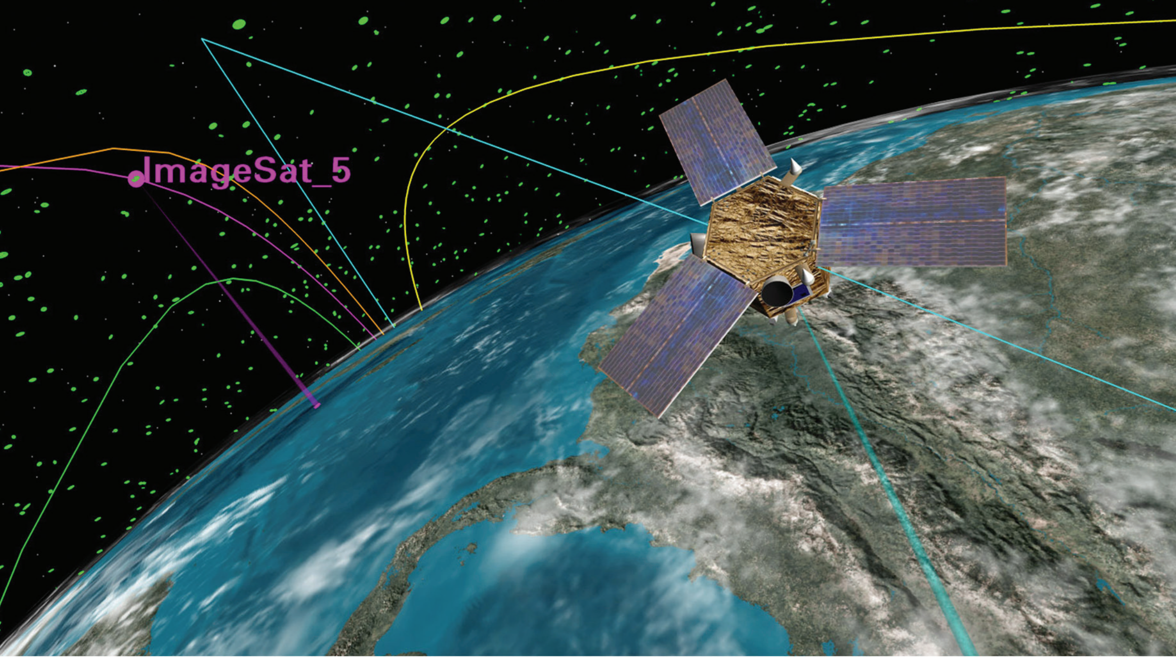
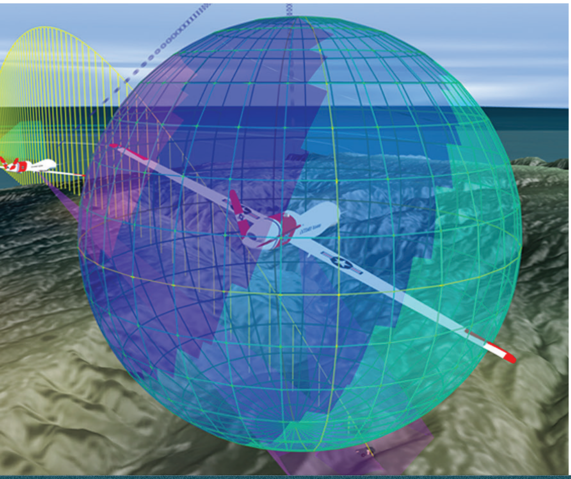
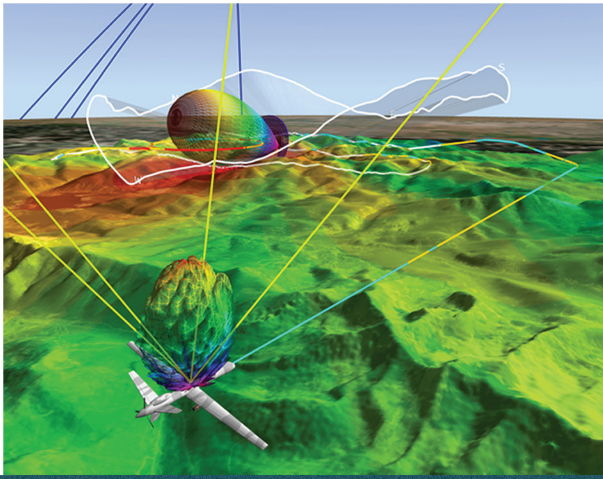


Spatial Temporal Information Systems

An Ontological Approach Using STK®

Linda M. McNeil • T. S. Kelso





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Preface

It wasn't too long ago that I remember sitting in the Mission Control Room at Wallops Island, Virginia, looking at the center screen as a rocket launch was in process. Minutes later, this same launch was again modeled within the STK software and shown by Jay Pittman, range commander and office chief at NASA Goddard Space Flight Center. Needless to say, I was blown away by the physics' dynamics and analysis. This was *rocket science*, visually stunning and with the capability of analyzing the ontology of the rocket and the objects around the rocket. It wasn't long after that time I began a new passion in my life: living and working in the modeling and simulation world of Spatial Temporal Information Systems using STK.

