1 The Inception of the ArcGIS Marine Data Model

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The increased commercial, academic, and political interest in coastal regions, oceans, and marginal seas has spurred fundamental improvements in the analytical potential of GIS, while extending the methodological framework for marine applications. Many challenges remain, such as addressing the multiple dimensionality and dynamism of oceanographic data, handling the temporal and dynamic properties of shoreline and coastal processes, dealing with the inherent fuzziness of boundaries in the ocean, the great need for spatial data structures that vary their relative positions and values over time, and, last but not least, the development of effective conceptual and data models of marine objects and phenomena.

Increased interest in marine and coastal applications of GIS led to the first-ever ESRI marine special interest group (SIG), which met at the ESRI® International User Conference in San Diego in July 2001. Members of the marine community expressed the need for a marine data model to facilitate the representation and analysis, in digital form, of features along coasts and in estuaries, marginal seas, and the deep ocean. A few months later, in the fall of 2001, leaders of the discipline from professional, academic, and government organizations came together for a workshop at ESRI in Redlands to contribute various perspectives toward the creation of a marine data model.

Why a marine data model?

As noted by Bartlett (2000), one of the most important lessons to be learned from collective experience in the application domain of marine GIS is capable planning and designing of the data model before attempting to implement a GIS database. With regard to ESRI products, many marine and coastal practitioners and organizations use the coverage data model. Although this has largely been successful, coverages have limitations with respect to topology. For example, features are aggregated into homogenous collections of points, lines, and polygons with generic, one- and two-dimensional "behavior" (Zeiler 1999). It has become more vital to distinguish between behavior within feature classes. For example, the behavior of a point representing a marker buoy is identical to that of a point representing a pulsing transponder; the behavior of a line representing a road is identical to the behavior of a line representing a dynamic shoreline. One of the goals of the marine data model is to provide a structured framework that more accurately represents the dynamic nature of water processes. Shapefiles and coverages can now be easily loaded as feature classes in the ArcGIS™ geodatabase for more organized, scalable, and flexible analysis. The marine data model development will provide data managers with a ready-made model for marine data so that they can spend more time at sea collecting data and in the lab analyzing their information, and less time at the computer planning the data structure. It should also be useful to GIS practitioners working as academic, government, or military oceanographers, coastal and marine resource managers, consultants, technologists, archaeologists, conservationists, geographers, fisheries managers, scientists, ocean explorers, and mariners alike.

ArcGIS 8 introduces the geodatabase, an object-oriented data model in which GIS features are smarter; they can be endowed with real-world behaviors for individual objects within the same categories, and relationships, domains, and ranges may be defined among them. (For an overview of ArcGIS object and geodatabase concepts see Zeiler 1999). This has exciting implications for marine and coastal applications, but questions and concerns in the community have surfaced. Given the existing investment, how and when should one make the transition to object-oriented ArcGIS 8? How well are marine application domain requirements met in the geodatabase structure now? What can the community do as a group to understand the technology and identify requirements? What are the potential benefits?

