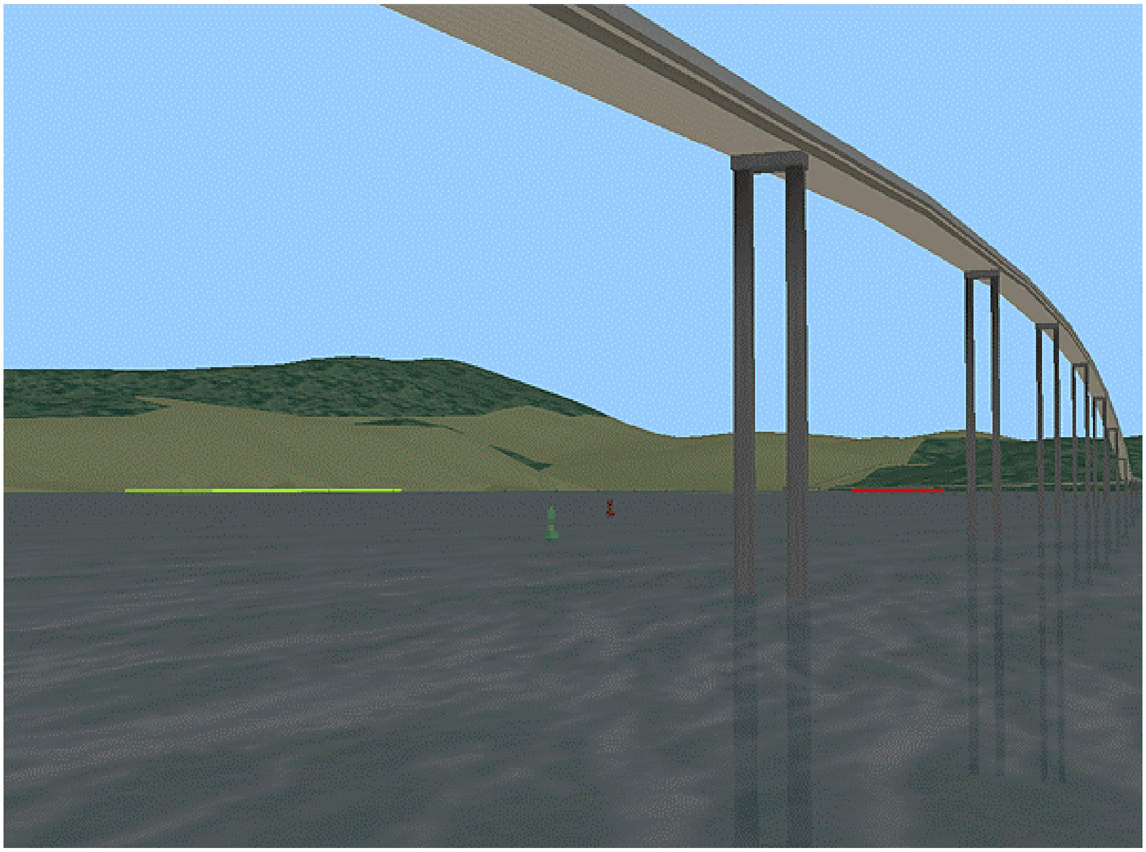
# Visualizing the Marine Environment: TerraTools® Capabilities for Maritime Visualization



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3D visualization is now widely used in cartography, GIS, civil engineering, architecture, and training and simulation, driven partly by the exponential increases in computing and graphics power and the greater availability of digital cartographic, GIS, and image data. Another important factor is the technology to automatically generate 3D visualizations from 2D digital data sources, instead of the expensive and time-consuming manual effort formerly required. Many of the standard ground-based visualization applications have corresponding applications in the maritime domain. This white paper describes some representative maritime applications of 3D visualization and shows examples generated using TerraTools®.

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## Applications of maritime visualization

While many of the maritime applications of visualization parallel terrestrial and aerial applications, it is not the case that all terrestrial simulation and visualization packages are necessarily suitable for use in building maritime simulations. The characteristics of bathymetric and nautical chart data can be very different from those of terrestrial datasets; the visualization construction process must be flexible enough to deal with these differences properly. Maritime navigation can be a life-or-death issue. The tools used to work with the data must have rigorous geodetic accuracy and a well defined and tested data flow, with objects in the final visualization traceable back to the original source data. TerraTools meets these criteria, with its rigorous, yet flexible, processing flow and ease of inspection and data verification.