Later, through working on my master's degree in the world of geoscience using geographical information systems at Salisbury University, I realized just how powerful this software was. However, I was hard-pressed to find "how to" manuals that were readily available. Just before graduation, to my delight, my career took me directly to Analytical Graphics, Inc. where I became the DC Metro technical trainer. Here, my thoughts were confirmed: The clients in my classroom repeatedly told me how desperately they wanted a book to hold and guide them into the world of STK. It was with this thought that this book was born.

During this time, the geospatial community had been starving for the answers to strong 4D analytics for a decade and longer. The results of this bursting need gave birth to the Spatial Temporal Symposium that was presented at the American Association of Geographers in 2011, in Seattle, Washington. Here, in the plenary session, Drs. Douglas Richardson and Michael Goodchild laid the foundation for addressing this need. Spatial relationships have been studied in a variety of ways since ancient time. This study of ontology is part of the nature of the cartographic evaluations. Adding time allows us to understand what is happening with these relationships, the shapes of things as they morph. But how do we map that, should it be dynamic or attributal? In Richardson's presentation, he simplified it as the "Five Challenges of Spatial Temporal Analysis" (Space-Time Symposium, April 13, 2011):

- Spatial-Temporal Models
- Temporal Scale
- Ontology
- Real-Time/Real-World Interaction
- Analytical Tools

What is interesting when I heard these five challenges iterated was that I immediately understood how well STK handles all five of these challenges. It gave further credence to the notion that we needed to have more written material in the hands of the scientists so that people might understand Spatial Temporal Information Systems (STIS) and the framework of STK software. STK is not just for the rocket scientist; it is for the geoscientist, the astrophysicist, the engineer, the student, and anybody who has the need to answer physics-based, event-prediction questions. Although there are other forms of STIS used, none show the correlative understanding of ontological relationships as well as STK.

STK has been around since 1989; it primarily resided with the aerospace world of satellite application, so the geospatial community, as a whole, had very little knowledge of what STK can really do. In the last decade, this software has been able to not only maintain the de facto 4D analytics of Satellite Tool Kit but also has become the premier software in analyzing full multi-hop communications and other 4D types of ontology. This has made way for AGI to give the software a new name, Systems Tool Kit (STK).

This book is not intended to be a "how to" book regarding a particular software. AGI offers training courses to do that. At this time, these classes are free of charge and provide a wealth of information. This book, instead, is intended to extend the comprehensive training course. It is a study of the ontology of STK—which can easily be transferred to the study of other software systems to understand why they analyze the way they do.

There aren't a lot of algorithms in this book, deliberately. It is designed to be a high-level, approachable book for engineering college students as well as the PhD who needs further insight into STIS from an ontological perspective. It is expected that the reader has a background in physics or engineering to be able to fully understand some of the concepts; however, it can be used readily by the analyst sitting behind a desk who just needs more information on STK. In the future, there will undoubtedly be more books on the subject. These books will be deeper in concept and narrower in topic. However, for this first book, we now have a foundation to begin the study of STIS from an ontological perspective.

Knowing how well the software could meet these spatial temporal challenges has come through being a student of STK for many years. While I was teaching at Analytical Graphics, Inc., I used many phrases regarding STK. I think my favorite one was taken from the "As Seen on TV" commercials where "But wait, there is more!" truly applies to this software. STK is not just for rockets, satellites, or space. It handles communication, aircraft, ground vehicle, and ship modeling as well. Dynamically, it can handle all of these items together, all based over time or even in real time. This software is absolutely "video games for adults" in every form. Dr. Michael Scott, my mentor and good friend, once told me that "STK is the sexiest software around." I totally agree. I hope you do, too.

Acknowledgments

I can't think of anybody who writes a book alone in a vacuum. We all need collaboration and a transference of knowledge. I would like to personally thank those people in my life who have made this book possible. This book is for you, your friends, and those who need a Spatial Temporal Information System like STK.

Dr. T. S. Kelso: As coauthor and collaborator for this book, T.S. has given insight and guidance for this book and much more. I have always enjoyed working with T.S. He is smart, funny, and most of all, he is a true astrophysicist. Thank you, T.S., for all you did in this book. Thank you for taking time from your busy life of conjunction analysis, conferences, and the never-ending saga of computer changes. Your work is amazing. There are times that I wish I had my PhD and could do what you do.

Paul Graziani: Paul is cofounder and CEO of Analytical Graphics, Inc. He also saw the need for this book and many more that are sitting on the back burner. Without his assistance, this book would not have been possible. AGI has been most gracious to me personally and to those the company employs. It honestly has been one of my favorite places to work. Thank you for the experience.

Dr. Vince Coppola: I love to learn. When you are around Vince, you are in a continual learning environment. One of my favorite things was to go in the back room on the third floor at AGI and dialog with Vince and Dr. James Woodburn. Vince spent a lot of time with me logically walking through how STK works. A lot of that information is distilled for you in this book. His insight into the algorithms, the functionality, and the physics helped me understand how to apply vast amounts of physics to Spatial Temporal Information Systems. His favorite application within the system is "interpolation." Vince collaborated with me on a white paper, "Spatial Temporal Analytics," written while I was still working at AGI. The white paper is the foundation of this book. Thank you, Vince. You're awesome.

The other folks at AGI: Joe Sheehan, Frank Linsalata, Todd Smith, Karen Haynes, Jonathan Lowe, Ed Gee, and the many more whose names I am not able to list. Thank you for all you have done. Rocket science just isn't as hard with your work.

Last, but most important, is an acknowledgment to my husband, *Warren McNeil.* Warren endured this book. The book took a lot of time away from our personal time with each other. When you reach empty nest time, enjoying alone time with your spouse is precious. Thank you for being gracious, kind, and supportive. I am so glad I married you.

