Solid Modeling of Directed-Energy Systems

By Joseph F. Sharrow

Not long ago, around the mid-1980s, development of most new mechanical systems—such as automobiles, consumer products, and military devices—was performed manually on a drafting table or drawing board, much like the present-day version shown in Figure 1. These tables and boards performed a necessary function, but they offered little assistance other than for drawing lines. Engineers used them to prepare layouts, or two-dimensional sketches of what they were designing. They then would take these layouts to a draftsman, who would create drawings of each part in the device. The drawings would subsequently be sent to a manufacturing facility.

This layout and drawing preparation process typically would need to be repeated multiple times because mistakes would be made, or design issues would be discovered late in the process. Similarly, the manufacturing process would sometimes require multiple iterations as well because of the inherent limitations in designing three-dimensional (3-D) devices on two-dimensional boards. This less-than-ideal process made it difficult to design and manufacture even mundane products and frequently resulted in things that just didn't work. With the emergence of early computerization, numerical analyses of more complex systems began to be performed. These analyses were conducted to ensure that the systems worked in the real world. For example, engineers might conduct a structural analysis of the forces in a loaded dump-truck bed to make sure that the frame wouldn't bend and fail. Because of the difficulty in performing these analyses, they would often require a specially trained group of structural engineers, expensive software, and large mainframe computers, limiting their use to only the largest, most well-funded companies or organizations.

Emergence of Computer-Aided Design (CAD) and Solid Modeling

With the availability of smaller scale computers and more economical software in the mid-to-late 1980s, CAD was born, initiating a period of rapid improvement in the design process. This was driven, in part, by the introduction of software packages such as AutoCAD. Initially, these software packages only attempted to automate drawing lines by making wireframe (stick-figure) versions on the computer of what previously had been made by hand on the drafting board. This reduced the difficulty in making changes in the development process, but it still limited the engineer's pallet to a two-dimensional space. What was really needed was a 3-D method of design. Solid modeling

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2012		**00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE	
Solid Modeling of Directed-Energy Systems	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center, Dahlgren Division,Corporate Communication, C6,6149 Welsh Road, Suite 239,Dahlgren,VA,22448-5130**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

See also ADA556728.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

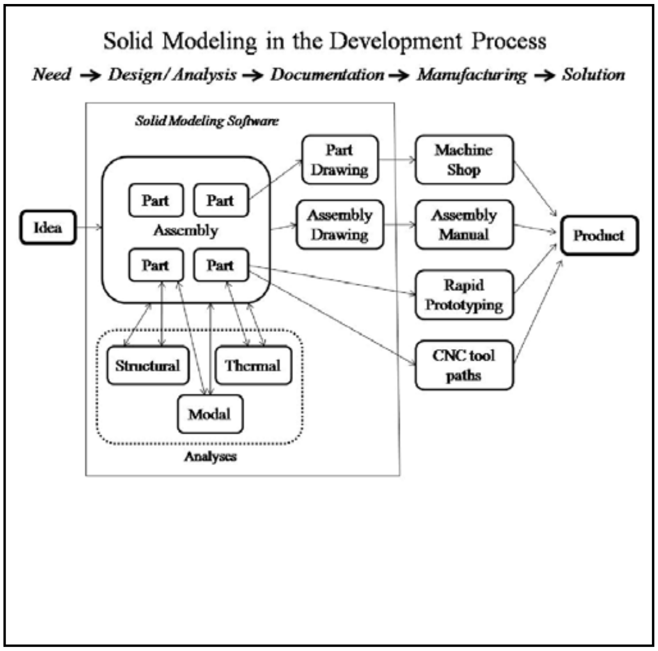

Figure 1. Drawing Board

addressed this need beginning in the late 1980s to early 1990s.

