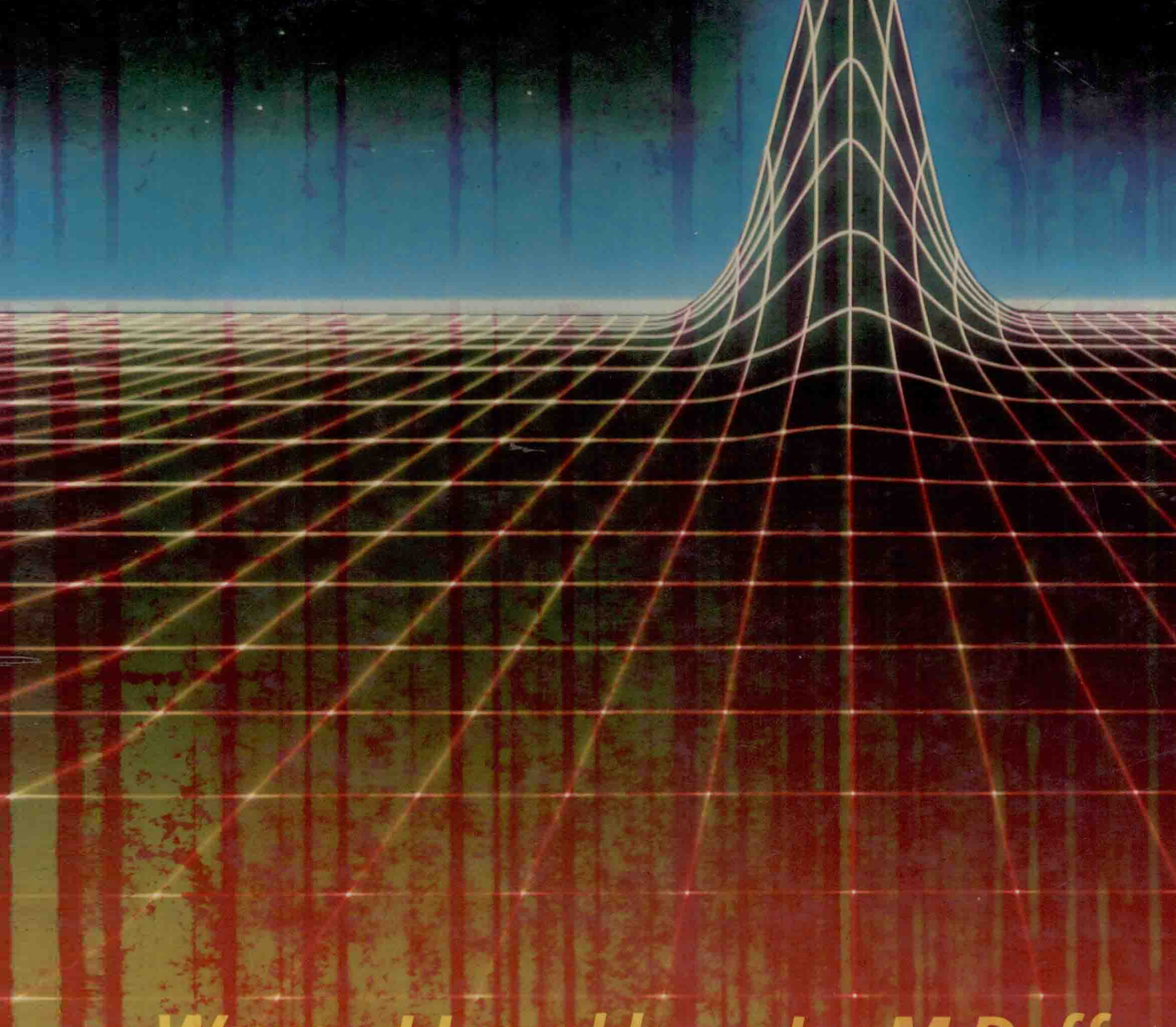
FUNDAMENTALS OF ENGINEERING DRAWING

TENTH EDITION



Warren J. Luzadder · Jon M. Duff

T E N T H

FUNDAMENTALS ENGINEERING

With an Introduction to Interactive Computer Graphics for Design and Production

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Industrial Technical Illustration, Van Nostrand Reinhold, 1982.
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other books by Luzadder