About the Authors

Linda McNeil, MSGIS-PA, is currently executive director of the Federation of Galaxy Explorers, a nonprofit space-based STEM educational program. Prior to this, she was a technical trainer for Analytical Graphics, Inc.; her primary function was to train professionals how to use STK software in multiple types of environments from DoD and Intel to NOAA, NASA, and more. She has a master's degree in geographical information systems and public administration from the University of Maryland's Salisbury University. Linda has been working with GIS and other information systems for the past decade. She has 25 years of experience with computer science systems.

Dr. T. S. Kelso is a noted authority on satellite orbits. He is currently a senior research astrodynamicist for the Center for Space Standards & Innovation (CSSI), AGI's research organization that promotes public awareness of space information. He is also the webmaster of CelesTrak, a website dedicated to tracking space objects (including debris) and monitoring them for in-orbit collisions. A retired Air Force colonel with 31 years of active duty, Dr. Kelso served as the first director of the Air Force Space Command Space Analysis Center (ASAC) at Peterson AFB in Colorado; led all Department of Defense analysis centers supporting the Columbia accident investigation; served as part of NASA's Near-Earth Object Science Definition Team; and consulted with the Massachusetts Institute of Technology to provide orbital models for the Hubble Space Telescope. During his career, he has held numerous teaching positions in the field of astrodynamics and has earned vast experience in research, analysis, acquisition, development, operations, and consulting. He is also an associate fellow of the American Institute of Aeronautics and Astronautics (AIAA).

Section I

The Basics

1

The Basics of Spatial Temporal Information Systems

Objectives of This Chapter

- What Is STK?
- Understanding the Basics
- Ontology Introduction
- STK Objects Introduction
- STK Tools Introduction

Introduction

Spatial Temporal Information Systems (STIS) is a name (title) of computer systems with an emerging form of spatial analysis. An STIS is defined by the positions of objects within the environment, the use of dynamic time intervals, ontology or the study of the relationships of the objects, real-time or real world modeling, and lastly, the use of analytical tools. It is a blend of traditional Geographical Information Systems (GIS) with the use of Modeling and Simulation techniques. Our focus of this book is to reveal how an STIS works from the ontological perspective. Our approach is to show how an ontological relationship can be formed in an STIS by evaluating the objects and tools used within the environment. This is not a study of the algorithms used but a focus on how the objects and tools form relationships. This is a study of ontology as it is used within an STIS. The software used to create this study is Analytical Graphics' primary software, Systems Tool Kit® (STK).

An STIS is a system that includes spatial analytics but focuses on position and time. Just as ESRI's Arc software is a GIS, AGI's STK is an STIS. This book is about an STIS example using STK as we focus on how the objects and the tools work together to really understand the relationship of the position of objects over time. The use of ontology allows us to understand these relationships formed by the use of objects and tools. The focus of this book breaks down the ontology by discussing each component of the ontological relationship—the objects, the tools, and the output. This is where the value of the book will be to you, the reader. When you understand the theory of ontology as it is applied to the system, you can apply this to any spatial temporal system and understand spatial analytics with almost any system. The idea of using ontology is unique. Ontology is a database form of analysis. This approach changes the way many people look at a system.

Analytical Graphics, Inc. (AGI) makes Systems Tool Kit (STK)—a high-fidelity modeling and simulation (M&S) tool that allows analysts and engineers to model the spatial and temporal relationships between objects operating on the land, on or under the sea, in the air, and in space. STK provides an easy-to-use framework to define the properties of each object in this simulated environment and how it moves and is oriented over time. This framework allows the user to dynamically explore in depth the relationships among the objects.

As with any high-fidelity tool, understanding and mastering the tool can be a challenge. AGI provides an array of training to all STK users, but even a weeklong exposure only cracks the surface of the power of STK. College courses are being taught around the world to help the user understand the software and leverage the tools. From the industry user to the college student in the classroom, it is for such students that this book was written. The book is designed to help the dedicated STK user develop a deeper understanding of how STK works and the importance of the data being used within it to tackle everyday analysis tasks. This book extends the comprehensive training course that is taught by AGI. It explains more about how the software works from the computer science perspective of ontological relationships. This is a fundamental on-the-shelf reference guide. This book was written during the publication of STK Professional version 9.2.3 and glances into version 10. Although the book is written to represent STK in a universal way that will transcend versions and levels of software capabilities, all interpretations of object attributes and software capabilities are based on this version.

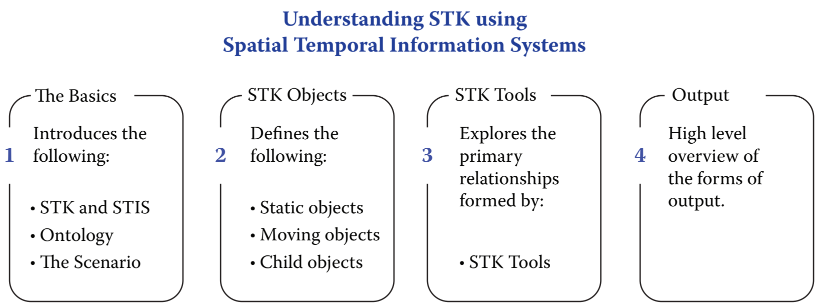

FIGURE 1.1
Outline of book.