Solid modeling is analogous to taking blocks of clay and cutting and forming them into the shape of a solid part on a computer. These 3-D parts are then put together in an assembly, more accurately representing real-world devices. Though originally used only in a limited way for specialized applications in the aircraft and automobile industries, it wasn't until the 1990s that solid modeling experienced widespread availability and mainstream acceptance due to software packages such as Pro/ENGINEER. Figure 2 summarizes how Pro/ENGINEER and other similar packages fit into the development of new products. The general flow of the process moves from left to right.

Initially, nearly all 3-D solid modeling packages required significant computing and graphics display power, necessitating the use of large graphics workstations running the UNIX operating system. Rapid advances in computing and graphics power have since enabled nearly all packages to run efficiently on personal computers (PCs) and laptops, bringing solid modeling and analysis capability into the mainstream.

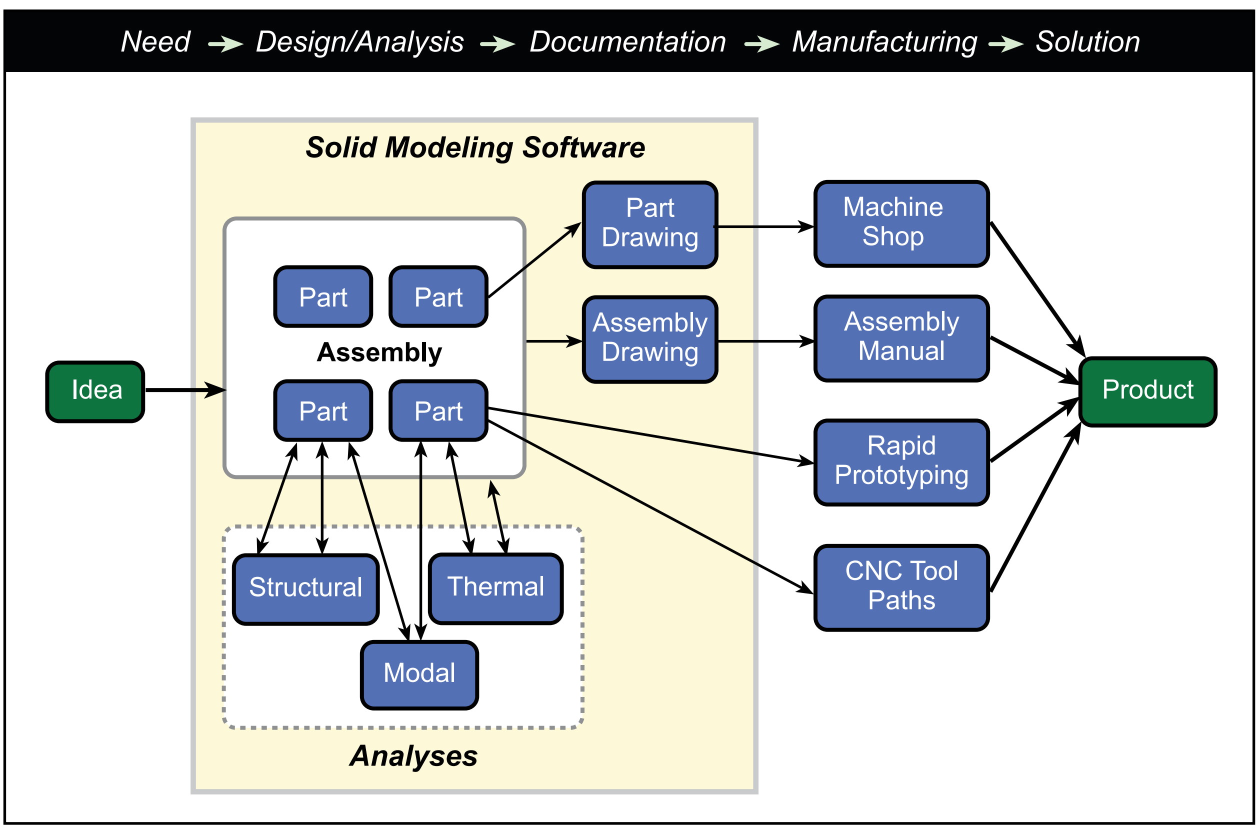

Figure 2. Solid Modeling in the Development Process

Solid Modeling of Directed-Energy Systems

Engineers working in the Directed Energy Division at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), use solid modeling to develop hardware for nearly all of its programs. Both Pro/ENGINEER and SolidWorks are used extensively to develop new products in virtual 3-D space. Additionally, the structural simulation package within Pro/ENGINEER is used to determine stresses and natural frequencies of parts and assemblies. Consequently, these packages have enabled a single mechanical engineer in the Directed Energy Division and a draftsman in the Engagement Systems Department at Dahlgren to perform the design and analysis work that would have required an entire group of engineers and draftsmen just a few years ago. Today, collaboration among many organizations using similar packages has become commonplace. Insofar as solid modeling has become an indispensable tool for development and collaboration, its successful implementation requires proper training and experience before engineers can use it effectively, just as medical surgeons require training in the use of advanced robotic surgical devices before they can be used effectively. Thus, while these high-tech modeling systems not only have reduced the number of personnel needed for design and development, they have enabled the Navy to get significantly more bang for its buck while supporting warfighting needs. An example of how solid modeling is currently being used is discussed below.

Navy Laser Weapon System (LaWS) Beam Director