Innovative Design with an Introduction to Design Graphics, Prentice-Hall, Inc., 1975.
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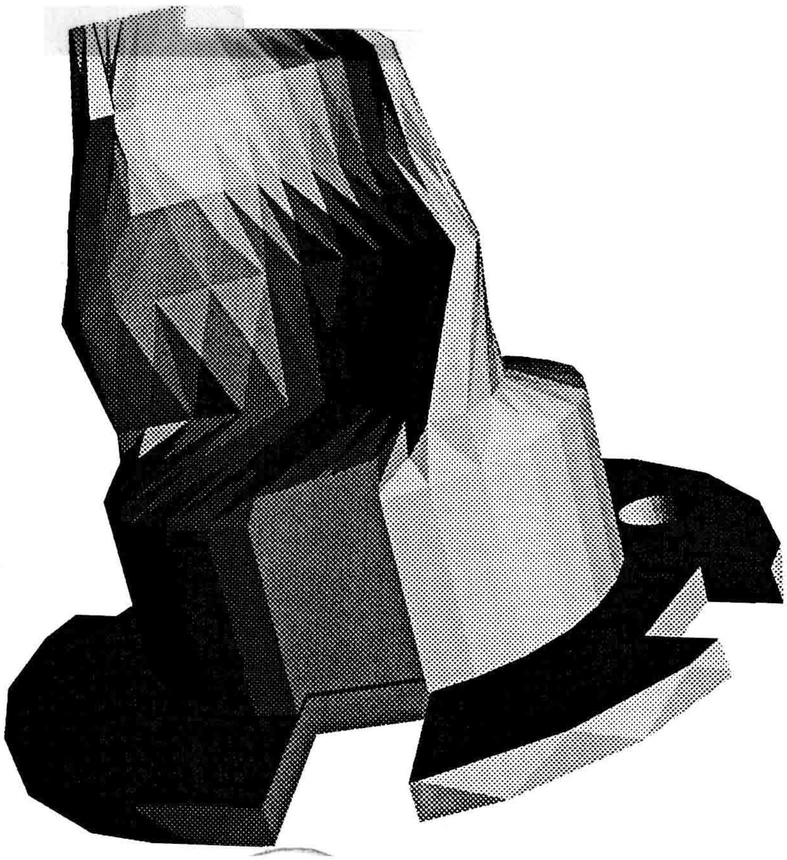

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FUNDAMENTALS OF ENGINEERING DRAWING

Preface

This edition of *Fundamentals of Engineering Drawing* begins the most extensive process of evolution in its nine edition history. Computer-aided Drafting and Design (CADD) is a reality across American industry, signaling a new approach to the study and practice of engineering drawing. This, and subsequent editions, will be based on the authors' shared belief that the more powerful the tools available for making engineering drawings, the greater is the importance that the fundamentals of engineering drawing be stressed and understood. Powerful CADD equipment in the hands of engineers or technologists well trained in design and drafting can result in greater productivity, better response to changing needs, and, in the end, a more competitive workforce.

This new edition is not based on one particular CADD software product. There are daily developments in the areas of standardization of CADD drawings, CADD equipment, and the methods used for operating CADD programs. Since this is a textbook on engineering drawing and not computer graphics, *Fundamentals of Engineering Drawing* will, over the next editions, reflect developments in computer science and computer graphics as they apply to the making of engineering documents. The field of expert systems has a bright future in the selection, preparation, and use of CADD drawings, and we expect future editions to reflect this.

Engineering drawing and CADD are both moving toward being based on solid geometry and solid modeling. The time when a designer would lay out flat diagrams on paper and then try to visualize the design in three dimensions is rapidly coming to a close. This edition stresses developing an ability to manipulate three-dimensional geometry—whether on the surface of a drawing or as a solid computer model.