This book is divided into four main sections for easier understanding: The Basics, STK Objects, STK Tools, and Output. Part I, The Basics, is comprised of three chapters in the exploration of STK graphical user interface (GUI) navigation, identifying the basic parts within the software, and a guide on how to build a scenario. The STK Objects section, Part II, takes a detailed look at primary STK Objects. These chapters focus on how to define the object's position and other attributes. In addition, the STK Objects section takes a deeper look at defining an object's constraints and how these constraints affect analysis. The STK Tools section, Part III, gives insight to leveraging the computation of intervisibility, event detection, and signal evaluations. The final section, Part IV, Output, discusses graphics using static graphics, dynamic maps, reports, graphs, and the data providers that work with this form of output (see Figure 1.1).

Understanding STK Basics

STK software has advanced analytical tools to help engineers and analysts understand line-of-sight event detection that occurs with objects both on Earth and in space. Aerospace Corporation's summary remarked that "access and visibility calculations were accurate to a high degree of confidence" (Aerospace Corporation, *Independent Verification and Validation*, 2000).

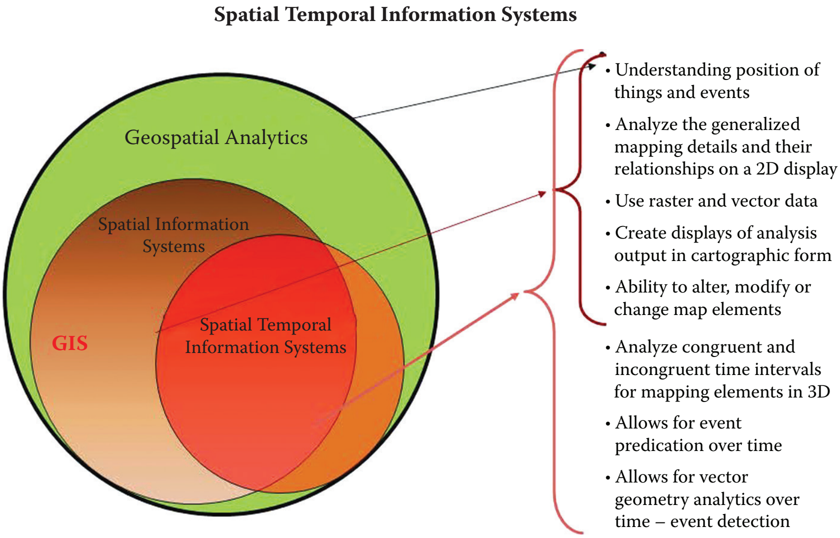

FIGURE 1.2
Spatial Temporal Information Systems.

STK is considered a Spatial Temporal Information System that models the position of objects at specific places and times. The dynamic interaction of objects combined with the event-detection tools allows the user to evaluate relationships from one or more objects to others over time. What sets STK apart from other modeling and simulation software are the time-dynamic event-detection capabilities. Cartographic output of these evaluations, as well as the ability to make movies and print graphs and reports, adds to the strength of STK. Formally, an STIS is defined as a specialized spatial information system that includes the element of time-based analysis. An STIS uses event prediction for objects, a 3D environment, and cartographic output (see Figure 1.2).

The STK interface provides an easy way to create objects and apply tools. Within STK, these objects and tools use physics-based modeling to answer questions and analyze specific time intervals within a variety of coordinate systems. Time intervals may be based on real or simulated time. Objects may be synchronized to the animation time clock defined within the software or have a user-defined time interval. Tools, which are used to evaluate the events or proximity of objects, use time intervals defined within an object or may be specifically user defined.

The Workflows of STK for Ontological Studies

There are two different workflows used within STK: (1) the basic workflow of the software interface, and (2) the engineering workflow used to define the semantic level of the object, tool, and output attributes that allows for easy object and tool development. STK's basic workflow is supported by a graphical user interface (GUI) that guides the user through the steps to develop a scenario and allows for interactive manipulation. STK's engineering workflow allows the user to configure attributes, also called properties, for the objects and tools to enhance analysis.

The GUI is built modularly to allow user customization (see Figure 1.3). Because STK uses many of Microsoft Window's rich tools within the workspace, the user is able to configure the window positions and orientations to create a unique workspace environment. This allows the workflow to be customized also.

STK is analytical software that evaluates the relationships between real-world modeled objects and tools used to calculate line of sight, intervisibility, statistical variations, and signal analysis. The Engineering Workflow guides the user to define the STK Objects and STK Tools to the level of fidelity needed for each evaluation. When developing objects, the user uses the property arrangement to customize unique property attributes and make the object more realistic in physics capabilities and characteristics. Each

