

SURFACE VEHICLE RECOMMENDED PRACTICE

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Recommended Practice for the Selection of Engineering Workstations

Foreword—The development of cost effective engineering workstations has resulted in a marketplace with many vendors, each offering a myriad of options or configurations. This proliferation has created confusion for the potential user who is seeking common workstation configurations for particular applications. The user needs a better definition of standard functions that should be expected from the workstation vendors. A functionality definition is required that describes performance and capacity ranges, and sets specific standards in the following areas:

- Hardware
- System Software
- Communications
- Graphics Display

This document defines a range of functional requirements to be met by a family of workstations. The resulting engineering workstation specifications are based on the commitment to existing and emerging industry standards. This commitment facilitates the following:

- Portability of application software from one vendor's workstation to another.
- Interoperability between vendor workstation families.
- A "single point of access" to compute resources.
- A consistent "user interface."
- "Seamless" communications across local and wide area networks serving a diverse hardware environment.
- Full support for a diverse application environment.

1. **Scope**—This SAE Recommended Practice defines a guideline to help engineering users select workstations by specifying vendor supported functionality with several levels of performance and capacity. These workstations will satisfy different engineering applications while maintaining interoperability. The objective is to specify a set of standards, not a single workstation, which must be addressed by vendors to meet the hardware and operating environment needs of engineers in their CAD, CAM, CAE and other activities.

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2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein.

2.1.1 ISO DOCUMENTS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

- ISO 1539: 1980—ISO Standard "Programming Languages—FORTRAN" (Also known as ANSI X3.9-1978)
- ISO 8652—Current ISO standard "Programming Languages—Ada"
- ISO 8802-3—Current ISO standard "Information Processing systems—Local Area Networks—Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications" (Also known as IEEE 802.3)
- ISO 8802-4—Current ISO standard "Information Processing systems—Local Area Networks—Part 4: Token-passing bus access method and physical layer specifications" (Also known as IEEE 802.4)
- ISO 8802-5—Current ISO standard "Information Processing systems—Local Area Networks—Part 5: Token ring access method and physical layer specifications" (Also known as IEEE 802.5)
- ISO 9314—Current ISO standard for Fibre Data Distributed Interface (FDDI) (Also known as ANSI X3.166)
- ISO 9592—Current ISO standard "Information processing systems—Computer graphics—Programmer's hierarchical interactive graphics system (PHIGS)" (Also known as ANSI X3.144)
- ISO 9594—Current ISO standard "Information processing systems—Open Systems Interconnection—The Directory—Parts 1–7 (Also known as CCITT X.500 series)
- ISO 9945-1—Current ISO/IEC standard "Information technology—Portable Operating System Interface (POSIX)—Part 1: System Application Programming Interface (API) [C Language]" (Also known as IEEE 1003.1)
- ISO 10021—Current ISO/IEC standard "Information processing systems—Text Communication—Message oriented text interchange system—Parts 1–7" (Also known as CCITT X.400)

2.1.2 ANSI DOCUMENTS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

- ANSI X3.64—Current ANSI standard "Additional Controls for Use with American National Standard Code for Information Interchange"
- ANSI X3.113—Current ANSI standard "Information systems—Programming Language—FULL BASIC"
- ANSI X3.159—Current ANSI standard "Programming Language C"
- ANSI 770X3.97—Current ANSI/IEEE "Standard Pascal Computer Programming Language"

2.1.3 OTHER DOCUMENTS

- CCITT X.25—CCITT Recommendation "Interface Between DTE and DCE for Terminals Operating in the Packet Mode on Public Data Networks"
- CCITT V.35—CCITT Recommendation "Data Transmission at 48 KBPS Using 60–108 KHz Group Band Circuits" for data communication over the telephone network
- EIA-232-D—Current ANSI/EIA standard "Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange" (revision of standard RS-232-C)
- EIA-343-A—Current EIA standard "Electrical Performance Standards for High Resolution Monochrome Closed Circuit Television Camera"
- EIA-449—Current ANSI/EIA standard "General Purpose 37-Position and 9-Position Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange"
- IEEE 488.1—Current ANSI/IEEE standard "IEEE Standard Digital Interface for Programmable Instrumentation"
- IEEE 488.2—Current ANSI/IEEE standard "IEEE Standard Codes, Formats, Protocols, and Common Commands" (For Use with ANSI/IEEE Standard 488.1-1987 IEEE Standard Digital Interface for Programmable Instrumentation)