The promise of a Computer-Integrated Manufacturing Technology, where CADD and CAM and Computer-aided Engineering work as a team has been realized. In such an environment, CADD becomes an extension of the engineer's mind, allowing the design, testing, manufacture, and evaluation of products in the memory of the computer before the first part is ever made. It is now imperative that everyone involved in the engineering process understand the relationship of the computer to drawing and design. This understanding makes each person a valuable member of the engineering team.

This edition has been extensively edited and revised, with outdated techniques eliminated and new material added in the crucial introductory chapters. The emphasis has been in integrating CADD into each chapter as it naturally occurs. Chapter 1 now includes an introduction to CADD as it logically fits into the field of modern engineering drawing. Chapter 2 introduces CADD equipment simply as additional tools available for making engineering drawings along with explaining traditional and CADD lettering techniques. Chapter 3 keeps many of the proven plane geometry constructions of previous editions and introduces new methods computers use for creating these same figures. Also in Chapter 3 is a presentation on solid modeling techniques, a subject critical to successful use of a CADD computer as a design tool. Chapter 4 begins a major expansion of traditional projection theory. This chapter now includes extensive sections on the coordinate axis systems used in CADD, including rotations. Chapters 5 and 9 integrate traditional and CADD techniques for achieving multiple principal and auxiliary views. It is for Chapter 17 then, after the theory has been presented in previous chapters, to apply the material presented on CADD and demonstrate how engineering drawings are actually made using computer devices. Chapter 17 leads the student through the steps necessary to complete an engineering drawing using CADD. Chapter 18 continues to present the latest developments in Computer-aided Manufacturing (CAM) and how CADD and CAM are integrated into a manufacturing system.

Elsewhere in this edition, several sections have been combined or deleted, most notably the inclusion of pipe fittings and welding in a chapter on joining and fastening, and the deletion of sections on reprographic techniques. The Glossary has been expanded into a full Appendix with shop and CADD terms, and the Bibliography has been updated.

To bring this text abreast of new technological developments, a number of leading industrial organizations have generously assisted the authors by supplying appropriate illustrations that were needed in developing specific topics. Every commercial illustration supplied by American industry has been identified using a courtesy line. The authors deeply appreciate the kindness and generosity of these many companies and the busy people in their employment who found the time to select these drawings and photographs that appear in almost every chapter.

The authors also would like to reaffirm their indebtedness to Professors George Shiers, W. L. Baldwin, R. H. Hammond, and Dennis R. Short. The chapter on electronics drawing has been used again in this edition. Professor Baldwin contributed the material on linkages in the chapter covering machine elements. Professor Hammond prepared the coverage on graphical algebra. Professor Short contributed computer-generated drawings which are displayed throughout the text as well as help on the preparation of Chapter 17. Commercial CADD drawings have been furnished by Computervision, IBM, Micro Control Systems, Hewlett-Packard, CalComp-Sanders, and the Ross Gear Division of TRW.

Professor Larry D. Goss of The University of Southern Indiana previously contributed material in Chapters 1 and 21, much of which has been carried over to this edition.

Special appreciation is extended for the assistance of Morris Buchanan and John Mitchell. Mr. Buchanan's contribution of the IBM Metric Standards and drawings in the ninth edition appears again in this text. Mr. Mitchell of Cincinatti Milicron was instrumental in securing photographs of industrial robots and examples of numerical control programs for machine tools which continue to be used in this new edition.

The authors are grateful as well for the assistance and encouragement given by Professors Jerry V. Smith, Dennis R. Short, Mary A. Sadowski, and others of the Department of Technical Graphics at Purdue University. Many of the new illustrations and text passages were critiqued and evaluated by the faculty.

Last, we would like to acknowledge two people for their outstanding work on this text. The first, Joan McCulley, production editor, handled the task of coordinating new and previous sections and illustrations in this vanguard edition. The second, Anne Bonanno, book designer, executed a handsome book, easy to use by teachers and students alike. Our sincere thanks go to both of them.

W.J.L.
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FUNDAMENTALS OF ENGINEERING DRAWING

The IBM Interactive Graphics Display System unlocks man's imagination. With the IBM system product designs can be prepared and plots and maps displayed in their expected form. Under program control data can be entered, displayed, and modified as needed by using the light pen, program function keyboard, or alphanumeric keyboard.

