APPENDIX A. ACRONYMS

3D	three dimensional
AI	artificial intelligence
ALAN	Acoustic local area network
ANSI	American National Standards Institute
AOSN	Autonomous Oceanographic Sampling Network
API	application program interface
ARPA	Advanced Research Projects Agency (formerly DARPA, originally ARPA)
atan2 (y, x)	arctangent function, returns angle to a point in proper quadrant
ATM	Asynchronous Transfer Mode
AUV	autonomous underwater vehicle
BSD	Berkeley Software Distribution (a Unix variant)
CB	center of buoyancy
CFD	computational fluid dynamics
CG	center of gravity
dB	decibel (logarithmic unit of measure of sound intensity)
DES	Data Encryption Standard
DIS	IEEE Distributed Interactive Simulation Protocol
DoD	U.S. Department of Defense
DOF	degrees of freedom
dynamics	AUV Underwater Virtual World component: hydrodynamics, network connections and other real-time models (e.g. sonar)
execution	AUV Underwater Virtual World component: robot execution level
FEC	forward error compression - encoding scheme that includes redundant information to reduce probability of data loss

ftp	File Transfer Protocol, refers both to host servers providing information and clients connecting for information retrieval
GPS	Global Positioning System
html	Hypertext Markup Language
http	Hypertext Transfer Protocol, refers both to host servers providing information and clients connecting for information retrieval
IEEE	Institute of Electrical and Electronics Engineers
I^3LA	Initiative for Information Infrastructure and Linkage Applications, a Monterey Bay regional K-16 educational network collaboration
IP	Internet Protocol
IPC	inter-process communications
Irix	Unix as implemented on SGI workstations
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
.iv	Open Inventor scene description language filename extension
Kbps	Kilobits per second
LAN	local area network
lynx	WWW browser with line mode interface, usable within application programs as a client to retrieve files from WWW
MAPS	MBARI-NASA Ames-Naval Postgraduate School-Stanford Aerospace Robotics Lab effort to build next-generation AUV
MBone	Multicast Backbone
Mbps	Megabits per second
MIDI	Musical Instrument Digital Interface
MIME	Multipurpose Internet Mail Extensions (RFC 1341)
MOE	measure of effectiveness
Mosaic	WWW browser with graphical user interface
mrouted	multicast router daemon
NPS	Naval Postgraduate School

nv	*network video* MBone application tool for video and graphics
OOSPICs	Object-Oriented Simulation PICtures
OS-9	Real-time operating system produced by Microware Inc.
OSI	Open Systems Interconnection reference model
PDU	protocol data unit
RBM	Rational Behavior Model
RFC	Request For Comments, draft Internet documents provided for information or standards development
ROV	remotely operated vehicle
rpm	revolutions per minute
RRA	Recursive Ray Acoustics sonar algorithm
SAF	semi-automated forces
sd	*session directory* MBone application tool for session advertisement and selection
SDV-9	Swimmer Delivery Vehicle, hull 9
SGI	Silicon Graphics Inc.
sonar	SOund Navigation And Ranging
SPL	sound pressure level
SSP	sound speed profile (measured versus depth)
SVP	sound velocity profile (typically a misnomer for SSP)
Tcl/Tk	Tool control language/Tool kit
TCP	Transmission Control Protocol, part of IP transport layer
telnet	virtual terminal protocol permitting remote system login
ttl	time-to-live packet hop counter
UDP	User Datagram Protocol, part of IP transport layer
URL	Universal Resource Locator
USN	U.S. Navy
UUV	unmanned underwater vehicle, may be controlled remotely
vat	*visual audio tool* MBone application tool for audio

viewer	AUV Underwater Virtual World component: networked 3D real-time graphics to remotely view robot operating in virtual world
vrml	Virtual Reality Modeling Language
VV & A	validation verification and accreditation
wb	*whiteboard* MBone application tool for shared drawing and images
WWW	World-Wide Web

APPENDIX B. VIDEO DEMONSTRATION

A. INTRODUCTION

This section briefly describes the contents and objectives of the video appendix.

B. NPS AUV OPERATING IN THE UNDERWATER VIRTUAL WORLD: THE SIGGRAPH MISSION

This video segment shows a six minute mission in the underwater virtual world. It first appeared in the Video Proceedings of the AUV 94 conference (Brutzman 94a). The original abstract follows:

> A critical bottleneck exists in Autonomous Underwater Vehicle (AUV) design and development. It is tremendously difficult to observe, communicate with and test underwater robots, because they operate in a remote and hazardous environment where physical dynamics and sensing modalities are counterintuitive.
>
> An underwater virtual world can comprehensively model all salient functional characteristics of the real world in real time. This virtual world is designed from the perspective of the robot, enabling realistic AUV evaluation and testing in the laboratory. Three-dimensional real-time graphics are our window into that virtual world. Visualization of robot interactions within a virtual world permits sophisticated analyses of robot performance that are otherwise unavailable. Sonar visualization permits researchers to accurately "look over the robot's shoulder" or even "see through the robot's eyes" to intuitively understand sensor-environment interactions.
>
> Distribution of underwater virtual world components enables scalability and real-time response. The IEEE Distributed Interactive Simulation (DIS) protocol is used for compatible live interaction with other virtual worlds. Network access allows individuals remote observation. *Mosaic* and the World-Wide Web provides open access to archived images, papers, datasets, software, sound clips, text and any other computer-storable media. This project presents the frontier of 3D real-time graphics for underwater robotics, ocean exploration, sonar visualization and worldwide scientific collaboration. (Brutzman 94a)