IEEE 770X3.97—Current ANSI/IEEE standard "Pascal Programming Language"

IEEE 1003.4—Current IEEE standard "Portable Operating System Interface for Computer Environments,"
Real Time Extensions

SPEC—Systems Performance Evaluation Cooperative, "SPEC Release 1.0 Benchmark Run Rules and
Reporting Rules"

XPG3—X/OPEN Company Limited, Portability Guide Issue 3, December 1988

3. Definitions

- 3.1 **Ada**—High level computer programming language named after Lady Ada Lovelace, Charles Babbage's computer programmer.
- 3.2 **ANSI**—American National Standards Institute.
- 3.3 **ANSI X3.9-1978**—1978 ANSI standard "Programming Language FORTRAN" (see ISO 1539: 1980)
- 3.4 **ANSI X3.144**—Current ANSI standard "Information Systems—Computer Graphics—Programmer's Hierarchical Interactive Graphics System (PHIGS) Functional Description, Archive File Format, Clear-Text Encoding of Archive File" (see ISO 9592)
- 3.5 **ANSI X3.166**—Current ANSI standard for Fibre Data Distributed Interface (FDDI) (see ISO 9314)
- 3.6 **Anti-Aliasing**—A technique used to provide a greater apparent resolution on the screen of a graphics display without the cost of a higher resolution display.
- 3.7 **BSD 4.3**—Berkeley Software Distribution (version 4.3).
- 3.8 **C**—A high level programming language (see ANSI X3.159).
- 3.9 **CCITT**—Comite Consultatif International de Telegraphique et Telephonique (an international consultative committee that sets international communications usage standards).
- 3.10 **CCITT X.400**—CCITT Recommendation "Message Handling Systems: System Model—Service Elements" (see ISO 10021)
- 3.11 **CCITT X.500**—CCITT Recommendation "Information processing systems—Open Systems Interconnection—The Directory—Parts 1–7" (also known as ISO 9594)
- 3.12 **CPU**—Central Processing Unit.
- 3.13 **Cray Station**—CRAY Research, Inc.'s proprietary remote job scheduling products.
- 3.14 **CSMA/CD**—Carrier Sense Multiple Access with Collision Detection.
- 3.15 **DCE**—Data Communications Equipment.
- 3.16 **DEC VT-100**—Digital Equipment Corporation proprietary ASCII text terminal emulation products.
- 3.17 **DEC VT-2xx**—Digital Equipment Corporation proprietary graphics terminal emulation products.
- 3.18 **Depth Queuing**—Graphics display technique in which an object being displayed that is farther from the viewer is darker; the closer an object, the brighter it is.