**Training:** The initial catalyst for 3D visualization, and still one of the main applications, is training. Military simulators allow the training of aircraft pilots or tank crews without the expense and danger of live exercises. Realistic visualizations allow the pilots to become familiar with inaccessible operational areas and to rehearse planned missions. Civilian aviation simulators allow pilots to familiarize themselves with the cockpits of new aircraft models, to practice approaches to airports, and to rehearse various emergency scenarios. Realistic 3D visualizations of harbors and channels allow pilots to familiarize themselves with the approach paths, landmarks, and hazards of a harbor, gaining valuable experience and confidence in a short period of time.

**Navigation:** A number of systems currently exist for the real-time display of a ship's position on 2D navigation charts, based on positions from GPS. An equivalent facility based on 3D visualizations derived from nautical charts would provide even greater benefits in terms of the information conveyed to the pilot, since the display would be visually verifiable out the window. Additional information such as the current tide state, currents, winds, and depths, could be added to the visualization to provide an integrated overview of the harbor conditions, thus making navigation safer.

**Environmental modeling:** Increasing interest in the quality of the earth's environment has led to a greater appreciation of the role of the oceans. 3D visualizations of the underwater topography in the littoral zone and deep water areas and of the shoreline terrain can help provide a better understanding of the many factors affecting water quality, currents, shoreline erosion/deposition, etc. The environmental impact statements required for major developments are much more easily understood with the inclusion of 3D visualizations. For instance, the Monterey Bay region has been extensively mapped, modeled, and studied. 3D visualization of the topography of the Bay and the underwater canyons has provided both scientific researchers and the general public a better understanding of its dynamics.

**Planning and Development:** Development of both shoreline and offshore areas has increased in recent years, as more cities realize the economic and quality-of-life benefits of developing waterfront areas. Accurately portraying and understanding the visual impact of new developments on the waterfront region allows more educated decision making both on the part of development and planning professionals and by the general public.

## Production of a typical marine visualization

Typical 2D maritime source data is shown in Figure 1 and includes channel markings, areas delineated as hazards to navigation, and point locations for navigational buoys. By combining this 2D data with bathymetric, terrain elevation, and cartographic data for the adjacent shoreline areas, TerraTools can automatically produce a realistic 3D visualization with a minimal amount of operator interaction.

The construction process begins by transforming the terrain elevation and bathymetric data into a form suitable for real-time display. The primary issue within maritime databases is merging the terrain elevation with the bathymetric information. The elevation and depth values must be transformed to a common vertical reference since bathymetric data is most often relative to tidal benchmarks, while terrain elevations use geodetic datums. The coastline is defined by a vector feature integrated into the terrain at sea level (typically defined as 0, but other values may be used) to ensure a precise interface between land and water. By requiring bathymetric depths to be below sea level and terrain heights to be above sea level, except for special cases, we can ensure that the ocean bottom does not protrude above the water, or that the ocean does not incorrectly cover portions of the land. Figure 2 shows a view of an underwater channel, which was modeled from depth contours and automatically integrated into a coarse-resolution bathymetric grid prior to constructing a polygon-efficient integrated TIN.