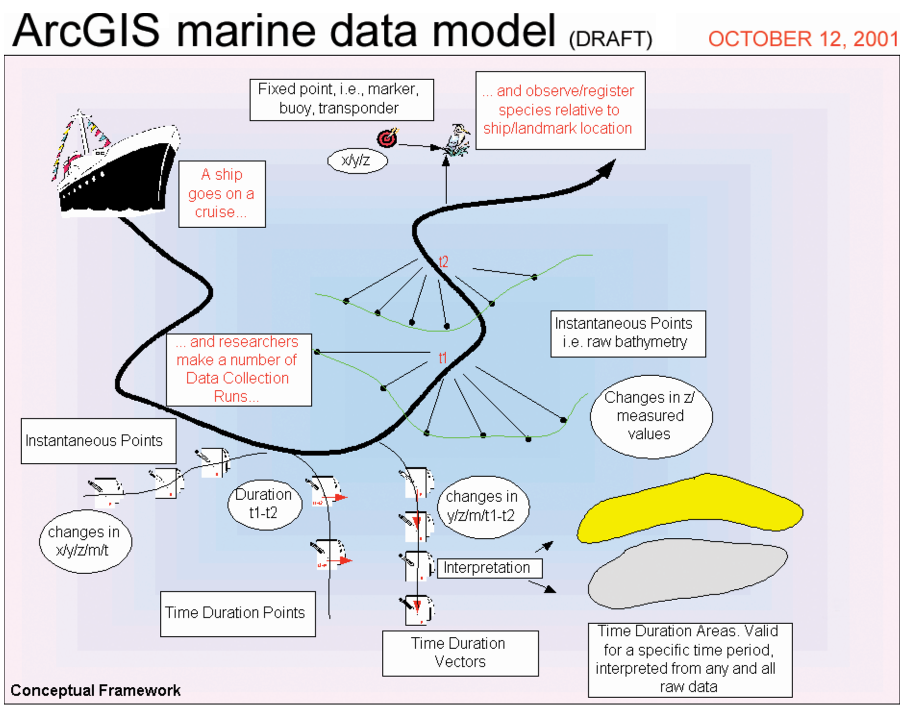


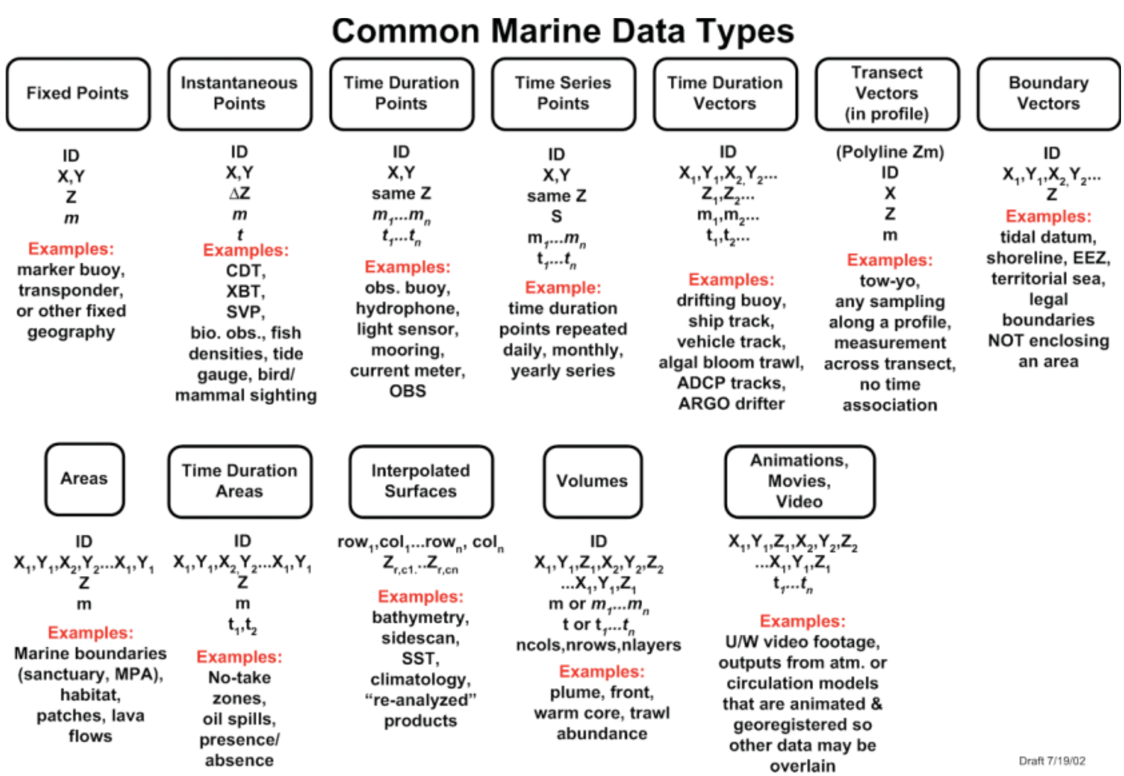
Figure 1: A schematic draft of the conceptual framework portion of the ArcGIS marine data model created by ESRI developer Steve Grisé. This diagram gives a visual representation of the elements of the data model as they relate to important aspects of marine data collection and analysis.