- 3.19 Double Buffering**—The concept of using two buffer registers between a computer's central processing unit and an input/output device in which one buffer is being refreshed while the other is being used for the input (or output) operation thereby resulting in increased performance and reduced flicker between screen updates.
- 3.20 DTE**—Data Terminal Equipment.
- 3.21 EIA**—Electronics Industries Association.
- 3.22 FDDI**—Fibre Data Distributed Interface (see ISO 9314 also ANSI X3.166)
- 3.23 FORTRAN-77**—High level computer programming language for FORMula TRANslation—1977 version; (see ISO 1539: 1980 also ANSI X3.9-1978).
- 3.24 GB**—Gigabyte; billions of bytes.
- 3.25 Gouraud Shading**—A shading technique used for the display of objects in which varying degrees of light intensity are calculated across each polygonal surface making up the object. This technique provides a more realistic image than constant shading but a somewhat less realistic image than provided by Phong shading.
- 3.26 IBM LU 6.2**—International Business Machines Corporation's Logical Unit type 6.2 proprietary format operating under SNA for application to application program communications across a network.
- 3.27 IBM 3179/3279G**—International Business Machines Corporation's proprietary SNA terminal with vector data stream products.
- 3.28 IBM 3279**—International Business Machines Corporation's proprietary SNA vector graphics terminal products.
- 3.29 IBM 5080**—International Business Machines Corporation's proprietary high performance graphics terminal products.
- 3.30 IEEE**—The Institute of Electrical and Electronic Engineers, Inc.
- 3.31 IEEE 802.3**—Current ANSI/IEEE standard for Local Area Networks "CSMA/CD Media Access Method" (see ISO 8802-3)
- 3.32 IEEE 802.4**—Current ANSI/IEEE standard for Local Area Networks "Token-Passing Bus Access Method and Physical Layer Specifications" (see ISO 8802-4)
- 3.33 IEEE 802.5**—Current ANSI/IEEE standard for Local Area Networks "Token Ring Access Method and Physical Layer Specifications" (see ISO 8802-5)
- 3.34 IEEE 1003**—See ISO 9945 "POSIX" standard
- 3.35 I/O**—Input/output.
- 3.36 ISO**—International Organization for Standardization
- 3.37 ISO/OSI**—International Organization for Standardization/Open Systems Interconnection.
- 3.38 LAN**—Local area network.
- 3.39 LISP**—LISt Processing programming language widely used in artificial intelligence applications.
- 3.40 MAP/TOP**—Manufacturing Automation Protocol/Technical Office Protocol.

- 3.41 **MB**—Megabyte; millions of bytes.
- 3.42 **Megapixel**—Millions of graphics display picture elements.
- 3.43 **MS DOS**—Microsoft Corporation's Disk Operating System for personal computers.
- 3.44 **NFS**—SUN Microsystems, Inc.'s Network File System specification.
- 3.45 **Non-Interlaced**—In raster graphics display tubes, every scanning line is refreshed for each sweep down the display as opposed to the interlace method used in standard television in which every other scanning line is refreshed during each sweep thereby requiring two sweeps to completely refresh the display.
- 3.46 **NTSC**—National Television Standards Committee.
- 3.47 **NURBS**—Non-Uniform Rational B-spline Surfaces.
- 3.48 **OSF/Motif**—Open Software Foundation X-Window based user interface product.
- 3.49 **Pascal**—High level computer programming language named after Blaise Pascal (see IEEE 770X3. 97).
- 3.50 **PC-DOS**—IBM Personal Computer Disk Operating System.
- 3.51 **PEX**—PHIGS+ Extensions to X-window.
- 3.52 **PHIGS**—Programmer's Hierarchical Interactive Graphics System (see ISO 9592, also known as ANSI X3.144).
- 3.53 **Phong Shading**—A compute-intensive shading technique used in the display of objects whereby the light intensity for every point on the object is calculated to obtain a very realistic image.
- 3.54 **Pixel**—The smallest addressable picture element of a graphics display.
- 3.55 **POSIX**—Portable Operating System Interface (see ISO 9945 also IEEE 1003).
- 3.56 **Postscript**—Adobe Systems Incorporated's proprietary device-independent, high-level, interpretive programming language with extensive graphics capabilities. It is primarily used to describe the appearance of text, geometric shapes and sampled images on printed pages.
- 3.57 **PU**—Physical Unit.
- 3.58 **QWERTY**—A standard keyboard named because the letters 'qwerty' appear in order in the row of keys directly above the keyboard left hand home row.
- 3.59 **RGB Output**—An output model for specifying a color, or a gray-scale, as a combination of the three primary colors of light (red, green, and blue) in particular concentrations. The intensity of each primary color is specified by a number in the range of 0 to 1. If all three colors have equal intensity, the perceived result is a pure gray on the scale from black to white (see EIA-343-A).
- 3.60 **RJE**—Remote Job Entry.
- 3.61 **RS-232**—Serial interface specification (see EIA-232-D).
- 3.62 **RS-449**—Serial interface specification (see EIA-449).
- 3.63 **Spec**—Systems Performance Evaluation Cooperative