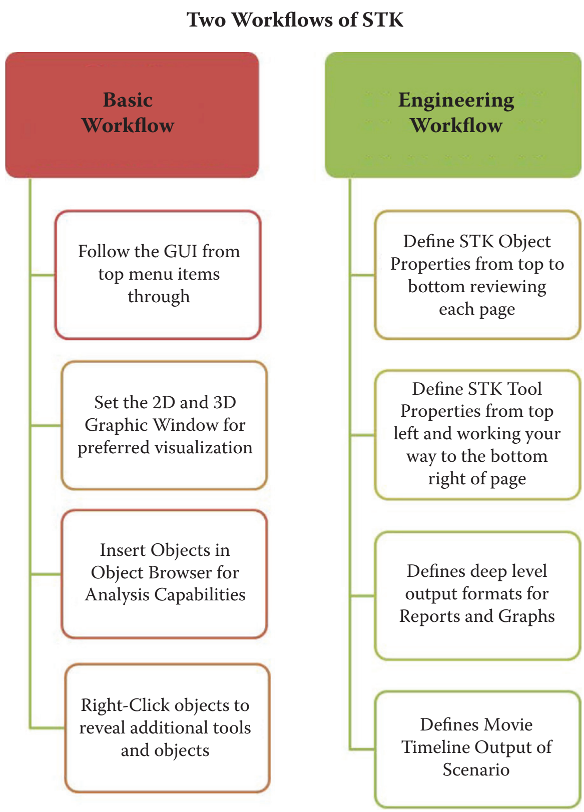

FIGURE 1.3
The basic workflow defines the environment of the scenario from a global perspective. The Engineering workflow is a systemic approach to defining the objects and tools in a more local manner using visual clues from the software features.

object has basic default parameters that allow computing for basic refinement. However, if more low-level, robust, and closer-to-real-life analysis is needed, then refining the properties and tools to match real-life characteristics is essential.

The STK object has a properties window with a list of several pages in the environment. Working these pages systematically from the top page down to the bottom is using the engineering workflow that is designed into the software. As these pages are modified to match a unique property, it allows the user to evaluate situations that simulate the real-life object it is modeling. Leveraging the engineering workflow allows users to easily develop ontological studies within the software. It is an approach to ease the use of how to develop scenarios, input objects, and use the tools within STK.

Ontology

To have robust analysis, the engineering workflow is used to develop the ontology of the STK Objects by using the STK Tools. In the computer science world, ontology is the formal study of set domains and their attributes, as well as the relationships between these objects. In other words, it is the semantic-level evaluation of the relationships between objects, tools, and output as they are defined. STK allows you to create ontological studies in repeatable iterations or deeper refined versions to assist you in understanding real-world problems and the solutions STK shows you. As you review the objects and tools within the sections of this book, the ontology should become apparent (see Figure 1.4).

Reports and graphs are also refined using the engineering workflow and are the output of the ontological studies. Some of the ways tools vary are in analysis time intervals, use of light-time delay, or signal qualities. All of these items can be modified by using deep-level property changes found within the workflow of the tool or within the data providers from the Reporting and Graphs Manager. The engineering workflow will be further defined for both objects and tools during the course of this book.

STK is visually as well as analytically accurate as long as the STK Objects and the relationships with the STK Tools are defined with a high degree of fidelity. The STK Objects have attributes and constraints that refine the dynamics, kinematics, and capability. The STK Tools also may be refined by constraints,

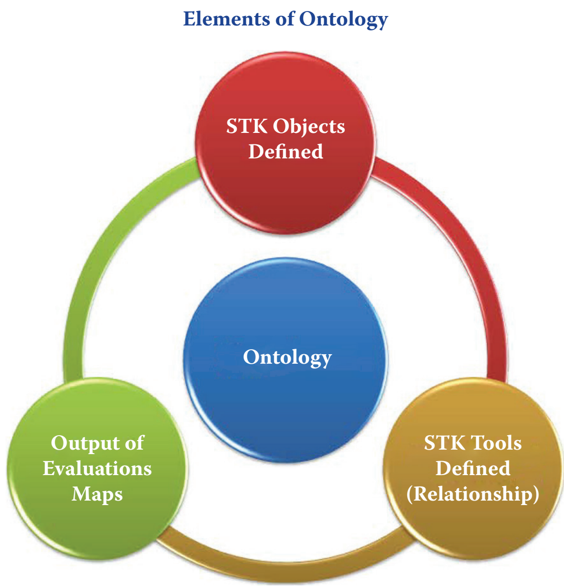

FIGURE 1.4
Elements of ontology.

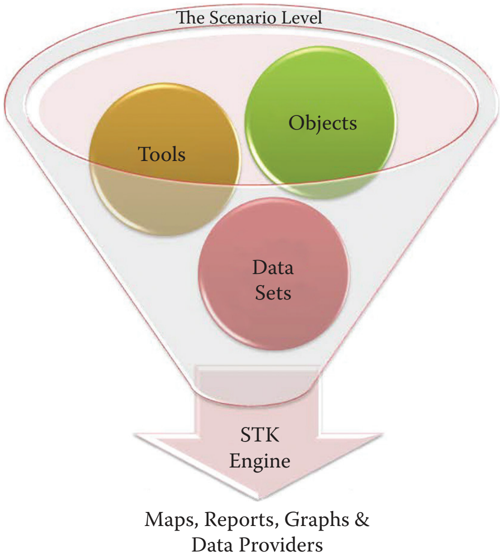

FIGURE 1.5
Dynamic STK.

step size, and methods of calculations. The attributes and constraints of both the STK Objects and Tools include data providers created to develop the computational data elements needed for the algorithms. In an integrated fashion, these elements of objects and tools and their defined properties result in an output evaluation. The time-dynamic geometry engine compiles the algorithms from these data providers of STK Objects and the relationships, as they are defined by the STK Tools. The output for these calculations is presented in reports, graphs, and visual responses (see Figure 1.5).

