Designation: F 2595 – 06

Standard Guide for
Unmanned Undersea Vehicle (UUV) Sensor Data Formats[1]

This standard is issued under the fixed designation F 2595; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

ASTM has prepared this series of standards to guide the development of autonomous unmanned underwater vehicles (UUVs). The standards address the key capabilities that a UUV system must possess in order to be considered autonomous and reconfigurable:

Autonomous—Capable of operating without operator input for extended periods of time. Implicit in this description is the requirement that the UUV's sortie accomplishes its assigned goal and makes the appropriate rendezvous for a successful recovery.

Reconfigurable—Capable of operating with multiple payloads. The top level requirement is established that the UUV systems will consist of:

Payloads to complete specific system tasking such as environmental data collection, area surveillance, mine hunting, mine countermeasures, intelligence/surveillance/reconnaissance (ISR), or other scientific, military, or commercial objectives.

Vehicles that will transport the payloads to designated locations and be responsible for the launch and recovery of the vehicle/payload combination.

While the payload will be specific to the objective, the vehicle is less likely to be so. Nevertheless, commonality across all classes of UUV with respect to such features as planning, communications, and post sortie analysis (PSA) is desirable. Commonality with regard to such features as launch and recovery and a common control interface with the payload should be preserved within the UUV class.

In accordance with this philosophy, ASTM identifies four standards to address UUV development and to promote compatibility and interoperability among UUVs:

F 2541–Standard Guide for UUV Autonomy and Control,
WK11283–Standard Guide for UUV Physical Payload Interface,
F 2594–Standard Guide for UUV Communications, and
F 2595–Standard Guide for UUV Sensor Data Formats.

The relationships among these standards are illustrated in Fig. 1. The first two standards address the UUV autonomy, command and control, and the physical interface between the UUV and its payload. The last two ASTM standards address the handling of the most valuable artifacts created by UUV systems, the data. Since there are many possibilities for communications links to exchange data, it is expected that the UUV procurement agency will provide specific guidance relative to these links and the appropriate use of the UUV communications standard. In a similar manner, specific guidance is expected for the appropriate use of the UUV data formats.

F 2541–Standard Guide for UUV Autonomy and Control—The UUV autonomy and control guide defines the characteristics of an autonomous UUV system. While much of this guide applies to the vehicle and how the vehicle should perform in an autonomous state, the relationship of the payloads within the UUV system is also characterized. A high level depiction of the functional subsystems associated with a generic autonomous UUV system is presented. The important functional relationship established in this guide is the payload's subordinate role relative to the vehicle in terms of system safety. The payload is responsible for its own internal safety, but the vehicle is responsible for the safety of the vehicle-payload system. Terminology is defined to provide a common framework for the discussion of autonomous systems. System behaviors and capabilities are identified that tend to make a system independent of human operator input and provide varying levels of assurance that the UUV will perform its assigned task and successfully complete recovery. A three-axis sliding scale is presented to illustrate the system's level of autonomy (LOA) in terms of situational awareness,