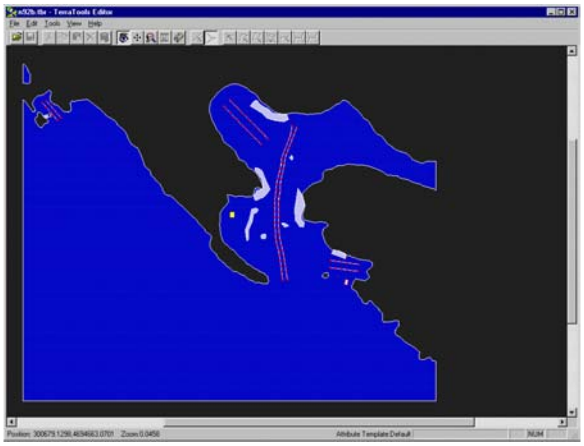


**Figure 1**:
2D GIS data showing harbor approach.

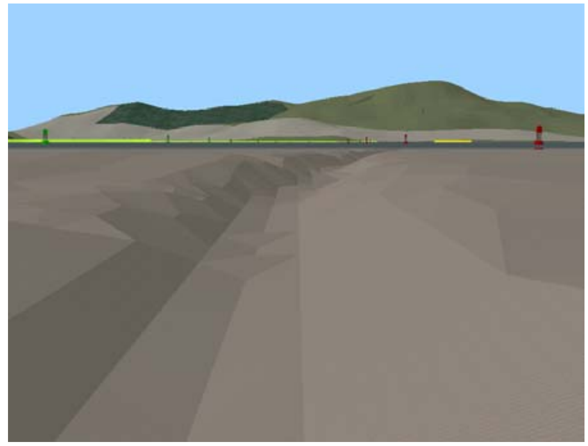


**Figure 2**:
Bathymetric surface, showing underwater channel.

Figure 3 depicts navigational hazard areas, which rise from the ocean floor to a user defined elevation above sea level. These areas can be easily delineated by users using the TerraTools GIS editor or selected from existing source vector data, with color-coding to indicate particular types or depths of hazards. Figure 4 shows a view of buoy models automatically placed at specified locations along the channel to aid in navigation.

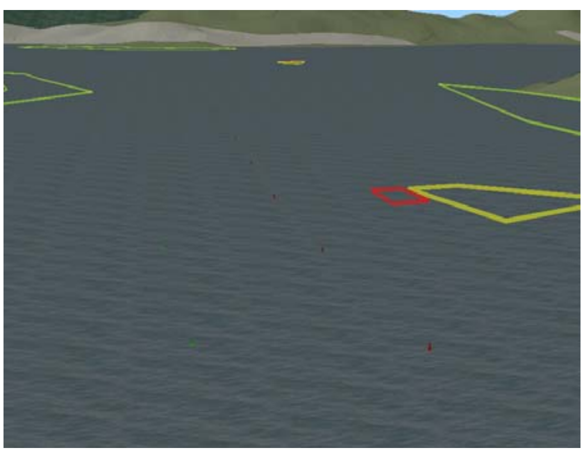


**Figure 3**:
Hazards to navigation, as seen from above.

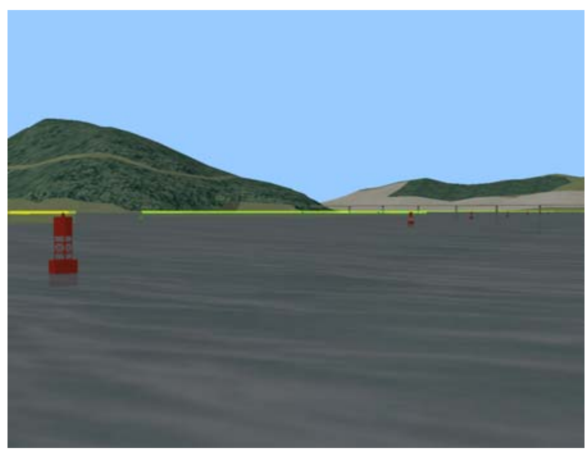
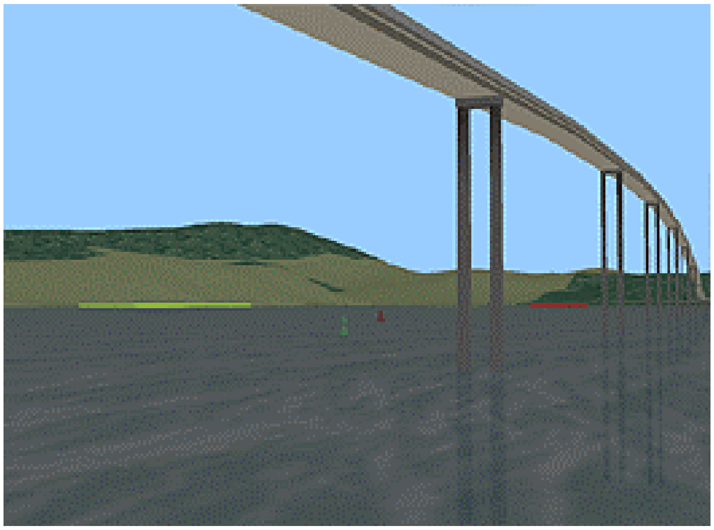