Delineation between Objects and Tools

Within STK, the delineation between objects and tools is not overt within the GUI. Objects and tools are two different things by function. STK Objects are physical objects that have a position in three-dimensional space. STK Tools define relationships between the STK Objects that are usually based with the time-dynamic geometry engine or by tools that enhance the STK Object. Within versions 9.*n* and previous, STK has a section for STK Tools, Tools and Attached Tools (Children Tools), that is within the STK Object Browser and STK Tools that are a right-click off the objects. However, because objects and tools function differently, we have chosen to divide them in an obvious way in this book.

Objects are the object classes that represent items of the real world. These items may be a fixed point for a facility, city, town, or target. They may also represent moving vehicles, such as missiles, ground vehicles, ships, or satellites. Objects may be a region of interest as represented by the polygonal area target or may be a point representing central bodies, such as moons, planets, and stars. If there were a grammar structure within STK, we would call the object class a set of nouns.

Whereas, using STK grammar, the object class represents nouns, the tool class represents the verbs of the grammar. Tools classes are event-detection tools. Primarily, they analyze intervisibility, but they may also calculate proximity analysis and signal evaluations. Access is the primary tool that handles intervisibility calculations. It is the underlying calculation for most event-detection tools. Other tools are Deck Access, Chains, Coverage, Conjunction Analysis, Vector Geometry, Terrain Conversion, and forms of communications with signal processing. Because of the difference in functionality, tools have been separated to show how they are used and defined within STK at a very semantic level.

Exploring the Objects

The STK Objects section provides valuable information about the robust nature of STK Objects. Objects within STK are used to model real-life buildings, equipment, or places within the software. The benefits of using the unique time-driven, object-orientated modeling within the STK environment become evident when attributes are defined on a semantic level for each object. The more realistic each object's attributes are in relation to the real-life object being modeled, the closer to real-life results ensue with the evaluations during the tool analysis, modeling, and simulation.

Objects are brought into the GUI environment using object-orientated methodology called encapsulation. Encapsulation is a class that allows the object to be accessed by an array of different methods depending on the level of access granted by the method. These different methods may or may not have unique attributes available. There are two main types of object methods that use encapsulation: the Scenario Object Selection Method and the STK Object Route or Position method (see Figure 1.6).

For instance, when you bring an aircraft into the STK Scenario environment, there is an array of Scenario Object Selection methods; one of them is "Insert Default." The default parameters within these properties are set for you to create a generic aircraft and define the properties at a very high level that only allows basic route waypoints to be selected. As you modify the STK Object Route properties, you may create an aircraft using Aircraft Mission Modeler (AMM). AMM is an enhanced modeler defined by aircraft type and

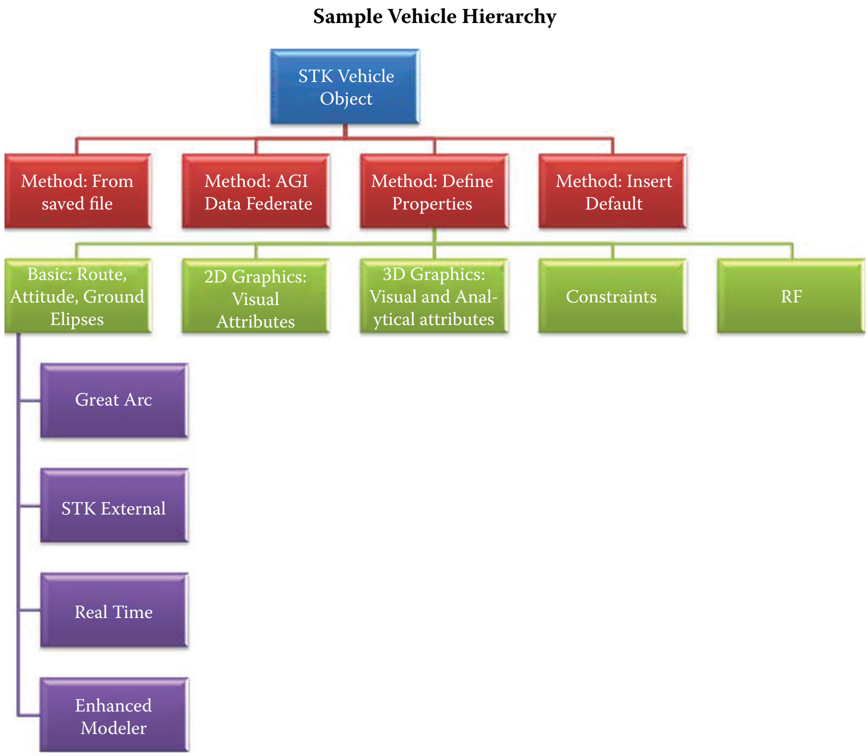

FIGURE 1.6
Sample of the vehicle hierarchy.

mission. This level of method allows you to create a low-level model with a propagation method used to model real flight found within the route definition of the STK Aircraft properties.

There are two types of primary objects: parent and child. Through the use of object-orientated programming methods, inherency, the parent–child relationship is established. Inherency is an object class that allows a subtype object to use the rich attributes of the parent object and also include unique attributes of its own to model a specialized behavior. With STK, the parent objects, often called Scenario Objects, have a position, orientation, and time interval that is unique. Children, or Attached Objects, are a subtype to the parent object and by default utilize many of the characteristics of the parent object, such as position, orientation, and time interval (see Figure 1.7).