Technical drawings may be created by techniques similar to those used at a regular drawing board. Drafting requirements for arcs, lines, dimensioning, notes, automatic scaling, parts lists, and three-dimensional pictorials are fully met in accordance with ANSI drafting standards by the applications program. (*Courtesy IBM Corporation*)

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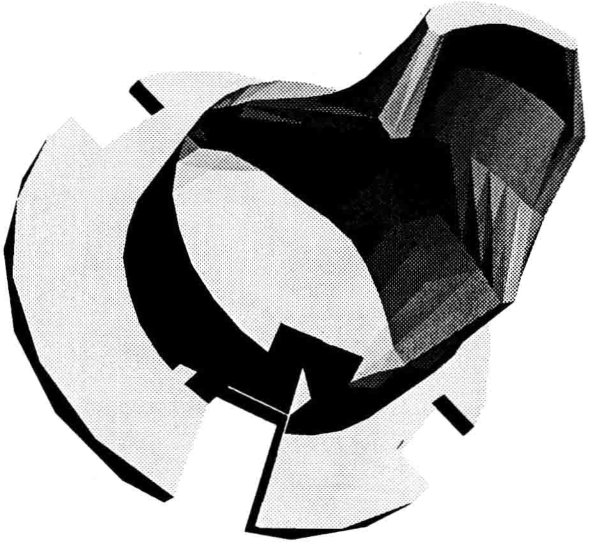
CHAPTER • 1

Introduction



1.1 A Brief History of Drawing

For almost twenty thousand years a drawing has been the main way that ideas have been communicated. The first drawings were made even longer ago, when prehistoric man tried to communicate ideas by marking in the dirt floors of caves. It is natural for humans to graphically draw their ideas because *drawing is a universal language*. Even today, when some drawings are made by computers, this is true. The first permanent drawings, made on the rock walls of caves, depicted people, deer, buffalo, and other animals. These drawings were made to express emotion and record experiences, long before the development of writing. When writing developed, drawing came to be used primarily by artists and engineers as a means of showing design concepts for pyramids, war chariots, buildings, and simple mechanisms.

One of the earliest drawings, found in Mesopotamia, shows the use of the wheel about 3200 B.C. The drawing depicts a wheelbarrow-like mechanism being used by a man to transport his wife. This early drawing was a crude picture, without depth or perspective. Another example of early drawing is a floor plan of a fortress made on a clay tablet around 4000 B.C.

At the beginning of the Christian era, *Roman architects* had become skilled in making drawings of proposed buildings. They used straight edges and compasses to prepare plan (top), elevation (front and side), and perspective