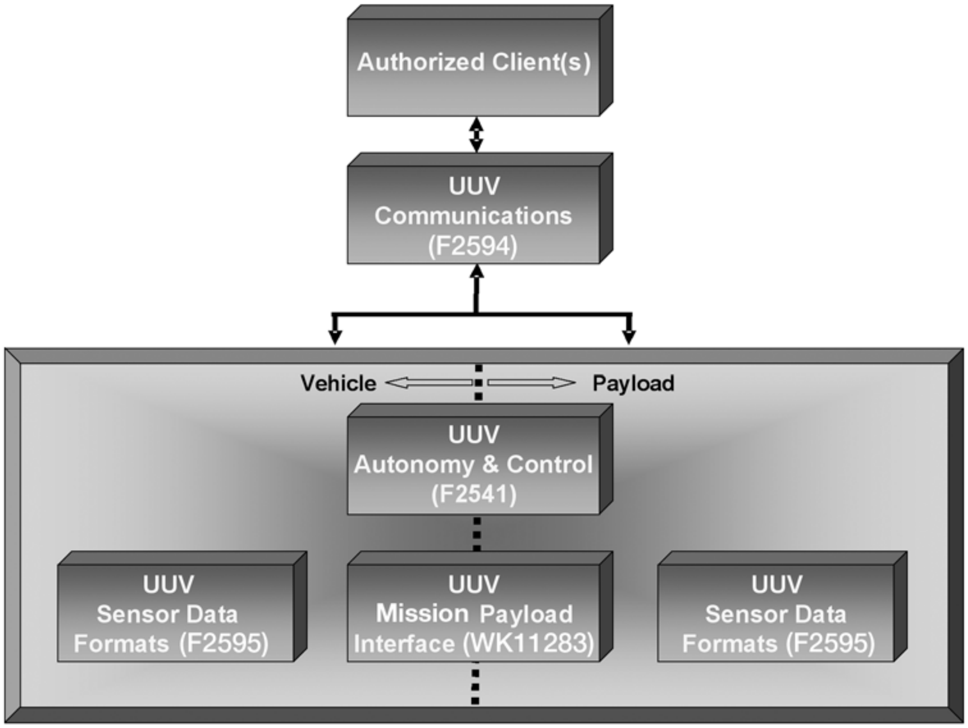

FIG. 1 Notional System Interfaces and Governing Standards

decision-making/planning/execution, and external interaction. The control interface (messages exchanged between the vehicle and the payload) is described and instantiations of this interface for the various classes of UUV are presented in associated appendices.

WK11283–Standard Guide for UUV Physical Payload Interface—The UUV physical payload interface guide is a physical and functional interface standard that guides the mechanical and electrical interface between the vehicle and the payload, and the functional relationship between the vehicle and the payload. In-as-much-as a single physical interface standard cannot address all classes of UUVs, this guide describes the physical interfaces in the body of the guide and provides appendices to guide the instantiation for each of the classes. This guide reinforces the relationship between the vehicle and the payload and confirms the permission-request responsibility of the payload and the permission-granted/denied authority of the vehicle.

F 2594–Standard Guide for UUV Communications—The UUV communications standard guides the development of offboard communications between the UUV system and the authorized clients, that is, those agents designated by the UUV operational authorities with responsibility for programming, operating, or maintaining, or a combination thereof, a UUV. An authorized client may also represent an end user of UUV and payload mission data. Such a standard is required to provide for UUV interoperability with multiple authorized agents and to provide the authorized agents with interoperability with multiple UUVs (preferably across the different classes of UUVs). Optical, RF, and acoustic methods of communication are considered. While RF communication is a matured communications mode and existing standards are referenced and adopted for offboard surface communication, underwater acoustic communication (ACOMMS) is an evolving field and interoperability between the different ACOMMS systems is also evolving. Typical ACOMMS systems and protocols are described with typical applications related to bandwidth and range. General comments are provided for optical communication as the use of this mode of communication may evolve in the future.

F 2595–Standard Guide for UUV Sensor Data Formats—The UUV sensor data formats guide provides the UUV and payload designer with a series of commonly accepted data formats for

[1] This guide is under the jurisdiction of ASTM Committee F41 on Unmanned Undersea Vehicle (UUV) Systems and is the direct responsibility of Subcommittee F41.02 on Communications.

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underwater sensors. These formats provide the opportunity for two-way interoperability. Their use facilitates the UUV system's ability to process historical environmental data for mission planning purposes. Likewise, use of these formats facilitates the end users' ability to catalog, analyze, and produce recommendations based on current field data. Fig. 1 suggests that both vehicle-specific data as well as payload sensor data should be stored in these data formats.

1. Scope

1.1 This guide establishes the basic sensor data format requirements for Unmanned Undersea Vehicles (UUVs). This guide is intended to influence the development process for the acquisition and integration of various sensor packages, but at the same time, not specify particular solutions or products. An additional intent of this guide is to address the data format standards specifically required for operation of the U.S. Navy's planned 21-in. Mission Reconfigurable UUV System (MR-UUVS), which is representative of its heavy weight class of UUVs. Although this initial release of UUV sensor data formats standards primarily focuses on the U.S. Navy's UUV missions comprising intelligence, surveillance and reconnaissance (ISR), mine countermeasures (MCM), and oceanographic data collection, there is broad utility across the spectrum of commercial applications as well.