Object classes use encapsulation and inherency to allow STK Objects to be modified and made more realistic by changing the default parameters and matching the actual properties of an object more closely. The more refined an object is, the more accurately the analysis will match real-world scenarios. Object properties allow for deep-level analysis of events, such as intervisibility,

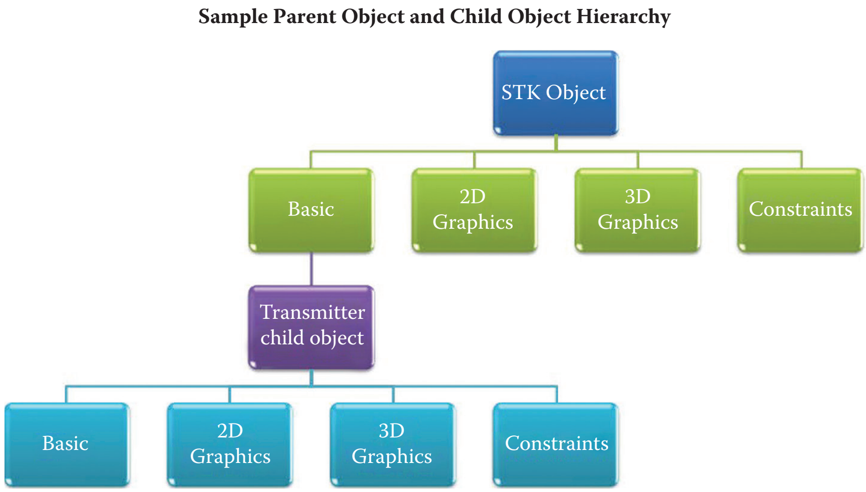

FIGURE 1.7
Parent–child hierarchy.

proximity, and qualitative evaluations. Propagators, or the predicted motion of an object, are calculated from within the properties of the object vehicle.

Building Relationships with STK Tools

The STK Tools section evaluates the primary tools within STK and gives you a semantic-level understanding on how they work and what types of relationships they are used for. STK Tools build and evaluate relationships within the STK environment. This section explores what event-detection

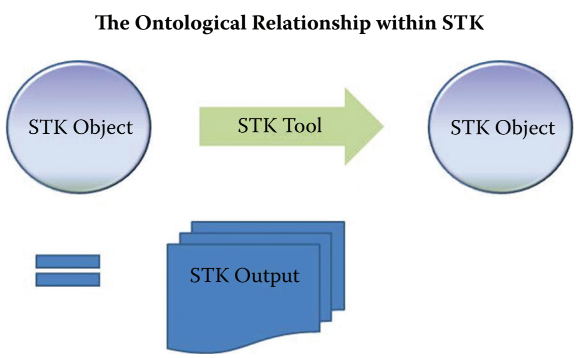

FIGURE 1.8
Ontological relationships.

tools are and how they calculate object intervisibility, proximity evaluations, signal quality for single communications, and multihops. Tools within STK are specific and are determined by the events that are needed to be evaluated. Intervisibility events are used to calculate within tools such as Access, Deck Access, Chains, Communication Devices, and Coverage. Another event tool calculated is Conjunction Analysis. This is used primarily with orbiting space vehicles or objects. Most event tools use the Access interpolated algorithm as the basic form of computation (see Figure 1.8).

Output

The last section of this book allows you to explore of the methods of output. Movies, static pictures, graphs, and reports are all forms of output within STK. As an intervisibility event is established, you can output reports and graphs that tell you the duration the objects can maintain the relationship, the time intervals in which they have the relationship, and even the look-angles used to establish the relationship. Cartographic output can be visualized in animation mode to simulate the object's movement over time or by creating static pictures of the events as they happen.

STK Tools evaluate the kinematics and dynamics of the STK Objects and how they interact with each other over a defined time interval. The interaction may be based on the proximity of the objects. It may consider the orientation of signal devices or the possibility of signal loss due to obstruction or degradation. Because space orientation and time intervals are critical for understanding, STK considers every object with its own coordinate system attached to the body frame to evaluate vehicle propagation and orientation evaluations and the application of constraints based on vector geometry of the object body. This tool capability gives relevance of time dynamics and physics applications to queries of, for example, when an object will be able to lock onto a signal or to understand how close objects are to one another. STK Tools evaluate the intervisibility, quality, and quantity of objects and signals. The output of this software allows you to visualize and analyze the objects and the tools from a modeling and simulation perspective.

Data Providers

Data providers are the low-level attributes of the STK Object or STK Tool used to refine the output of an analysis. Components of the STK Object and STK Tool attributes are broken down into three primary types: Geometric, Time, and Calculations. They are hierarchical in format. Therefore, some of the property page attributes may contain time-interval information and vector-geometry-related information from the same page. Data providers are used heavily to create and customize data displays, reports, and graphs. They also are used to provide detailed verification and validation of the results. Data providers have the ability to break apart the computation algorithm and derive new algorithms at runtime of the STK Engine. Data providers are powerful. With version 10, expect to be able to leverage data providers better using the Time and Calculation Tools.

What to Expect

As we begin to explore the world of STK, we can apply the approach of this study to many other software applications. Our goal is to understand the world of Spatial Temporal Information Systems. By using the approach of ontological studies, we can understand the implications of creating relationships between objects, defining the objects, and then modifying these objects (see Figure 1.9).

