortification
AH060 Underground Bunker
AH070 Checkpoint
SU001 Military Base

Residential
AI020 Mobile Home/Mobile Home Park
AI030 Camp

Recreational
AK020 Amusement Park Attraction
AK030 Amusement Park
AK040 Athletic Field
AK050 Tennis Court(s)
AK060 Campground/Campsite
*AK061 Picnic Site
*AK070 Drive-In Theater
*AK080 Drive-In Theater Screen
AK090 Fairground
AK091 Exhibition Grounds
AK100 Golf Course
*AK101 Golf Driving Range
AK110 Grandstand
AK120 Park
*AK121 Lookout
AK130 Race Track
AK150 Ski Jump
AK155 Ski Track
AK160 Stadium/Amphitheater
AK170 Swimming Pool
AK180 Zoo/Safari Park

Miscellaneous
*AL005 Animal Sanctuary
AL012 Archeological Site
AL015 Building
AL018 Building Superstructure Addition
AL019 Shed
AL020 Built-Up Area
AL030 Cemetery
*AL040 Cliff Dwelling
AL045 Complex Outline
AL050 Display Sign
AL073 Flagstaff/Flagpole
*AL075 Gallery
*AL080 Gantry
*AL090 Grave Marker
AL100 Hut
AL101 Cabin
AL105 Settlement
*AL110 Light Standard/Light Support
*AL116 Calvary Cross
AL130 Monument
AL135 Native Settlement
*AL141 Telescope
*AL155 Overhead Obstruction Location
AL170 Plaza/City Square
AL120 Missile Site
*AL195 Ramp
AL200 Ruins
AL201 Historic Site/Point of Interest
AL220 Steeple
*AL250 Underground Dwelling

Other
ZD020 Void Collection Area

10. TRANSPORTATION

Miscellaneous
AL060 Dragon Teeth
AL210 Snow Shed/Rock Shed

Railroad
AN010 Railroad
AN050 Railroad Siding/Railroad Spur
AN060 Railroad Yard/Marshalling Yard
AN075 Railroad Turntable
AT100 Electrified Railroad Pylon

Road
AP010 Cart Track
AP020 Interchange
AP030 Road
AP040 Gate
AP041 Barrier
AP050 Trail
*AP060 Drove

Associated Transportation
AQ010 Aerial Cableway Lines/Ski Lift Lines
AQ020 Aerial Cableway Pylon/Ski Pylon
*AQ021 Mast
AQ030 Boardwalk
AQ040 Bridge/Overpass/Viaduct
AQ045 Bridge Span
AQ050 Bridge Superstructure
AQ055 Bridge Tower/Bridge Pylon
AQ056 Bridge Pier
AQ058 Constriction/Expansion
AQ060 Control Tower
AQ062 Crossing
AQ064 Causeway
AQ065 Culvert
AQ070 Ferry Crossing
AQ080 Ferry Site
AQ090 Entrance/Exit
AQ100 Landmark Post/Distance Post
AQ110 Mooring Mast
AQ111 Prepared Raft or Float Bridge Site
AQ113 Pipeline/Pipe
AQ116 Pumping Station
AQ118 Sharp Curve(s)
AQ120 Steep Grade
AQ125 Station (Miscellaneous)
AQ130 Tunnel
AQ135 Vehicle Stopping Area/Rest Area
AQ140 Vehicle Storage/Parking Area
AQ150 Flight of Steps

Aerodrome
GB005 Airport/Airfield
GB006 Airfield
*GB007 Airport Area
GB010 Airport Lighting
GB015 Apron/Hardstand
GB020 Arresting Gear
GB025 Blast Barrier
GB030 Helicopter Landing Pad
GB035 Heliport
GB040 Launch Pad
GB045 Overrun/Stopway
GB050 Revetment (Airfield)
GB055 Runway
GB057 Shoulder
GB060 Runway Radar Reflector
GB065 Seaplane Base
GB070 Seaplane Landing/Seaplane Take-Off Area
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<td>Route/Distance Marker</td>
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<td>Fueling Areas</td>
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11. UTILITY

**Power Generation**
- AD010 Power Plant
- AD020 Solar Panels
- AD030 Substation/Transformer Yard
- AD040 Nuclear Reactor

**Communications/Transmission**
- AT005 Cable
- AT010 Disk/Dish
- AT020 Early Warning Radar Site
- AT030 Power Transmission Line
- AT040 Power Transmission Pylon/Line
- AT041 Telpher
- AT045 Radar Transmitter
- AT050 Communication Building
- AT060 Telephone Line/Telegraph Line
- AT070 Telephone-Telegraph Pylon/Pole
- AT080 Communication Tower
- ______ Telephone Station
- ______ Communication Nodes
- ______ Poles

**Other**
- ZD020 Void Collection Area
- ______ Condensation Line
- ______ Steam Line

12. VEGETATION

**Cropland**
- EA010 Cropland
- EA020 Hedgerow
- EA030 Nursery
- EA031 Botanical Garden
EA040  Orchard/Plantation
EA050  Vineyards
EA055  Hops

**Rangeland**
EB010  Grassland
EB015  Grass/Scrub/Brush
EB020  Scrub/Brush
EB030  Land Use/Land Cover (Vegetation)

**Woodland**
EC010  Bamboo/Cane
EC015  Forest
EC020  Oasis
EC030  Trees
EC040  Cleared Way/Cut Line/Firebreak

**Wetland**
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Wetlands

**Miscellaneous Features**
EE000  Miscellaneous Vegetation

**Other**
ZD020  Void Collection Area

Some general features which may also be included in one or more of the above are as follows:

**Control Points**
ZB020  Benchmark
ZB030  Boundary Monument
ZB035  Control Point/Control Station
ZB036  Distance Mark
ZB040  Diagnostic Point
ZB060  Geodetic Point

**Magnetic Variation**
ZC040  Magnetic Disturbance Area
ZC050  Isogonic Lines
ZC051  Magnetic Pole

**Miscellaneous**
ZD001  Network
ZD003  Artifact Location
ZD012  Geographic Information Point
ZD015  Point of Change
ZD020  Void Collection Area
ZD040  Named Location
ZD045  Text Description