**Figure 4**:
Buoy and hazards to navigation, from sea level.



Models depicting dock, shoreline, or marine structures can also be added to the visualization. If specific CAD models of these structures exist, they can be easily imported, or applicable models from the TerraTools model library may be used. TerraTools has the capability to import 3D models from AutoCAD, Bentley Microstation, 3D Studio MAX, Multigen Creator, and Socet Set and Socet SIM, to provide additional flexibility and reality to visualizations. Bridge structures (Figure 5) can be automatically generated from source data attributed with specifications of the type of bridge, pier placement, height, and other parameters.

**Figure 5**:
Automatically generated bridge model.

The processes described above can be easily encapsulated in a TerraTools project flow graph, making the construction of a harbor database an automated process. When the geospatial source data changes, the visualization can be rebuilt from the same flow graph with a single menu selection. This is particularly important for navigation data, which is updated frequently to reflect changing navigation hazards.

The project flow graph can also be used to build other harbors with similar types of input data, by simply substituting the appropriate data files in the data import nodes. This extends the level of automation to multiple databases, and facilitates the rapid and consistent production of harbor visualizations. The TerraTools process flow graph minimizes time-consuming and costly editing of the visualization and allows immediate automated regeneration when updates, large or small, have been made to the source data.

## Maritime visualization examples

This section briefly describes some representative maritime visualizations produced by TerraSim. Additional details and scenes from other visualizations are available on the TerraSim website, http://www.terrasim.com.

### Camp LeJeune JCOS

A good example of the integration of bathymetric and terrain data is the Camp LeJeune JCOS Exercise database, which involved the construction of a 140km by 140km terrain skin for the Marine Corps to support simulation training in littoral zone warfare. TerraTools was used to automatically create an integrated terrain skin from independent land and bathymetric data sources, consisting of deep and shallow water bathymetry, barrier island beach and dune structures, a shallow intracoastal waterway, and numerous islands within the coastal area.

Several digital elevation sources were utilized to create the land component of the terrain skin, including USGS DEM, NIMA DTED, and a one-meter DEM over key areas of sand dunes. Various bathymetric sources were utilized, primarily NAVOCEAN and WES, with DBDB V data used to fill in gaps in the WES bathymetry. Additional feature modeling was performed to integrate the high-resolution bathymetry with a depth profile model for the Intracoastal Waterway. A destructible bridge crossing the waterway is viewed in Figure 6 from water level, showing the bottom of the waterway and the bridge structure both above and beneath the water surface.

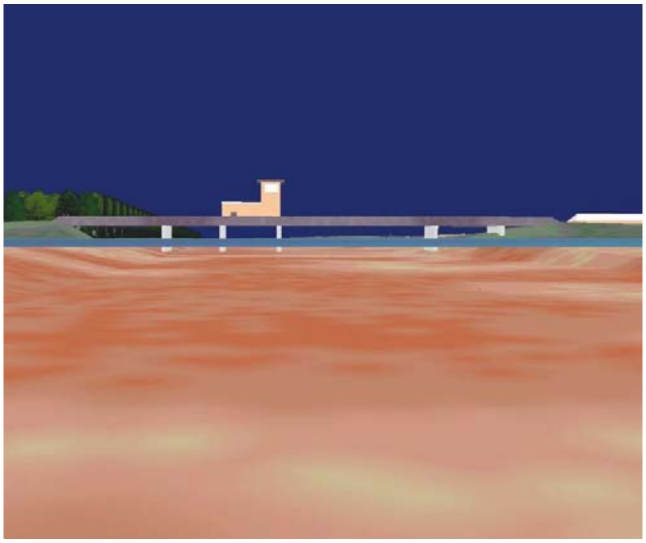


**Figure 6**:
Destructible bridge over Intracoastal Waterway

As in previous database construction tasks performed by TerraSim, automatic feature integration was a key requirement. Roads, hydrography, and airfields were automatically integrated into the terrain. Built-up areas were integrated and their polygon budgets adjusted to allow for placement of cultural features. A high-resolution inset covering a 2km by 1.5km area along the beach and dune area was integrated into the DTED Level II DEM covering the land portion of the database in order to provide a high-fidelity littoral zone.