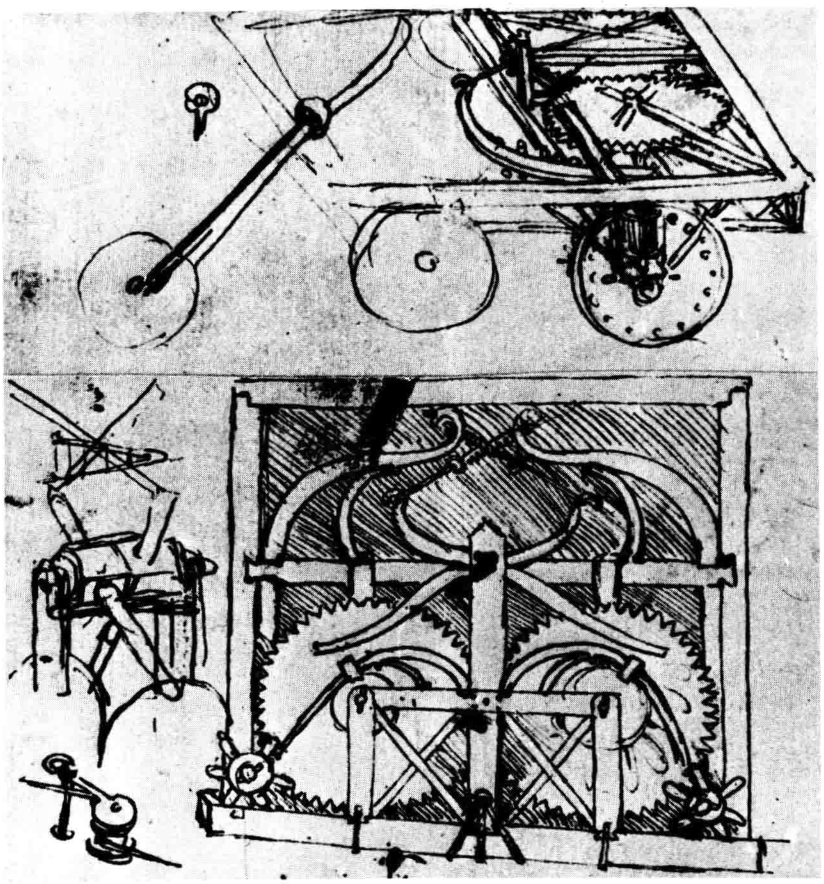


FIG. 1.1 Idea sketch prepared by Leonardo da Vinci (1452–1519). Leonardo's "automobile" was to have been powered by two giant springs and steered by the tiller, at the left in the picture, attached to the small wheel. *(From Collection of Fine Arts Department, IBM Corporation)*

views. However, the theory behind engineering drawing, the theory that enabled architects to depict views on various planes, was not developed until the Renaissance period. Even though *Leonardo da Vinci* was probably aware of these theories, his classical training as an artist influenced his engineering drawings like the one shown in Fig. 1.1. No multiview drawings (top, front, side views) made by Leonardo have been found. He knew the value of pictorial drawing in showing how parts of a mechanism fit together. It is interesting to note that even in this day of space travel, engineers continue to use pictorials to supplement multiview drawings (see the pictorial drawing of Skylab in Fig. 1.2).

Most of the very early drawings still existing today were made on parchment, a very durable type of paper. Although the paper that was developed in Europe in the twelfth century made the use of drawings more prevalent, the paper was too fragile. Of the thousands of engineering drawings of fortresses, buildings, and mechanisms made during the twelfth through fifteenth centuries, only a few exist today. Pictures made into pottery, carvings, and weavings were more permanent than paper drawings, and many of these artifacts have survived.

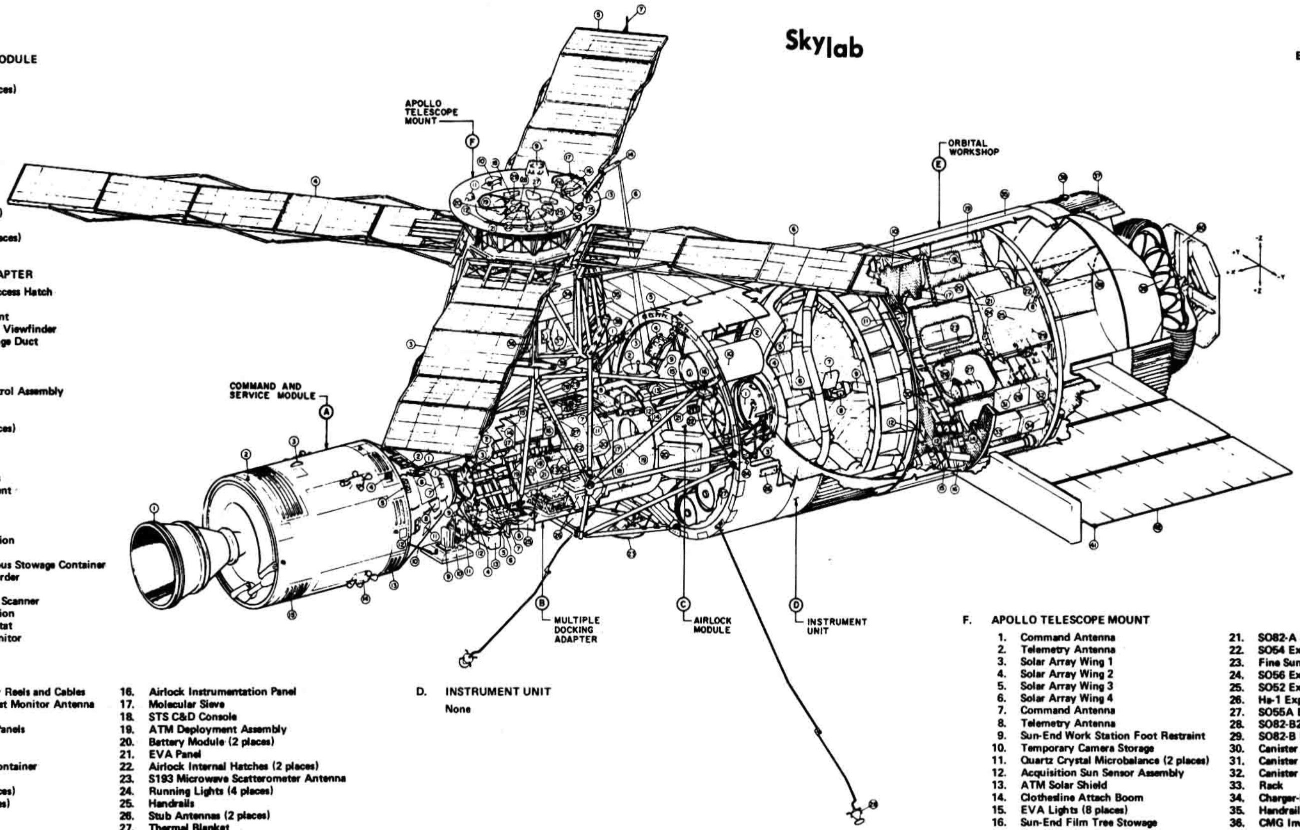
1.2 The Interrelationship of Engineering Drawing and Design