1.2 Readers of this guide will find utility in referencing Guides F 2541, F 2594, and WK11283. There is a clear relationship that exists in terms of data formats, external interfaces, and information/data exchange that can be applied in context with the standards invoked in these documents.

1.3 The main body of this guide, Section 5, provides general guidelines for sensor data, including water column and ocean bottom undersea search and survey (USS) measurements, and above-waterline data. It describes required records, but does not attempt to specify individual record formats, except as already established in existing documentation. Whenever possible, data formats are suggested to conform to existing convention to facilitate data processing and use. This guide generally notes where standard U.S. Department of Defense (DoD) formats are established or *de facto* commercial formats exist and are adequate, such as widely accepted World Meteorological Organization (WMO) or Intergovernmental Oceanographic Commission (IOC) standards.

1.4 Though the general guidelines established in this guide apply to most oceanographic sensor data, the data types specifically considered here are limited to: water column measurements (including temperature, salinity, currents, optical clarity, and bioluminescence), ocean bottom measurements (including bathymetry, acoustic images, and sub-bottom), ambient noise, and related geophysical parameters. Specific above-waterline ISR sensor data is addressed by reference to governing U.S. military standards for certain data types. Discussion of electromagnetic and electro-optical (EM/EO) data formats (including atmospheric refractivity) is also included.

1.5 Section 6 covers related mission data formats such as timing. It also serves as a placeholder for future discussion of vehicle-specific mission data formats. Navigation, vehicle status, and related vehicle information data formats are expected to be addressed in subsequent versions of this guide. Also included in this section are brief discussions on external interface and command and control formats. Section 7 introduces the topic of metadata formats. Amplification of this subject is warranted and will be incorporated into future versions of the guide. Section 8 briefly identifies general data storage media concerns for UUVs, but does not attempt to mandate decisions best made by system developers based on mission needs. Onboard data storage decisions will be driven by power requirements, data volume, and media cost. Section 9 presents an abbreviated summary of the currently recommended data format standards where they could be identified. Finally, Section 10 exists primarily as a placeholder to address relevant technology forecasts that could impact future data formats.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

F 2541 Guide for Autonomy and Control for Unmanned Undersea Vehicles (UUVs)

F 2594 Guide for Unmanned Undersea Vehicle (UUV) Communications

WK11283 Guide for Unmanned Undersea Vehicle (UUV) Mission Payload Interface

2.2 *DoD Documents:*[3]

DoD Bathymetric Library (DoDBL)

DoD Directive 8320.2 Data Sharing in a Net-Centric Department of Defense

2.3 *IEEE Standards:*[4]

ISO/IEC 12207 Standard for Information Technology Software Life Cycle Support

IEEE/EIA 12207 Industry Implementation of International Standard

2.4 *ISO Standard:*[5]

ISO/TC 211 Geographic Information/Geomatics

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from the U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., N.W., Mail Stop: SDE, Washington, DC 20401.

[4] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331.

[5] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland.

2.5 *Military Standards:*[6]

MIL-STD-2500B(2) National Imagery Transmission Format (Version 2.1) for the National Imagery Transmission Format

MIL-D-89029 Military Specification for Bathymetric Databases[7]

MIL-PRF-89049 Vector Product Format (VPF)[8]

MIL-PRF-89049/10 Tactical Ocean Data—Level 0

MIL-PRF-89049/11 Tactical Ocean Data—Level 1

MIL-PRF-89049/12 Tactical Ocean Data—Level 2

MIL-PRF-89049/14 Tactical Ocean Data—Level 4

MIL-STD-2401 Standard Practice—WGS84[9]

MIL-STD-2407 Interface Standard (VPF)[10]

MSC 64(67) Annex 17 Adoption of New and Amended Performance Standards

MSC 86(70) Annex 17 Adoption of New and Amended Performance Standards for Navigational Equipment

2.6 *Other Documents:*

Ambient Noise Data Base (ANDB) Preliminary Database Definition Document, NRL SSC 21 January 2005[11]