- 3.64 **SPECfp**—SPEC floating point performance measure
- 3.65 **SPECmark**—SPEC overall performance measure
- 3.66 **SPEC Thruput**—SPEC Thruput performance measure
- 3.67 **TCP/IP**—Transmission Control Protocol/Internet Protocol.
- 3.68 **Tektronix 4XXX**—Tektronix Inc.'s proprietary graphics terminal products.
- 3.69 **Unix System V**—Current version of the portable computer operating system developed by Bell Laboratories of AT&T.
- 3.70 **WAN**—Wide area network.
- 3.71 **X/Open GUI**—X/OPEN Corporation specification for a graphical user interface (future).
- 3.72 **X-Window System**—Massachusetts Institute of Technology's defacto standard portable distributed windowing system.
- 3.73 **X.25**—CCITT Recommendation "Interface Between DTE and DCE for Terminals Operating in the Packet Mode on Public Data Networks" (see CCITT X.25).
- 3.74 **V.35**—CCITT Recommendation "Data Transmission at 48 KBPS Using 60—108 KHz Group Band Circuits" for data communication over the telephone network (see CCITT V.35).
- 3.75 **X.400**—CCITT Recommendation "Message Handling Systems: System Model - Service Elements" (see ISO 10021).
- 3.76 **X.500**—CCITT Recommendation "Information processing systems—Open Systems Interconnection—The Directory—Parts 1–7 (see ISO 9594).
- 3.77 **Z Buffering**—Technique used in hidden-surface algorithms in which the z-depth value of each pixel being examined is compared against the value stored in the buffer to see which pixel is closer to the viewer. The pixel closest to the viewer is then displayed. High depth z buffering is accomplished by using additional bits in the z-buffer (24 bit).

4. **Trademarks**

Ethernet—Trademark of Xerox Corporation
 Motif—Trademark of Open Software Foundation
 Network File System—Trademark of Sun Microsystems, Inc.
 NFS—Trademark of Sun Microsystems, Inc.
 OSF—Trademark of Open Software Foundation
 Postscript—Registered trademark of Adobe Systems, Inc.
 SPEC—Trademark of the Standard Performance Evaluation Corporation
 SPECmark—Trademark of the Systems Performance Evaluation Cooperative
 Unix—Registered trademark of AT&T
 X/Open—Registered trademark of X/Open Company, Ltd.
 X Window System—Trademark of Massachusetts Institute of Technology

- 5. **Technical Compliance Matrix**—The workstation specifications are contained in the Technical Compliance Matrix, which is divided into two sections: (1) Standard Workstation Characteristics (See Figure 1A, Figure 1B; and (2) Minimum Performance and Capacity Ranges (See Figure 2.) These two sections are described below.

5.1 Technical Compliance Matrix—(See Figure 1A, Figure 1B)—Figure 1 contains the standard workstation characteristics that must apply to all workstations claiming compliance with this document. This section is organized into four categories:

- a. Hardware—Workstation CPU, I/O, memory, addressing hardware.
- b. System Software—Operating systems, languages, file system and windowing support.
- c. Communications—LAN, WAN, gateways, and emulators.
- d. Graphics Display—Display size, resolution, and graphics performance features.

Each category contains three columns of information: Characteristic items, Base System specifications or standards, and User Option specifications or standards.

- 1. Characteristic—This column briefly describes each workstation attribute.
- 2. Base System—The features indicated in the base system specification for each item are those features which a workstation vendor must provide as standard features on all workstations. It is anticipated that users would require all of these features on an engineering workstation. The base system specifications would typically define the minimum in the range of performance for any workstation.
- 3. User Options—User Options are those features which could be purchased as required for specific tasks and needs. However, the workstation vendor must supply and support all of the user options. Third party products could meet the user option requirements if they are supplied and supported by the workstation vendor. Each user option is marked to indicate whether it must be available from the workstation vendor on all workstation models, or available on at least one model within a product family.