The Directed Energy Warfare Office (DEWO) and Directed Energy Division at Dahlgren are currently developing the Navy LaWS for the Naval Sea Systems Command's Directed Energy and Electric Weapon Systems (DE&EWS) Program Office (PMS 405). The program's goal is to take advantage of currently available industrial laser technology and incorporate it into a future naval weapon system. As part of the development process, major subsystems have been integrated with a Kineto Tracking Mount (KTM) into a LaWS beam director. The KTM/beam director was modeled and analyzed using Pro/ENGINEER. Ultimately, the resulting LaWS will be installed on Navy ships on the Close-In Weapon System (CIWS) gun mount. During field testing in June 2009 at the Naval Air Warfare Center, China Lake, California, the prototype KTM/beam director successfully destroyed five unmanned aerial vehicles (UAVs). The actual beam director used in the China Lake testing is shown in Figure 3; the Pro/ENGINEER assembly model used for development is shown in Figure 4.

The LaWS effort took advantage of many aspects of solid modeling including collaboration, structural and modal analysis, and manufacturing drawing creation. The project required development of new, unique hardware, as well as the integration of electronic models from commercial vendors. The KTM model was provided by L-3 Brashear and was originally designed using Pro/ENGINEER. The beam-directing telescope model was provided by RC Optical Systems, Incorporated, and was originally made in SolidWorks. These models were combined with many new optical and structural components developed by the Directed Energy Division into a single, comprehensive assembly model. This model was instrumental in understanding the interaction of the many components, and its use increased accuracy and precision that would have been impossible with old-fashioned two-dimensional development processes. Figure 5 shows a cross section through the main portion of the beam director, revealing the complexity of the many parts and subassemblies required for such a device. In addition to modeling the mechanical components, the actual laser beams were also included to better understand their path through the various mirrors and optical devices in the beam director, and to better highlight any interference they might have with structural components within the KTM or telescope.

Numerous analyses were performed to make sure that everything worked the way it was intended. One major analysis addressed the telescope mount. To ensure that the beams were stable at range, the mount had to be extremely stiff. The best way to ensure this was to perform a structural analysis using the structural simulation package within Pro/ENGINEER. Figure 6 shows the results of that analysis: a displacement plot in which different colors represent how much the telescope will move when the KTM rotates at its maximum speed. The large cylindrical object simulates the mass of the telescope. The minimum amount of displacement is indicated by blue, and the maximum is shown in red. This analysis verified that the movement of the telescope, relative to the optical components within the optics breadboard, was acceptable and should perform well at the range specified by the program office.