AOCO COMINT Joint Interface Control Document Standards[12]

AOCO ELINT Joint Interface Control Document Standards[12]

Charter File Format, Naval Oceanographic Office[13]

Digital Bathymetric Database, Variable Resolution (DBDB-V) Version 5, Naval Oceanographic Office[13]

Generic Sensor Format (GSF) Specification, Version 2.02, Naval Oceanographic Office, 20 June 2003[11]

Geoacoustic Database Variable Resolution (GDBV) Database Definition Document, NRL Stennis Space Center, 19 December 2003[11]

L-PUMA Forward Looking Sonar (FLS) ICD, Interface Control Document (ICD) for the Littoral Precision Underwater Mapping (L-PUMA) System Forward Looking Sonar (FLS), NAVSEA 8293252

Marine Geophysical Data Exchange Formats (MGD-2000), National Geophysical Data Center[13]

Mine Countermeasures Report Format (MCMREP)[14]

Software Requirements Specification for the Mine Warfare and Environmental Decision Aids Library (MEDAL), Build 7 Maintenance Release, MEDAL-DI-00001-5.1.0, Office of Naval Research, May 2002[11]

Tactical Decision Aids (TDAs), Applicable TDAs include the aforementioned MEDAL, plus Interactive Multisensor Analysis Training (IMAT), Personal Computer (PC) IMAT, Geophysical Fleet Mission Program Library (GFMPL) and the Advanced Refractive Effects Prediction System (AREPS)[11]

UNIfied Sonar Imaging Processing System (UNISIPS) Version 5, Naval Oceanographic Office[15]

3. Terminology

3.1 *Acronyms:*

3.1.1 *ANDB*—Ambient Noise Database

3.1.2 *AOCO*—Airborne and Overhead Cooperative Operations

3.1.3 *AREPS*—Advanced Refractive Effects Prediction System

3.1.4 *ASCII*—American Standard Code for Information Interchange

3.1.5 *ASW*—Anti-Submarine Warfare

3.1.6 *ATA*—Advanced Technology Attachment

3.1.7 *BIIF*—Basic Imagery Interchange Format

3.1.8 *CCS*—Combat Control Systems

3.1.9 *CMOS*—Complementary Metal Oxide Semiconductor

3.1.10 *COI*—Communities of Interest

3.1.11 *COMINT*—Communications Intelligence

3.1.12 *CONOPS*—Concept of Operations

3.1.13 *COTS*—Commercial Off The Shelf

3.1.14 *DBDB-V*—Digital Bathymetric Database - Five

3.1.15 *DCGS-N*—Distributed Common Ground Station-Navy

3.1.16 *DoD*—Department of Defense

3.1.17 *DoDBL*—Department of Defense Bathymetric Library

3.1.18 *DVL*—Doppler Velocity Log

3.1.19 *ELINT*—Electronic Intelligence

3.1.20 *EM/EO*—Electromagnetic/Electro - Optical

3.1.21 *EARS*—Environmental Acoustic Recording System

3.1.22 *FGDC*—Federal Geographic Data Committee

3.1.23 *FLS*—Forward Looking Sonar

3.1.24 *GDBV*—Geoacoustic Database Variable Resolution

3.1.25 *GDD*—Global Data Dictionary

3.1.26 *GEODAS*—Geophysical Data System

3.1.27 *GFMPL*—Geophysical Fleet Mission Program Library

3.1.28 *GIF*—Graphics Interchange Format

3.1.29 *GIG*—Global Information Grid

3.1.30 *GOOS*—Global Ocean Observing System

3.1.31 *GRL*—Global Revocation Library

[6] Available from National Geospatial-Intelligence Agency (NGA), NGA Office of Corporate Relations Public Affairs Division, MS D-54, 4600 Sangamore Rd., Bethesda, MD 20816-5003, Jan. 1995.

[7] MIL-D-89029 is the current data standard for Digital Bathymetric Databases including DBDB-0.1 (0.1 minute horizontal resolution) and DBDB-0.5 (0.5 minute resolution). Both of these databases are classified.