5.2 Technical Compliance Matrix (see Figure 2)—Figure 2 contains performance and capacity ranges that will distinguish different workstation models and different levels of user requirements. These individual items are divided into four categories:

- a. Processor performance requirement
- b. Graphics performance requirement
- c. Graphics display requirement
- d. Memory and disk capacity requirement

The level of each of the individual items in Figure 2 should be specified independently of the other items listed. Vendors should specify the highest level, for each item, that a particular workstation model meets or exceeds.

5.2.1 PROCESSOR PERFORMANCE TEST SPECIFICATIONS—The performance test measurements for Figure 2, Processor Performance, of the Technical Compliance Matrix should be performed according to the SPEC Release 1.0 Benchmark Run Rules and Reporting Rules as specified in the SPEC license and in the benchmark instructions.

5.2.2 GRAPHICS DISPLAY PERFORMANCE—The performance test measurements for Figure 2, Graphics Display Performance, of the Technical Compliance Matrix should be performed according to accepted industry practice. However, some of these tests will yield results that are not fully equivalent from one workstation family to another. In subsequent versions of this document, it is intended that these specifications will be changed to reflect the work of the NCGA Graphics Performance Characterization (GPC) committee, if they become widely accepted. Other graphics display performance tests, such as flat shading or raster painting speeds, may also be considered for inclusion in a future version.

5.3 Technical Compliance Matrix Notes

5.3.1 NOTE 1—"Server" products should be consistent with the workstation family and be capable of supporting shared work-group services such as auxiliary storage, communications and peripherals. The server should provide sufficient functionality to support a distributed network environment. The detail-level implementation and richness of this functionality will be a significant factor in the selection of workstation strategic suppliers. Specific features should include (but not be limited to) the following list:

- a. Shared file services
- b. Computational serving ability
- c. System administration services
- d. Communications gateway ability
- e. Peripheral manager providing control of shared local area network (LAN) resources such as printers, plotters, disks, etc.
- f. Additional interface ports/slots
- g. Network initial program load ("boot") capability

5.3.2 NOTE 2—Display Bit Planes include Z buffer and translucency bits.

5.4 **Options Not in Technical Compliance Matrix**—The following list of items, which are not included in the Technical Compliance Matrix, is intended to convey valid user requirements which are not presently universal enough to be specified as mandatory. However, these items are suggested for consideration as value-added options, may be specified in acquisition documents and may become items in the Technical Compliance Matrix at a later date.

5.4.1 HARDWARE OPTIONS AND PERIPHERALS

- a. NTSC video support
- b. Scanners
- c. Audio
- d. Multiple processor support

For applications which take advantage of multiple processors, it is recommended that the SPEC Thruput measurement be utilized for product comparisons.

5.4.2 COMMUNICATIONS/EMULATIONS

- a. LAN
 - 1. FDDI
- b. WAN/Gateway/Emulation Products
 - 1. IBM 3179G/3279G supporting vector data stream
 - 2. IBM 3174 controller emulation
 - 3. IBM LU 6.2 peer-to-peer communications
 - 4. RJE (56 Kb)
 - 5. IBM 5080 remote emulation
 - 6. DEC VT-100 emulation
 - 7. DEC VT-2XX emulation
 - 8. Tektronix 4XXX emulation
 - 9. CRAY station support
 - 10. ISO 10021 (CCITT X.400) electronic mail and ISO 9594 (CCITT X.500) Directory Services
- c. Network administration tools

5.4.3 OPERATING ENVIRONMENT

- a. Operating System
 - 1. Real-time UNIX/POSIX support (IEEE P1003.4)
 - 2. Multiple processor support
- b. DOS under UNIX/POSIX
 - 1. VGA or EGA graphics in a variable size window up to full screen
- c. Language Support
 - 1. Ada (ISO 8652)
 - 2. BASIC (ANSI X3.113)
 - 3. LISP
 - 4. Object oriented C
 - 5. Pascal (ANSI 770X3.97)
- d. Windowing System
 - 1. 3D extensions (PHIGS in an X Window or PEX)
- e. Distributed Processor System Support
- f. User Interface—IEEE P1201 Committee Standard when adopted

6. **Examples**—Examples of possible workstation configurations are shown in Figures 3 to 7 for various application areas, using Figure 2 of the Technical Compliance Matrix. The shaded areas represent the approximate level requirement for that particular range. These examples do not represent a standard for a particular workstation, and some application areas cover a wide range of requirements.