After modeling and analysis were completed, manufacturing drawings of custom parts were created by the Engagement Systems Department to be

Figure 3. LaWS Beam Director

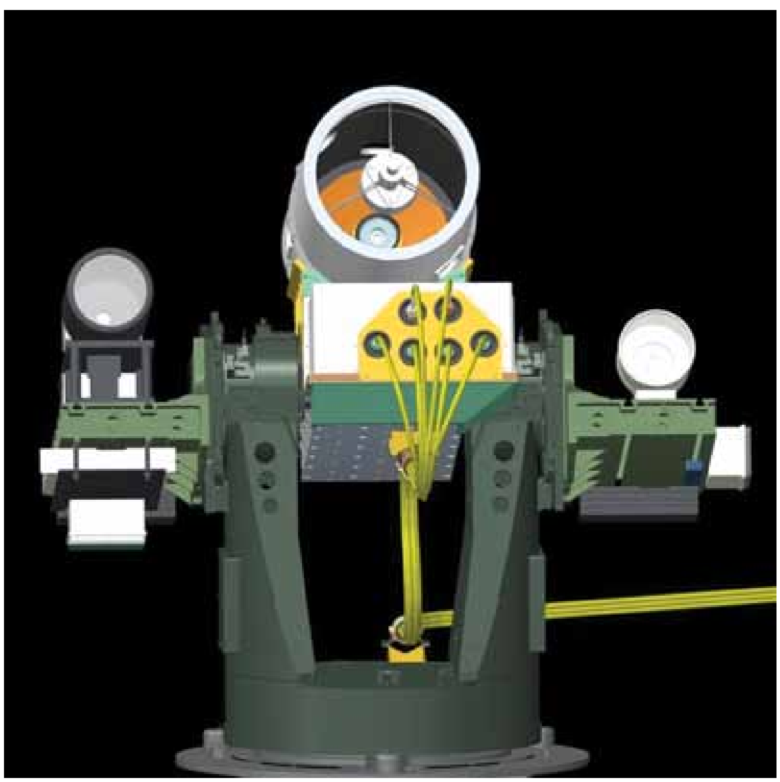

Figure 4. LaWS Beam Director Assembly Model

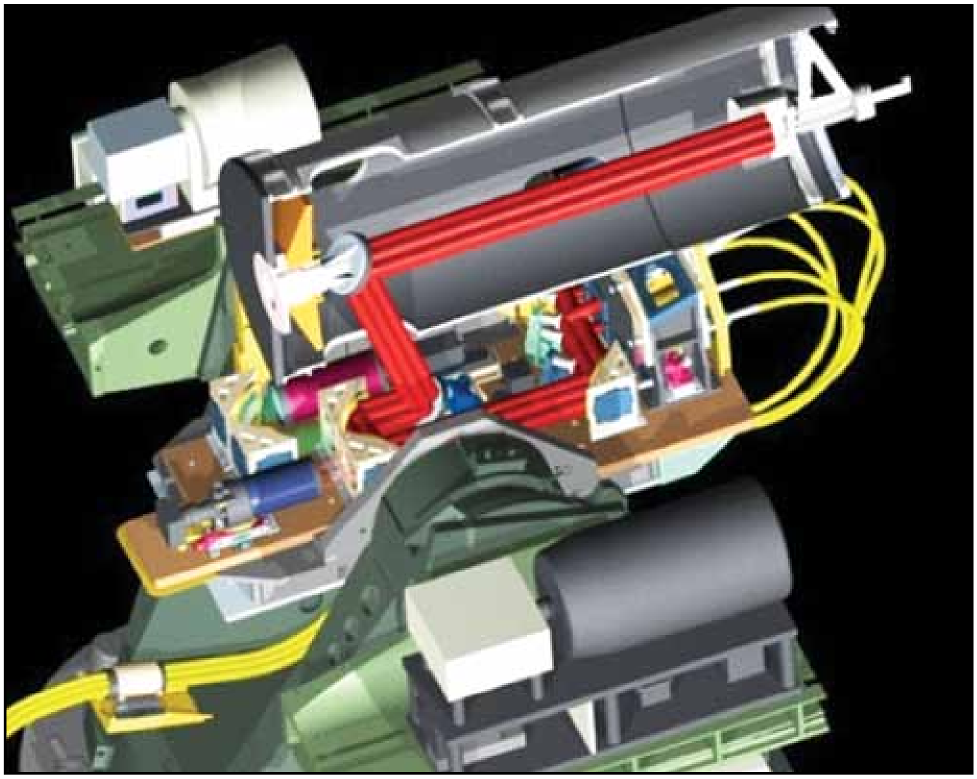

Figure 5. LaWS Beam Director Cutaway

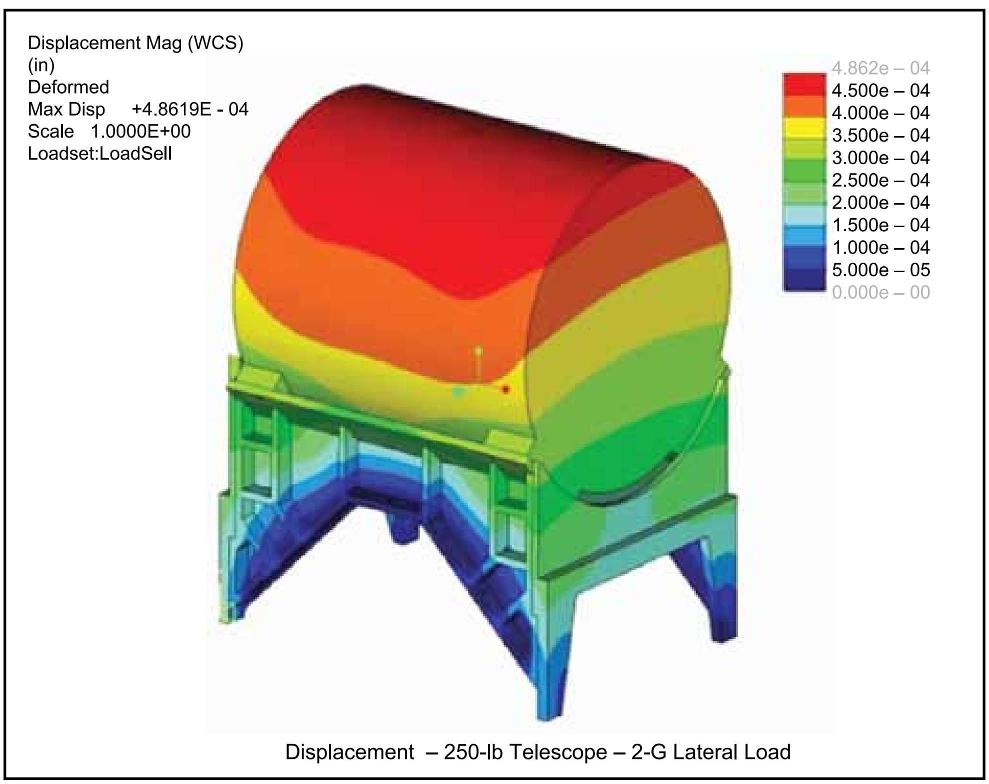

Figure 6. Displacement Plot

sent to manufacturing facilities, such as machine shops. One example is shown in Figure 7, which shows the first sheet of the multisheet drawing needed to manufacture the large plates that support the telescope from the center platform of the KTM. One of these plates is also shown in the displacement plot in Figure 6.

Even though it would be possible for one person to do all of the modeling, analyses, and drawings for a particular program, a more efficient process takes advantage of using the best skills available by collaborating with other experts. Collaboration enables assembly, part, and drawing files to be sent electronically, eliminating the need for collocating personnel. Drawings for the LaWS program, for instance, were made using noncollocated personnel across base at NSWCDD. They could just as easily have been made using personnel from across the country.