[8] VPF is a format for vector databases and is used primarily for geospatial data including terrain, bathymetry and additional layers of information.

[9] Charting standard based upon the WGS-84 ellipsoid. Virtually all military GPS systems use the WGS-84 ellipsoid as the basis for their generated positions.

[10] Interface of Vector Product Format data to other systems and displays.

[11] Available from the Office of Naval Research, 1002 Balch Blvd., Code N14, Stennis Space Center, MS 39522-5001.

[12] Airborne & Overhead Cooperative Operations Unclassified ELINT Joint Interface Control Documents (V 3.2, & V 3.3), 25 March 2005 with Errata Sheets 1 and 2 and COMINT Joint Interface Control Documents (V 4.0), 25 March 2005 with Errata Sheets 1 and 2, available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., N.W., Mail Stop: SDE, Washington, DC 20401.

[13] Available from National Geophysical Data Center, E/GC 325 Broadway, Boulder CO, 80305-3328.

[14] Available from Commander, Mine Warfare Command, 325 Fifth Street SE, Corpus Christi, TX 78419-5032.

[15] Available from The Naval Oceanographic Office's Oceanographic and Atmospheric Master Library (OAML), 1002 Balch Blvd., Code N14, Stennis Space Center, MS 39522-5001.

3.1.32 *GSF*—Generic Sensor Format
3.1.33 *HFBL*—High-Frequency Bottom Loss
3.1.34 *HIE*—Historical Ice Edge
3.1.35 *ICD*—Interface Control Document
3.1.36 *IDL*—Interactive Data Language
3.1.37 *IEEE*—Institute of Electrical and Electronics Engineers
3.1.38 *IMAT*—Interactive Multisensor Analysis Training
3.1.39 *MINT*—Imagery Intelligence
3.1.40 *IOC*—Intergovernmental Oceanographic Commission
3.1.41 *IOOS*—Integrated Ocean Observing System
3.1.42 *IRIG*—Inter Range Instrumentation Group
3.1.43 *ISO/TC 211*—International Organization for Standardization Technical Committee 211
3.1.44 *ISR*—Intelligence, Surveillance, and Reconnaissance
3.1.45 *ISR&T*—Intelligence, Surveillance, and Reconnaissance & Targeting
3.1.46 *JAUS*—Joint Architecture for Unmanned Systems
3.1.47 *JPEG*—Joint Photographic Experts Group
3.1.48 *JICD*—Joint Interface Control Document
3.1.49 *LFBL*—Low-Frequency Bottom Loss
3.1.50 *L-PUMA*—Littoral-Precision Underwater Mapping
3.1.51 *MIZ*—Marginal Ice Zone
3.1.52 *MCM*—Mine Countermeasures
3.1.53 *MCMREP*—Mine Countermeasures Report
3.1.54 *MEDAL*—Mine-warfare Environmental Decision Aids Library
3.1.55 *MGD*—Marine Geophysical Data
3.1.56 *MLO*—Mine-Like Object
3.1.57 *MIW*—Mine Warfare
3.1.58 *MRUUVS*—Mission Reconfigurable Unmanned Undersea Vehicle System
3.1.59 *NGA*—National Geospatial-Intelligence Agency
3.1.60 *NGDC*—National Geophysical Data Center
3.1.61 *NAVOCEANO*—Naval Oceanographic Office
3.1.62 *NITF*—National Imagery Transmission Format
3.1.63 *NOAA*—National Oceanic and Atmospheric Administration
3.1.64 *NSIF*—NATO Secondary Imagery Format
3.1.65 *NSP*—National System Processor(s)
3.1.66 *NTP*—Network Timing Protocol
3.1.67 *PC-IMAT*—Personal Computer - Interactive Multisensor Analysis Training
3.1.68 *PUMA*—Precision Underwater Mapping
3.1.69 *SAE*—Society of Automotive Engineers
3.1.70 *SAS*—Synthetic Aperture Sonar
3.1.71 *SATA*—Serial Advanced Technology Attachment
3.1.72 *SI*—International System of Units
3.1.73 *SIGINT*—Signals Intelligence
3.1.74 *SLS*—Side Looking Sonar
3.1.75 *SML*—Sensor Modeling Language
3.1.76 *SN*—Shipping Noise
3.1.77 *SPL*—Sound Pressure Level
3.1.78 *SSN*—Submersible Ship Nuclear
3.1.79 *SUBLAN*—Submarine Local Area Network
3.1.80 *SWFTS*—Submarine Warfare Federated Tactical Systems
3.1.81 *TACLAN*—Tactical Local Area Network
3.1.82 *TDA*—Tactical Decision Aids
3.1.83 *TIFF*—Tagged Image File Format
3.1.84 *TSP*—Tactical System Processor(s)
3.1.85 *UNISIPS*—Unified Sonar Image Processing System
3.1.86 *USS*—Undersea Search and Survey
3.1.87 *UUV*—Unmanned Undersea Vehicle
3.1.88 *VD*—Vertical Deflection
3.1.89 *WMO*—World Meteorological Organization
3.1.90 *XML*—Extensible Markup Language