Hardware				
Characteristic	Base System Requirements	User Option Availability	All Models	Some Model(s)
CPU	32 bit			
Bus Structure	Open, specifications published			
Random Access Memory	Minimum of 8 MB with error correction or detection			
Virtual Addressing	64 MB per process	2 GB per process		X
I/O Support	EIA-232-D	V.35 or EIA-449		X
	3 Button Mouse			
	QWERTY Keyboard			
		Removable Media - (e.g. tape, floppy, optical, etc.)	X	
		Digitizing Device		X
Physical Environment	Normal office environment (e.g. power, heat, noise)			
Printer Support		Parallel Interface Centronics or IEEE 488.2	X	
Server Capability		See Note 1		X

System Software				
Characteristic	Base System Requirements	User Option Availability	All Models	Some Model(s)
Operating System	ISO 9945 (IEEE 1003) Compliance			
	X/Open XPG 3 Base Level Compliance			
		BSD 4.3 Extensions	X	
Language Support		UNIX System V Extensions	X	
		PC-DOS or MS-DOS		X
		ISO 1539:1980 (FORTRAN 77)	X	
Distributed File System		C (ANSI X3.159)	X	
		NFS Version 2	X	
Windowing System	X-Window Version 11.3 or greater			
	Multiple Processes			
	X server with support for graphics hardware			
	Xlib & xtintrinsics			
	Libraries supporting PHIGS (ISO 9592)			
	X/OPEN GUI or OSF/Motif (w/ window manager and libraries)			
		MURBS Support		X
		Phong Shading		X
Hardcopy support		Postscript		X

FIGURE 1A—STANDARD WORKSTATION CHARACTERISTICS

Communications

Characteristic	Base System Requirements	User Option Availability	All Models	Some Model(s)
Local Area Network	ISO 8802-3 or ISO 8802-5	ISO 8802-3	X	
	TCP/IP			
	BSD 4.3 network extension services			
	ISO/OSI commitment			
Wide Area Network, Gateways, Emulators		MAP/TOP specification		X
		ANSI X3.64 support	X	
		IBM 3x78 emulator with file transfer	X	
		IBM 3274 PU type 2.X plus C library		X

Graphics Display

Characteristic	Base System Requirements	User Option Availability	All Models	Some Model(s)
Display Characteristics	Non-interlaced Monitor	Monochrome		X
		Grayscale		X
		Color	X	
	12" display size (minimum)	12"-16" screen	X	
		At least 19" screen	X	
		Flat-faced		X
		RGB output		X
Display Resolution	0.7 megapixel display area (minimum)	See Section II		
High Performance Graphics Hardware		Hidden line & surface removal		X
		Z buffering (16 bit)		X
		High depth Z buffering (24 bit)		X
		Double buffering		X
		Depth queing		X
		Anti-aliasing (4K by 4K addressable)		X
		Overlay Plane facilities		X
		Gouraud Shading		X

FIGURE 1B—STANDARD WORKSTATION CHARACTERISTICS (CONTINUED)

Processor	Performance Requirement				
	Level 1	Level 2	Level 3	Level 4	Level 5
Overall Performance (in SPECmarks)	2 to < 10	10 to < 25	25 to < 50	50 to < 100	100 or more
Floating Point Operations (in SPECfp)	1 to < 5	5 to < 25	25 to < 50	50 to < 125	125 or more