Engineering design uses engineering drawing as the way to communicate and document ideas. Engineers, drafters, and other members of the design team must work closely on the design project and speak the same language: *the language of engineering drawing*. A design engineer, though not responsible for the actual production of the drawings, must be able to read and understand all aspects of the drawing. At the very least, the design engineer must be able to make clear, concise sketches that can be given to technologists and drafting technicians for the actual preparation of the drawings.

Any person on the design team who makes engineering drawings must combine *classroom study* of engineering graphics with *practical experience* in company methods, standards, and practices. This knowledge may include such things as manufacturing methods, numerical control, and digital computer applications (Chapters 1–5 and 12–18).

Engineering drawings present technical information to tens or even hundreds of individuals who may be engineers, managers, suppliers, machinists, installers, or repairmen.

Skylab



A. COMMAND & SERVICE MODULE

1. SPS Engine
2. Running Lights (8 places)
3. Scimitar Antenna
4. Docking Light
5. Pitch Control Engines
6. Crew Hatch
7. Pitch Control Engines
8. Rendezvous Window
9. EVA Handholds
10. EVA Light
11. Side Window
12. Roll Engines (2 places)
13. EPS Radiator Panels
14. SM RCS Module (4 places)
15. ECS Radiator

B. MULTIPLE DOCKING ADAPTER

1. Axial Docking Port Access Hatch
2. Docking Target
3. Exothermic Experiment
4. Infrared Spectrometer Viewfinder
5. Atmosphere Interchange Duct
6. Area Fan
7. Window Cover
8. Cable Trays
9. Inverter Lighting Control Assembly
10. L-Band Antenna
11. Proton Spectrometer
12. Running Lights (4 places)
13. Infrared Spectrometer
14. Film Vault 4
15. Film Vault 1
16. SO82 (A&B) Canisters
17. M512/M479 Experiment
18. Area Fan
19. Composite Casting
20. Film Vault 2
21. TV Camera Input Station
22. Utility Outlet
23. M168 STS Miscellaneous Stowage Container
24. Redundant Tape Recorder
25. Radial Docking Port
26. 10-Band Multispectral Scanner
27. TV Camera Input Station
28. Temperature Thermostat
29. Radio Noise Burst Monitor
30. ATM C&D Console