The ArcGIS Data Model working group was initiated to help address these concerns and to support the marine community in making this important transition. The progress of the working group, as well as the general development of the model, and related Microsoft® PowerPoint® slide presentations, can be found on the Web at *dusk.geo.orst.edu/djl/arcgis*. The site includes a form visitors may use to record their interest in the marine data model. Of the initial hundred visitors to the site, a group of 20 was selected to form a review panel for the model. And in addition to development of the data model itself, a comprehensive draft conceptual framework document (upon which this chapter is largely based) was also prepared (Wright et al. 2001), providing a descriptive analysis of the data model development and evolution.

Specific features of the model

A key advantage of the ArcGIS marine data model is that it will help users employ the more advanced manipulation and analysis capabilities of ArcGIS, particularly the ability to capture the behavior of real-world objects in a geodatabase, and the support of more complex rules that can be built into the geodatabase. For users, the data model provides a basic template for implementing GIS projects (i.e., inputting, formatting, geoprocessing, and sharing data; creating maps; performing analyses; etc.); for developers, it provides a basic framework for writing program code and maintaining applications. And while

Figure 2: The common marine data types listed here are the result of a brainstorming session at the first marine data model workshop. This list is evolving and changing with review of the data model.



ArcGIS data models do not create formal data standards, they do promote existing ones, to simplify the integration of data at various jurisdictional levels (i.e., local, state/provincial, national, global). Specific goals include:

- Production of a common structure, a "geodatabase template," for assembling, managing, and publishing marine data in ArcGIS.
  1. For example, the model is specified in an industry-standard modeling notation called the Unified Modeling Language (UML). And because UML code is easily converted to an ArcGIS geodatabase, users can immediately begin populating the geodatabase rather than having to design it from scratch.
  2. Users can produce, share, and exchange data in similar formats.
  3. Unified approaches encourage development teams to extend and improve ArcGIS software.
- Extending the power of marine GIS analyses by providing a framework for incorporating behaviors in data, and dealing more effectively with scale dependencies.
- Providing a mechanism for the implementation of data content standards, such as the Federal Geographic Data Committee (FGDC) Hydrography Data Content Standard for Inland and Coastal Waterways, critical for the Coastal National Spatial Data Infrastructure.

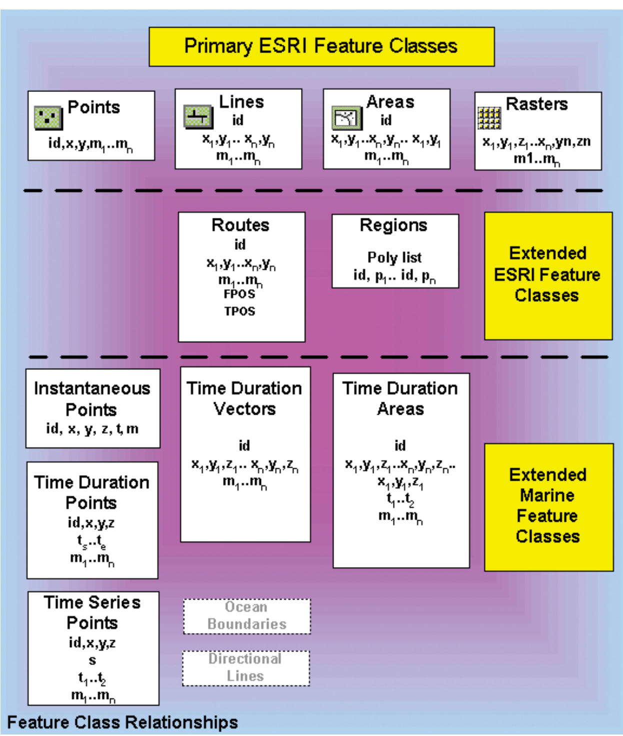


Figure 3: The primary ESRI feature classes are the building blocks of the data model. These are the most commonly used features that provide a topological structure for the underlying data.