Graphics	Performance Requirement				
	Level 1	Level 2	Level 3	Level 4	Level 5
Refresh-3D (in Kvectors/second)	< 10	10 to < 100	100 to < 300	300 to < 1000	1000 or more
Refresh-2D (in Kvectors/second)	< 100	100 to < 300	300 to < 1000	1000 or more	
Gouraud Shading (in Kpolygons/sec)	0 to < 1	1 to < 5	5 to < 20	20 to < 100	100 or more

Graphics	Display Requirement				
	Level 1	Level 2	Level 3	Level 4	Level 5
Display Area (in megapixels)	0.7 to < 1.0	1.0 to < 1.3	1.3 to < 4.0	4.0 or more	
Display bit planes (in bits per pixel)	1 to 7	8 to 23	24 to 39	40 or more	
Color Palette	< 256 K	256 K to < 16M	16 M or more		

Memory and Disk	Capacity Requirement				
	Level 1	Level 2	Level 3	Level 4	Level 5
Random Access Memory (in MB)	8 to < 16	16 to < 32	32 to < 64	64 to < 128	128 or more
Local Disk Capacity (in MB)	0 to < 300	300 to < 1000	1000 to < 5000	5000 or more	

FIGURE 2—PERFORMANCE AND CAPACITY RANGES

Performance Requirement					
Processor	Level 1	Level 2	Level 3	Level 4	Level 5
Overall Performance (in SPECmarks)	2 to < 10	10 to < 25	25 to < 50	50 to < 100	100 or more
Floating Point Operations (in SPECfp)	1 to < 5	5 to < 25	25 to < 50	50 to < 125	125 or more

Performance Requirement					
Graphics	Level 1	Level 2	Level 3	Level 4	Level 5
Refresh-3D (in Kvectors/second)	< 10	10 to < 100	100 to < 300	300 to < 1000	1000 or more
Refresh-2D (in Kvectors/second)	< 100	100 to < 300	300 to < 1000	1000 or more	
Gouraud Shading (in Kpolygons/sec)	0 to < 1	1 to < 5	5 to < 20	20 to < 100	100 or more

Display Requirement					
Graphics	Level 1	Level 2	Level 3	Level 4	Level 5
Display Area (in megapixels)	0.7 to < 1.0	1.0 to < 1.3	1.3 to < 4.0	4.0 or more	
Display bit planes (in bits per pixel)	1 to 7	8 to 23	24 to 39	40 or more	
Color Palette	< 256 K	256 K to < 16M	16 M or more		

Capacity Requirement					
Memory and Disk	Level 1	Level 2	Level 3	Level 4	Level 5
Random Access Memory (in MB)	8 to < 16	16 to < 32	32 to < 64	64 to < 128	128 or more
Local Disk Capacity (in MB)	0 to < 300	300 to < 1000	1000 to < 5000	5000 or more	

FIGURE 3—EXAMPLE PERFORMANCE AND CAPACITY RANGES
TECHNICAL PUBLISHING WORKSTATION

Performance Requirement					
Processor	Level 1	Level 2	Level 3	Level 4	Level 5
Overall Performance (in SPECmarks)	2 to < 10	10 to < 25	25 to < 50	50 to < 100	100 or more
Floating Point Operations (in SPECfp)	1 to < 5	5 to < 25	25 to < 50	50 to < 125	125 or more

Performance Requirement					
Graphics	Level 1	Level 2	Level 3	Level 4	Level 5
Refresh-3D (in Kvectors/second)	< 10	10 to < 100	100 to < 300	300 to < 1000	1000 or more
Refresh-2D (in Kvectors/second)	< 100	100 to < 300	300 to < 1000	1000 or more	
Gouraud Shading (in Kpolygons/sec)	0 to < 1	1 to < 5	5 to < 20	20 to < 100	100 or more

Display Requirement					
Graphics	Level 1	Level 2	Level 3	Level 4	Level 5
Display Area (in megapixels)	0.7 to < 1.0	1.0 to < 1.3	1.3 to < 4.0	4.0 or more	
Display bit planes (in bits per pixel)	1 to 7	8 to 23	24 to 39	40 or more	
Color Palette	< 256 K	256 K to < 16M	16 M or more		