4. Significance and Use

4.1 While the emphasis of this initial UUV data formats guide is focused on the collection and processing of environmental parameters gleaned from UUV sensors executing military operations, it is relatively easy to translate these guidelines to the commercial sector. The type of data collected may differ, but the standardization of the data formats, whether for scientific, economic, or military applications does not. Standardized data formats are equally leveraged for myriad pursuits such as determining the extent of global warming, maintaining security of offshore petroleum facilities, or measuring the sustainability of the oceans' biomass. Military applications of UUVs often mandate unusual and even non-standard data collections and formats. As a result, conforming to national and international standards may not always be possible. However, to the maximum extent practicable, data collection formats and standards should follow World Meteorological Organization (WMO), Intergovernmental Oceanographic Commission (IOC), and similar national and international standards.

4.2 The U.S. Navy has recently updated the vision for UUV operations in its UUV Master Plan.[16] This Master Plan articulates nine high-priority prospective UUV missions. The top priority for UUV missions is the collection of maritime ISR data. Data formats for communications intelligence (COMINT) and electronic intelligence (ELINT) information have been addressed in unclassified documents described by Airborne & Overhead Cooperative Operations (AOCO). These Joint Interface Control Documents (JICD) stipulate essential formats and standards for tactical sensors and their associated communications systems in order to be interoperable with national overhead and airborne intelligence, surveillance, and reconnaissance and targeting (ISR&T) architectures and systems.

4.3 Other UUV military missions specifically called out in the Master Plan include conducting mine countermeasures (MCM), anti-submarine warfare (ASW), and oceanography. In the case of these three capabilities, ocean data collection is integral to the mission. Payloads capable of executing this data collection have already been established for surface and air-deployed sensors and are readily extended to UUVs. However, there may be some payloads, such as bioluminescence sensors, that may not be currently configured to fit UUV form factors.

[16] The Navy Unmanned Undersea Vehicle (UUV) Master Plan, November 9, 2004.

4.4 Tactical Decision Aids (TDAs), generally computer programs and models, are used to support sensor and weapons systems throughout the military. As a result, quality environmental data are required as inputs to these programs. TDAs such as Mine Warfare and Environmental Decision Aids Library (MEDAL), Interactive Multisensor Analysis Training (IMAT), PC IMAT, Geophysical Fleet Mission Program Library (GFMPL) and the Advanced Refractive Effects Prediction System (AREPS) are examples. The goal of all environmental data collected by military UUVs is that it readily supports these and other TDAs and operational requirements without heavy manipulation from one data format to another.

4.5 UUVs collect data on ocean properties, underwater terrain, obstructions and mines, the presence of chemical or biological agents in air and water samples, and above-the-surface photographic and radio frequency samples. The collection of this data leverages a primary advantage of the UUV, which is to gather data covertly in a denied maritime setting that can be used by intelligence and mission planners in developing and executing tactical actions. The underwater data, along with accurate navigational fixes, must also be available to the UUV for its use in maintaining safe operational depth and executing precise navigation and maneuvering. Finally, the data are also integral to performing any post-mission analysis and mission reconstruction.