In summary, the marine data model will also help marine GIS users to learn and understand ArcGIS. For instance, in the core ArcGIS data model, arc–node topology can be used in conjunction with other new and powerful data structures. Routes and regions are relegated to feature classes. And relationships between tables can be preserved, maintained, and easily managed. Most importantly, already existing shapefile and coverage data can be loaded into the geodatabase for more efficient and effective data management by the marine community as a whole.

The marine data model represents a new approach to spatial modeling in a way that promotes better integration of many important features of the ocean realm, both natural and artificial, and provides more accurate representations of location and spatial extent, along with a means for conducting more complex spatial analyses of the data. The model also considers how marine and coastal data might be more effectively integrated in space and time, particularly into the all-important third and fourth dimensions. The data model, although still limited to 2.5-d, includes “placeholders” to represent the fluidity of ocean data and processes.

Because many marine activities require depth values (z) as an integral part of data collection and analysis, the marine data model attempts to explicitly define z-values in the geometry of the features. Point features typically have an x and y field, and most often in the case of marine data a “z-value” field must be appended for depth. The marine data model includes “z-aware” features; these are points that recognize the z-value as a part of their “shape” field.

As measurements gathered at sea are usually time dependent, different types of time-dependent features are included in the data model. The suggested data model structure explicitly distinguishes between geographic features associated with measurements at a specific point in time (e.g., instantaneous points) versus features that are associated with attributes that are collected over a duration of time (e.g., time duration points, vectors, or areas). Data collected on the coast