The LaWS program exemplifies how the Directed Energy Division uses solid modeling to enhance the quality and effectiveness of Navy directed-energy capabilities. As a result, warfighters will be better armed with more effective weapons and capabilities for future naval conflicts.

Acknowledgment

The author would like to acknowledge the valuable contributions of the Engagement Systems Department's drafting group in support of numerous DEWO and Directed Energy Division programs.

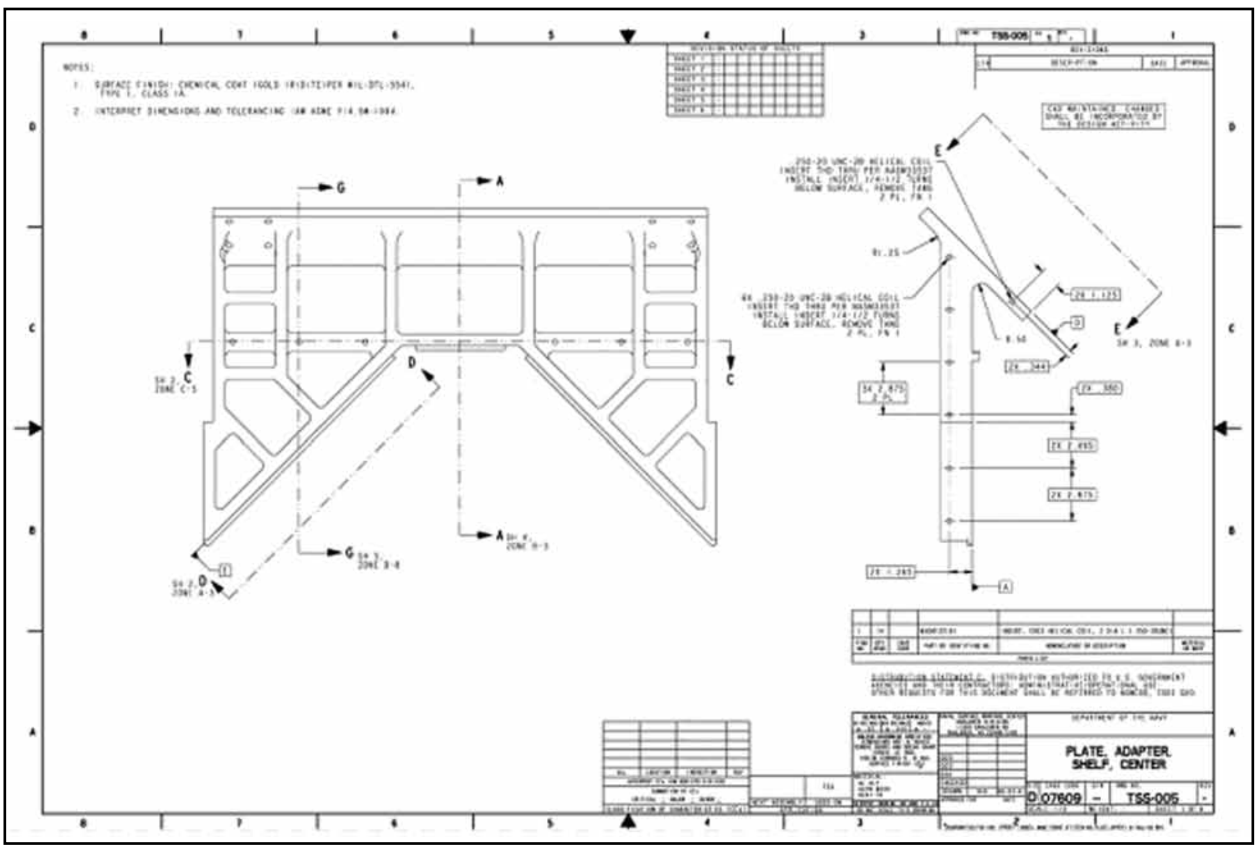

Figure 7. Manufacturing Drawing