Capacity Requirement					
Memory and Disk	Level 1	Level 2	Level 3	Level 4	Level 5
Random Access Memory (in MB)	8 to < 16	16 to < 32	32 to < 64	64 to < 128	128 or more
Local Disk Capacity (in MB)	0 to < 300	300 to < 1000	1000 to < 5000	5000 or more	

FIGURE 4—EXAMPLE PERFORMANCE AND CAPACITY RANGES
DRAFTING AND LAYOUT WORKSTATION

Performance Requirement					
Processor	Level 1	Level 2	Level 3	Level 4	Level 5
Overall Performance (in SPECmarks)	2 to < 10	10 to < 25	25 to < 50	50 to < 100	100 or more
Floating Point Operations (in SPECfp)	1 to < 5	5 to < 25	25 to < 50	50 to < 125	125 or more

Performance Requirement					
Graphics	Level 1	Level 2	Level 3	Level 4	Level 5
Refresh-3D (in Kvectors/second)	< 10	10 to < 100	100 to < 300	300 to < 1000	1000 or more
Refresh-2D (in Kvectors/second)	< 100	100 to < 300	300 to < 1000	1000 or more	
Gouraud Shading (in Kpolygons/sec)	0 to < 1	1 to < 5	5 to < 20	20 to < 100	100 or more

Display Requirement					
Graphics	Level 1	Level 2	Level 3	Level 4	Level 5
Display Area (in megapixels)	0.7 to < 1.0	1.0 to < 1.3	1.3 to < 4.0	4.0 or more	
Display bit planes (in bits per pixel)	1 to 7	8 to 23	24 to 39	40 or more	
Color Palette	< 256 K	256 K to < 16M	16 M or more		

Capacity Requirement					
Memory and Disk	Level 1	Level 2	Level 3	Level 4	Level 5
Random Access Memory (in MB)	8 to < 16	16 to < 32	32 to < 64	64 to < 128	128 or more
Local Disk Capacity (in MB)	0 to < 300	300 to < 1000	1000 to < 5000	5000 or more	

FIGURE 5—EXAMPLE PERFORMANCE AND CAPACITY RANGES
WIREFRAME AND SURFACES WORKSTATION

Processor	Performance Requirement				
	Level 1	Level 2	Level 3	Level 4	Level 5
Overall Performance (in SPECmarks)	2 to < 10	10 to < 25	25 to < 50	50 to < 100	100 or more
Floating Point Operations (in SPECfp)	1 to < 5	5 to < 25	25 to < 50	50 to < 125	125 or more

Graphics	Performance Requirement				
	Level 1	Level 2	Level 3	Level 4	Level 5
Refresh-3D (in Kvectors/second)	< 10	10 to < 100	100 to < 300	300 to < 1000	1000 or more
Refresh-2D (in Kvectors/second)	< 100	100 to < 300	300 to < 1000	1000 or more	
Gouraud Shading (in Kpolygons/sec)	0 to < 1	1 to < 5	5 to < 20	20 to < 100	100 or more

Graphics	Display Requirement				
	Level 1	Level 2	Level 3	Level 4	Level 5
Display Area (in megapixels)	0.7 to < 1.0	1.0 to < 1.5	1.5 to < 4.0	4.0 or more	
Display bit planes (in bits per pixel)	1 to 7	8 to 23	24 to 39	40 or more	
Color Palette	< 256 K	256 K to < 16M	16 M or more		

Memory and Disk	Capacity Requirement				
	Level 1	Level 2	Level 3	Level 4	Level 5
Random Access Memory (in MB)	8 to < 16	16 to < 32	32 to < 64	64 to < 128	128 or more
Local Disk Capacity (in MB)	0 to < 300	300 to < 1000	1000 to < 5000	5000 or more	

FIGURE 6—EXAMPLE PERFORMANCE AND CAPACITY RANGES
SOLIDS MODELING WORKSTATION