C. AIRLOCK MODULE

1. Deployment Assembly Reels and Cables
2. Solar Radio Noise Burst Monitor Antenna
3. Handrails
4. DO21/DO24 Sample Panels
5. (Removed)
6. Clothesline (EVA use)
7. Permanent Stowage Container
8. STA IVA Station
9. Nitrogen Tanks (6 places)
10. Oxygen Tanks (6 places)
11. Molecular Sieve
12. Condensate Module
13. Electrical Feedthru Cover
14. Electronics Module 1
15. EVA Hatch
16. Airlock Instrumentation Panel
17. Molecular Sieve
18. STS C&D Console
19. ATM Deployment Assembly
20. Battery Module (2 places)
21. EVA Panel
22. Airlock Internal Hatches (2 places)
23. S193 Microwave Scatterometer Antenna
24. Running Lights (4 places)
25. Handrails
26. Stub Antennas (2 places)
27. Thermal Blanket
28. Discone Antenna (2 places)

D. INSTRUMENT UNIT

None

E. ORBITAL WORKSHOP

1. OWS Hatch
2. Nonpropulsive Vent Line
3. VCS Mining Chamber and Filter
4. Stowage Ring Containers (24 places)
5. Light Assembly
6. Water Storage Tanks (10 places)
7. TO13 Force Measuring Unit
8. VCS Fan Cluster (3 places)
9. VCS Duct (3 places)
10. Scientific Airlock (2 places)
11. WMC Ventiation Unit
12. Emergency Egress Opening (2 places)
13. M509 Nitrogen Bottle Stowage
14. SO19 Optics Stowage Container
15. S149 Particle Collection Container
16. SO19 Optics Stowage Container
17. Sleep Compartment Privacy Curtains (3 places)
18. M131 Stowage Container
19. VCS Duct Heater (2 places)
20. M131 Rotating Chair Control Console
21. Power and Display Console
22. M131 Rotating Chair
23. WMC Drying Area
24. Trash Disposal Airlock
25. OWS C&D Console
26. Food Freezers (2 places)
27. Food Preparation Table
28. M171 Ergometer
29. MO92 Lower-Body Negative Pressure
30. Stowage Lockers
31. Experiment Support System Panel
32. Biomedical Stowage Cabinet
33. M171 Gas Analyzer
34. Biomedical Stowage Cabinet
35. Meteoroid Shield
36. Nonpropulsive Vent (2 places)
37. TACS Module (2 places)
38. Waste Tank Separation Screens
39. TACS Spheres (22), Pneumatic Sphere
40. Refrigeration System Radiator
41. Acquisition Light (2 places)
42. Solar Array Wing (2 places)

F. APOLLO TELESCOPE MOUNT

1. Command Antenna
2. Telemetry Antenna
3. Solar Array Wing 1
4. Solar Array Wing 2
5. Solar Array Wing 3
6. Solar Array Wing 4
7. Command Antenna
8. Telemetry Antenna
9. Sun-End Work Station Foot Restraint
10. Temporary Camera Storage
11. Quartz Crystal Microbalance (2 places)
12. Acquisition Sun Sensor Assembly
13. ATM Solar Shield
14. Clothesline Attach Boom
15. EVA Lights (8 places)
16. Sun-End Film Tree Stowage
17. Handrail
18. SO82-B Experiment Aperture Door
19. Hα-2 Experiment Aperture Door
20. SO82-A Film Retrieval Door
21. SO82-A Experiment Aperture Door
22. SO54 Experiment Aperture Door
23. Fine Sun Sensor Aperture Door
24. SO56 Experiment Aperture Door
25. SO52 Experiment Aperture Door
26. Hα-1 Experiment Aperture Door
27. SO55A Experiment Aperture Door
28. SO82-B2 Experiment Aperture Door
29. SO82-B Film Retrieval Door
30. Canister Solar Shield
31. Canister
32. Canister Radiator
33. Rack
34. Charger-Battery-Regulator Modules (18 places)
35. Handrail
36. CMG Inverter Assembly (3 places)
37. Control Moment Gyro (3 places)
38. Solar Wing Support Structure (3 places)
39. ATM Outriggers (3 places)

FIG. 1.2 Skylab—manned orbital scientific space station. The Skylab was designed to expand our knowledge of manned earth-orbital operations and to accomplish carefully selected scientific, technological, and medical investigations. (*Courtesy National Aeronautics and Space Administration*)