Camp LeJeune is a complex terrain skin, with a moderate level of feature integration, due to the complexity of the littoral zone and the disparate source data used to model the synthetic environment. TerraTools allowed for efficient integration of the source data and allocation of polygon budgets to support realistic simulation and training within the littoral zone environment.

## San Diego

Shown below are two more examples of the visualization environment, generated to depict what an officer from the bridge or a ship's navigator would expect to see while entering the San Diego harbor. Landmark buildings are clearly identifiable and are shown exactly as they would be viewed from the ship.


**Figure 7**:
Approach to the San Diego harbor. Prominent high-rises and landmark buildings are visible from a distance. The harbor entrance is at the far left of the image.


**Figure 8**:
Harbor entrance as the viewer turns and approaches at closer range; from the surface of the water, harbor breakwater jetty is visible as dark raised areas on either side of the central approach.

## TerraTools for maritime visualization

The same capabilities that make TerraTools the leading system for ground-based visualization and simulation enable it to generate complex, detailed, and realistic 3D visualizations of maritime and littoral environments with a minimal amount of manual effort.

TerraTools works within a geodetic framework, allowing it to rigorously integrate disparate data sources within a common representation. Accurate bathymetry is important for realistic ship navigation, but its generation from various sources and integration with land-based data sources can be difficult. TerraTools supports the import and integration of a number of different bathymetric and terrain elevation formats for the construction of an accurate and consistent terrain and sea floor. The visible shape of breakwaters or hills is often used as a navigational aid; the TerraTools proprietary integrated triangulated irregular network (iTIN) representation represents terrain and bathymetric surfaces as realistically as possible for a given number of polygons.

The processing steps required to generate visualization are captured in the TerraTools graphical user interface, which depicts the process with an easy-to-understand flow-graph metaphor (Figure 9). An initial flow-graph is set up using a TerraTools wizard or by re-using one from an earlier project. The operator can then easily modify the flow-graph to reflect data sources or processes specific to a certain project.