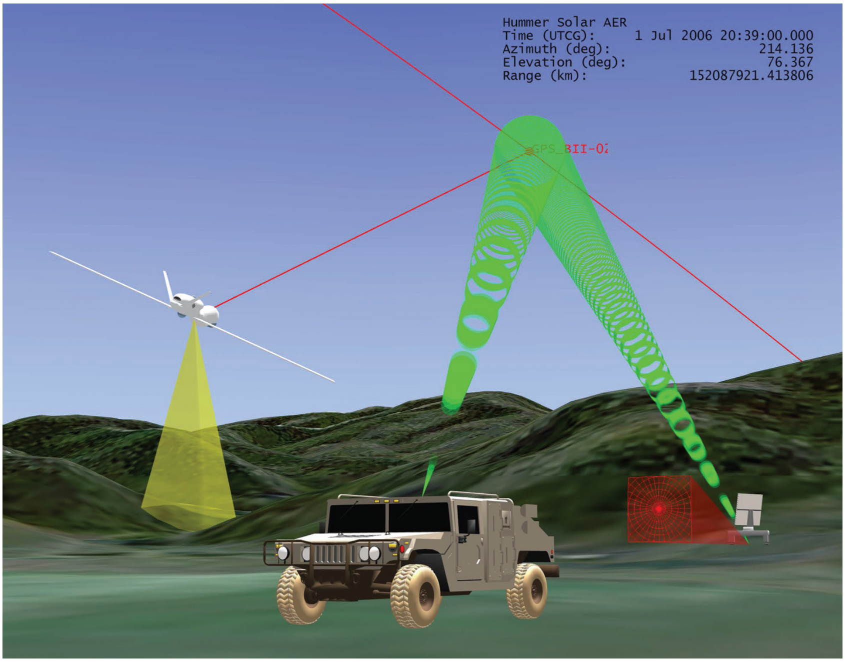

FIGURE 1.9
Example of object relationships.

2

Ontology

Objectives of This Chapter

- Defining Ontology
- Understanding the Level of Properties
- Exploring STK Objects, STK Tools
- Exploring the 2D and 3D Object Windows

Defining Ontology

Ontology in STK is used as a formalized study of the STK Objects, STK Tools, and the results from the analysis. The word *ontology* dates back to ancient Greek philosophy. The basic Platonic metaphysical meaning of the word is "the understanding and conceptualization of entities in categories and their generalizations." However, in the late 1900s, computer scientists such as Dr. Thomas Gruber from Stanford University modified this term as "the conceptualization analysis of objects and relationships in body of knowledge sharing and knowledge acquisition." In other words, ontology is the study of concepts or objects and their relationships within a domain. The use of ontology captures the data structures derived from the relationships and makes them visible. Dr. Gruber's work is currently governed by standards within the Resource Description Framework (RDF) and the OWL Web Ontology Language Guide for Computer Science. With STK, we use Dr. Gruber's definition of ontology to fit within the domain of the Spatial Temporal Information System (STIS) software.

Ontology within STK creates a focused level of study regarding how relationships are formed and defined between STK Objects. This study includes not only the semantic level of the STK Objects and the STK Tools that form the relationship but also the output of those relationships. The rigor of the study is completed by a full understanding of the semantic level of the STK Objects, including the methods and attributes of the object. STK Object attributes are defined by the properties and constraints. In addition to defining the STK Object, the STK Tool must also be defined. The tool defines the relationship between the STK Objects and builds the algorithms for a computed output or analysis result. The newly formed equations from the objects and the relationships are computed by the STK engine. The data, when computed, are visible to the user by the use of maps, graphs, reports, and simulation. When either the STK Object or the STK Tool has been modified, the data need to be recomputed and the output will reflect the changes from the results.

It is easiest if we think of each part of STK as individual sets of information within a domain (see Figure 2.1). For instance, the Root level of the software is the global domain of the software where the scenario level resides, whereas the STK Objects, STK Tool, and output (graphs and reports) are localized sets. The STK Objects are defined by attributes and constraints that modify their spatial relationship as they are analyzed and compared to other STK Objects. As mentioned before, the STK Tools are what define the set relationships among the STK Objects. These set relationships can be based on spatial position, distance, angles, orientation, and line of sight. After forming the relationships of the objects using the STK Tools, the primary algorithms are then computed using the STK Engine, allowing the output to be displayed. By creating set domains for each part of the software, we may refine the attributes of each entity within the sets and fully understand our analysis.

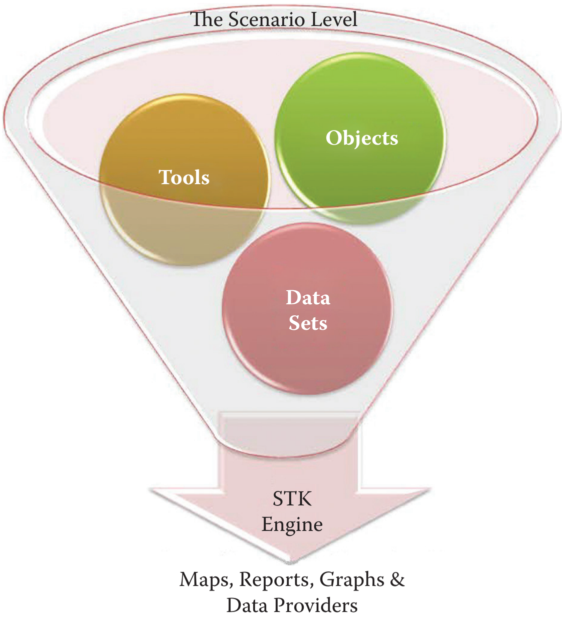

FIGURE 2.1
Dynamic STK.