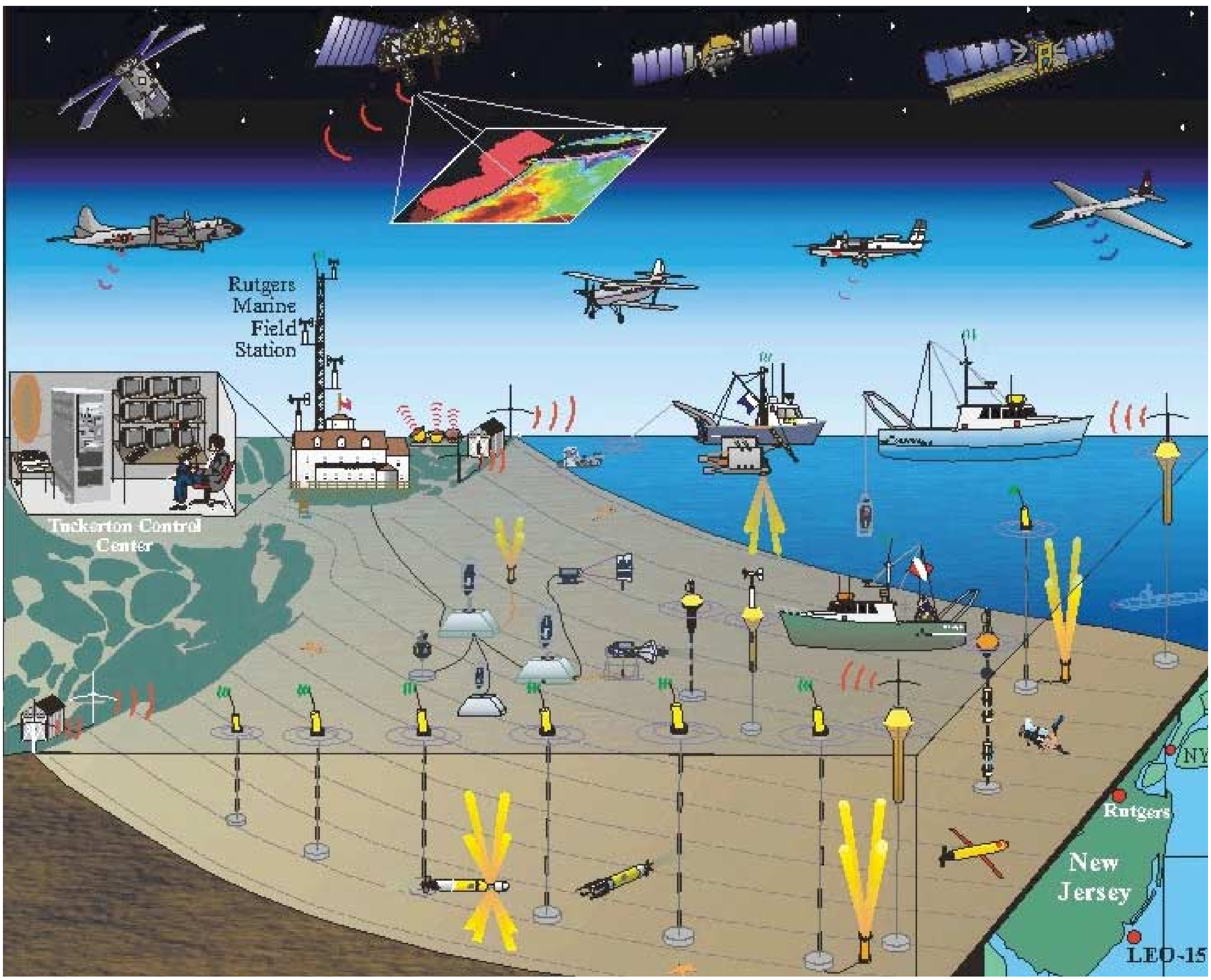


IMAGE COURTESY OF COASTAL OCEAN OBSERVATION LAB, INSTITUTE OF MARINE AND COASTAL SCIENCES, RUTGERS UNIVERSITY, NEW BRUNSWICK, N.J. MARINE.RUTGERS.EDU/COOL

Figure 4: With improved technology comes the ability to collect data in many new ways. This visual representation features many of the data collection methods available today. At the Coastal Geo-Tools Conference in Charleston, South Carolina, in 2001, Jack Dangermond, president of ESRI, spoke of floats that may be employed in the future to gather data from the ocean surface to the seafloor.

and shorelines, for example, often must attribute tidal variance, wave activity, and even atmospheric pressure; all can be more effectively incorporated into the marine data model using time duration points. This principle can also be applied to lines. A trawl or observation run has a beginning and end time used to calculate the effort expended in the collection. A "time duration vector" *(figure 3)* accommodates this type of marine feature class. A primary goal of the marine data model is to make it easier to create spatial data sets that reflect specific differences in data collection and analysis needs of the marine GIS user community not currently addressed by standard GIS models.

Conclusion

Although the focus of the ArcGIS marine data model is on both the deep ocean and the coast, it attempts to represent the essential elements for a broad range of marine and coastal data types and processes. One model cannot include a comprehensive catalog of objects meeting the needs of all user groups and applications. This model is a starting point upon which to build and leverage the experiences of a broader range of practitioners—much broader, in fact, than the specialties of the initial Marine Data Model working group. It will also be desirable to understand the similarities that may exist between the marine model and related data modeling efforts in hydrology, biodiversity and conservation, and land parcel management. Steve Grisé, ESRI development lead for the marine and other data models, says that designing a data model is like designing a new minivan: once it's designed and built you still don't know how a specific family will actually use it. Once a data model is designed and initially implemented, then its most useful applications will become clearer, and it can be refined accordingly.

Acknowledgments

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