C. NPS AUTONOMOUS UNDERWATER VEHICLE

This video segment shows the basic functionality of the NPS AUV. It first appeared in the Video Proceedings of the IEEE International Conference on Robotics and Automation 1992, and the Video Proceedings of the Eighth International Symposium on Unmanned Untethered Submersible Technology (Brutzman 92a, 92b, 93a). The original abstract follows:

> The Naval Postgraduate School (NPS) Autonomous Underwater Vehicle (AUV) is an eight foot long, 387-pound untethered robot submarine designed for research in adaptive control, mission planning, navigation, mission execution, and post-mission data analysis. Neutral buoyancy, eight plane surfaces and twin propellers allow precise maneuverability.
>
> Simulation programs running on Iris three-dimensional graphics workstations are used to evaluate NPS AUV software and predict system performance prior to each mission. Graphics simulations can replay in real time actual data collected in the pool. The taped playback demonstrates reconstruction and visualization of vehicle track, control systems dynamic response, logic and state changes, plotted locations of individual sonar returns, and expert system classification of detected objects.
>
> Ongoing NPS AUV research is investigating linear and nonlinear control techniques, advanced sonar classification, failure mode analysis using neural networks, dynamic path and search planning, use of cross-body thrusters for hovering control, alternate AUV operating architectures, incorporation of Global Positioning System (GPS) receiver navigation, and construction of an underwater virtual world to permit complete and realistic testing of every aspect of AUV operation in the laboratory. (Brutzman 92a, 92b, 93a)

D. LIVE EXHIBIT AND WORLDWIDE MULTICAST AT *The Edge,* SIGGRAPH 94

This segment shows the NPS AUV Underwater Virtual World exhibit at *The Edge*, SIGGRAPH 94 (Brutzman 94b, 94c). Video photographer is Michael J. Zyda.

E. NPS AUV WORLD-WIDE WEB HOME PAGE

This video segment shows how to connect to the NPS AUV home page and retrieve the underwater virtual world distribution. Installation is also demonstrated.

F. EXTENDED NPS AUV MISSION REPLAYS

Additional NPS AUV missions are run from the underwater virtual world archive distribution, evaluating a variety of hydrodynamic and sonar responses.

G. NPS AUV POSTURE CONTROL

This video segment demonstrates in-water test tank results from early 1994. It first appeared in the Video Proceedings of the AUV 94 conference (Brutzman 94a) by authors A.J. Healey, D.B. Marco, R.B. McGhee, D.P. Brutzman, R. Cristi and F.A. Papoulias. The original abstract follows:

> Recent work with the NPS AUV II demonstrates further development of the execution level software to incorporate hover control behavior in the NPS hover tank. Of particular interest is the use of the ST 100 and ST 725 high frequency sonars to provide data about the environment. Thus positioning can be accomplished without the use of beacons.
>
> Motion behaviors may be instituted that include diving and pitch control under thruster power, heading control at zero speed, lateral and longitudinal positioning, as well as the automatic initiation of filters as needed when a new target is found. A simple task level language is developed that will be used to direct tactical level output to a port which communicates with execution level software. (Healey abstract, Brutzman 94a)

H. MBone: AUDIO/VIDEO INTERNET TOOLS FOR INTERNATIONAL COLLABORATION

This video segment describes and demonstrates use of the MBone. It was recorded from a worldwide MBone broadcast of the May 1994 International Advanced Robotics Programme (IARP): Mobile Robots for Subsea Environments, hosted by the Monterey Bay Aquarium Research Institute (MBARI). It originally appeared at in the Video Proceedings of the AUV 94 conference (Brutzman 94a). MBone media strengths and limitations videoconference are formally evaluated in (Gambrino 94) using this videoconference. The original abstract follows:

> Recently it has become possible to broadcast live audio and video over the Internet using the Multicast Backbone (MBone). This development holds great promise as an enabling technology for collaborative work among underwater vehicle researchers separated by long distances.
>
> This talk describes technical considerations related to use of the MBone, which is the virtual network used for these Internet sessions. Anyone with direct Internet connections, adequate bandwidth and a workstation can receive multicast. We hope to demonstrate that worldwide collaboration among underwater robotics researchers is not only feasible but even convenient.
>
> For more information on how to connect your lab to MBone, refer to "MBone Provides Audio and Video Across the Internet" in the April 94 issue of *IEEE COMPUTER*, pp. 30-36. This article is also available for electronic retrieval in PostScript, text, and hypertext versions:
> ftp://taurus.cs.nps.navy.mil/pub/i3la/mbone.ps
> ftp://taurus.cs.nps.navy.mil/pub/i3la/mbone.txt
> ftp://taurus.cs.nps.navy.mil/pub/i3la/mbone.html (Brutzman 94a)