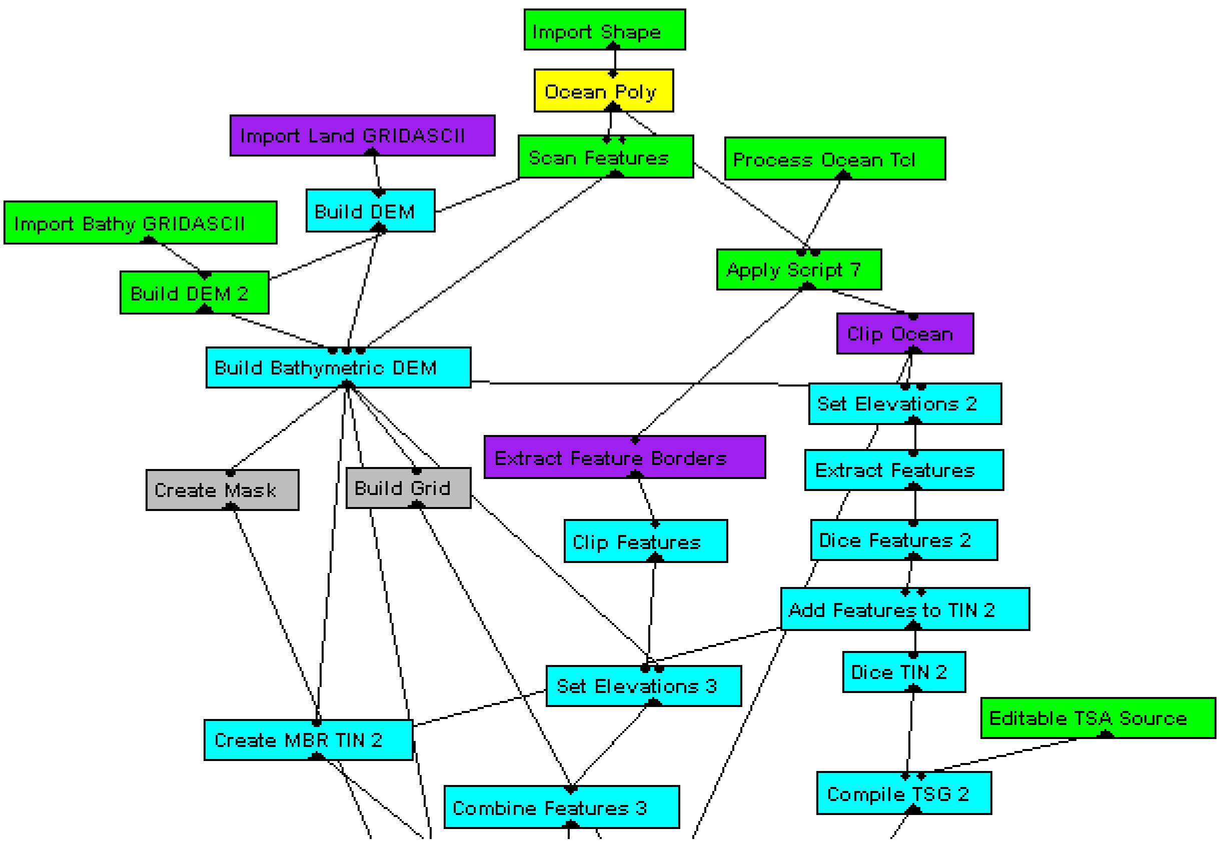



**Figure 9**:
TerraTools process flow graph GUI

The flow-graph interface allows the operator to monitor the status of each step of the processing as it occurs. Nodes awaiting processing are light blue, those currently processing are purple, successfully completed nodes are green, and those which encounter error conditions are yellow or red, depending on the severity of the error. If processing errors occur, the output of any import or processing node can be examined by clicking on the node to bring up the data within an appropriate viewer. Modifications to the input data can be made using either an external GIS or the editor included within TerraTools.

Once the initial visualization has been constructed, any modifications to the processing flow require only that dependent nodes in the graph, (those which use the output of the modified node), be re-executed, thus reducing the amount of re-processing time required. In combination with TerraTools' highly efficient processing and utilization of machine resources, this allows an extremely rapid generate-modify-update cycle. A highly optimized visualization can therefore be produced within a short period of time.

TerraTools includes processing nodes for operations typically required for visualization generation that can be combined as needed. In addition, scripting nodes allow customized processing based on input data attributes. These allow the operator to map data-specific attributes into appearances or geometries, within the semantics of the current project. For instance, an input nautical chart layer may give a point location, with attributes indicating that it represents a certain type of buoy. A scripting node can be used to automatically translate this attribute into the correct buoy model, placed at that location.

One of the most expensive procedures in 3D visualization is the generation of models. TerraTools addresses this problem with an extensive model library of buoy and marker models, which can be automatically placed at positions given in nautical chart data or specified by the user. 3D models of shore structures, such as docks, anchorages, and cranes, can be taken from the model library or created using standard modeling packages and easily imported into TerraTools. Large buildings near the shore are often important navigation landmarks. Building models can be extruded from 2D footprints, imported from external sources or generated in a number of ways, depending on the data available and the level of detail required.

TerraTools can also automatically create a wide range of bridge model types, including truss, suspension, and arch bridges, with their geometry parametrically controlled by specifying pier locations, bridge height, etc. The bridge deck, specified as a 2D profile, is then extruded to create the road surface. A variety of parametric bridge templates are included for easy specification of bridge structure and appearance.