4.6 The DoD has begun an effort to build the Global Information Grid (GIG). As an integral part of the GIG, a data strategy is being developed. DoD Directive 8320.2 starts the chain of requirements specifying how data will be shared. The UUV data formats standards espoused in this guide and any future revisions should be developed in accordance with this strategy. The requirement to associate metadata so that data can be discoverable is invoked in DoD 8320.2. The requirement that data semantic and structural agreements shall be promoted through communities of interest (COIs) is another important concept introduced by DoD 8320.2. Data content needs to be determined and agreed upon by producers of the data and the customers of the data. Clearly, for this guide to be most beneficial across both the military and civilian UUV communities, it needs to be developed closely with the customers of UUV data and supported by continual feedback from the UUV community.

5. Sensor Data Formats

5.1 *General Water Column and Ocean Bottom Guidelines*—Water column and ocean bottom data measurements and metadata formats are most useful for analysis during and after a mission if the following are included:

5.1.1 Measurement value or values,

5.1.2 Geo-referencing (latitude/longitude), including depth,

5.1.3 Resolution of the measurement,

5.1.4 Averaging (ensemble) choices,

5.1.5 Time at which the measurement was taken, and

5.1.6 Accuracy and precision of the primary and supporting measurements.

5.2 *Low Volume Data Versus High Volume Data*:

5.2.1 Low volume data can be described as observations that do not occur at a rapid rate. The desired low volume format is XML. Specifically, adherence to the Sensor Modeling Language (SML) as an XML vocabulary for self-describing dynamic sensor data is recommended.

5.2.2 High volume data includes multi-beam data and imagery. General data formats for this type of data are described in 5.5.

5.3 *Governing U.S. Military Specifications*—Two specifications that should be invoked for presenting water column and ocean bottom data are MIL-PRF-89049 and, MIL-D-89029. The 89049 standards cover certain layer types within the digital nautical chart production environment such as bottom contours, OP AREAS, etc. The 89029 is the current data standard for Digital Bathymetric Databases including DBDB-0.1 (0.1 minute horizontal resolution) and DBDB-0.5 (0.5 minute resolution). Both of these 89029 databases are classified.

5.4 *Specific Water Column Guidelines*:

5.4.1 *Temperature and Salinity*—Temperature and salinity measurements are often point measurements at UUV depth. If possible, averaging of data should be avoided. Plain text metadata for the measurement normally consists of the value of the measurement; the resolution or precision of the measurement; and the latitude, longitude, depth, and time of the measurement. If averaging or sub-sampling of the data was performed, the method should be fully described in the metadata.

5.4.2 *Ocean Currents*:

5.4.2.1 Current information can be measured in a variety of ways aboard UUVs. Most widely used methods include Doppler Current Profilers or Doppler Velocity Logs (DVL), set and drift calculations, and deployment of fixed current measurement instruments. Glider UUVs, for example, may measure current by determining set and drift from their predicted navigation solution. As a result, the calculated current may not be depth related or point specific but integrated over the track from point to point. This data must be annotated to reflect that it is not point data, but averaged data. If averaging, sub-sampling of the data or other data processing method is used the method should be fully described by the metadata. All current data should be collected in delimited ASCII format (or easily convertible binary) containing location, time, depth, speed and direction values when possible.

5.4.2.2 DVLs are sonar systems designed to measure Doppler information from debris and bubbles in the water column for the purpose of determining speed and direction of the vehicle. DVLs are often used as part of an integrated undersea navigation solution that includes inertial sensors. DVLs can also be used in "bottom lock" or "ice lock" mode to track the bottom or pack ice above the vehicle for very accurate navigation input. For environmental characterization, raw DVL current data should be provided at the rate collected and averaged in post-processing to ensure the integrity of the ensemble averaged data. The processing method should be defined by the metadata. Depth bins at the highest resolution possible are preferred, but different bins can be used to optimize the UUV's mission.

5.4.3 *Optical Clarity and Bioluminescence*—Optical clarity and bioluminescence are used in planning and executing mine warfare (MIW) operations. Optical clarity and bioluminescence data are collected from a variety of platforms to include