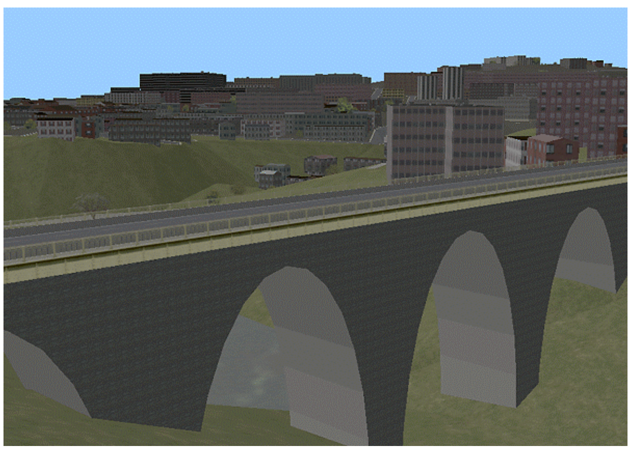


**Figure 10**:
Arch bridge

**Figure 11**:
Suspension bridge

Once the visualization is built, it must be viewed and distributed. TerraTools can output databases in standard simulation formats, including OpenFlight™ and SEDRIS, or in the TerraSim Tiled Scene Graph (TSG) format, a terrain paging format optimized for fast display and interaction. TSG databases can be viewed directly in TSGFLY, the native 3D viewer supplied with the TerraTools product. It supports real-time interaction in both fly and drive modes, as well as navigation along pre-defined paths. This allows free exploration of a scene, as well as rehearsal of pre-defined approach paths. Display of large areas is optimized by the use of levels-of-detail (LODs), reducing the amount of detail displayed on objects far from the viewpoint. This allows harbor features to be represented as simple polygonal structures or even textured flat surfaces when the viewer is far away, which require less hardware resources for display. As the viewer approaches the harbor features, the LODs switch to high-resolution 3D models, suitable for close-range navigation and inspection.

The current release of TerraTools, 1.4, is fully supported on both SGI IRIX workstations and Windows NT/2000 workstations with OpenGL graphics cards. TerraTools projects are fully cross-platform compatible between IRIX and Windows workstations. An extensive and detailed on-line help system is included.

### TerraTools data import/export capabilities

TerraTools can import a variety of cartographic, GIS, CAD, bathymetric and image data formats and export standard simulation and visualization formats.

Bathymetric data import formats:

- CHRTR (DBDB-V export format)
- TDF 2.0
- CDBW (California Department of Boating and Waterways)
- YXZ headerless ASCII

Cartographic data import formats:

- NIMA Digital Nautical Chart (DNC®), VPF®, ITD®, DTED®
- USGS DLG, DEM, SDTS
- XML

3D model/CAD import formats:

- Bentley MicroStation® DGN
- AutoCAD® DXF
- 3D Studio MAX®
- BAE Systems SocetSet®
- MultiGen® OpenFlight®

GIS data import formats:

- ArcView® Shape®, Shape3D®
- GRIDASCII, MOSS

Image data formats:

- TIFF, GeoTIFF
- RGB
- NIMA CIB®, CADRG®

Database export formats:

- MultiGen® OpenFlight® 14.2, 15.4
- SEDRIS 3.0.x
- TerraSim® Tiled Scene Graph (TSG) format
- VRML

## Making visualization work for you

TerraSim stands ready to assist you in adding 3D maritime visualization to your list of capabilities.

**TerraTools sales and support:** TerraTools is available for sale, with comprehensive training courses available to make your operators immediately productive. Tailored training courses for specific applications are also available, as is consultation on database construction problems.

**TerraSim custom visualization construction services:** TerraSim also performs custom visualization construction, working with your data or coordinating the acquisition of suitable data from outside sources. Content, formats, and delivery schedules are tailored to your requirements. Delivered visualizations can be distributed freely with TerraSim's real-time free-flight viewer, TSGFLY. TerraSim can also perform ongoing maintenance and update of the visualization, if desired.

Please contact us at the address below to discuss how TerraSim can best fulfill your visualization requirements.

TerraSim, Inc. is a small business headquartered in Pittsburgh, PA. It was founded in 1996 by four members of the Digital Mapping Laboratory of Carnegie Mellon University to transition technology for highly automated geospatial visualization. Its business is composed of sales of its TerraTools product, contract research and development, and specialized geospatial database construction services. TerraSim can be contacted at: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