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StandardGuide for Unmanned Undersea Vehicles (UUV) Autonomy and Control[1]

This standard is issued under the fixed designation F2541; 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 likely to be less so. Nevertheless, commonality across all classes[2] 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:

F2541 Guide for UUV Autonomy and Control
WK11283 Guide for UUV Mission Payload Interface
F2594 Guide for UUV Communications
F2595 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 and data storage standard.

F2541–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,

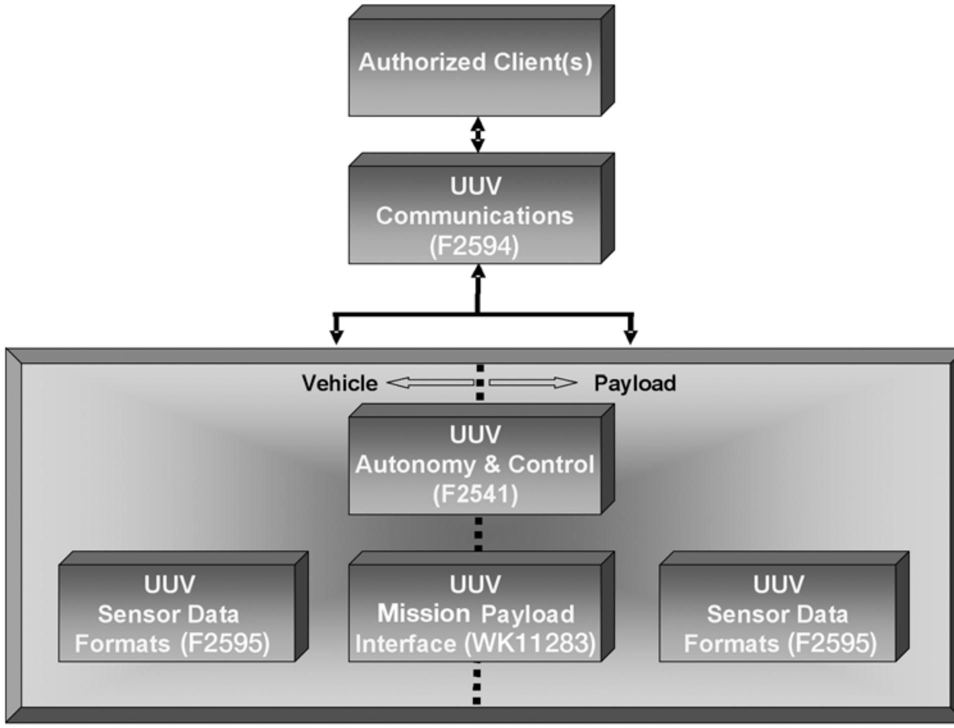

FIG. 1 Notional System Interfaces and Governing Standards

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 Mission Payload Interface—The UUV mission payload interface guide is a physical and functional interface standard that guides:

The mechanical and electrical interface between the vehicle and the payload.

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 a guide to 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.

F2594–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 a UUV, or a combination thereof. 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.

F2595–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

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[2] UUV Master Plan.

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 covers the need for UUVs to operate autonomously, without constant human intervention, and with flexibility based on their payloads and missions places unique requirements on UUV developers. Because the UUV community is expected to expand both its developer base and its user base in the next several years, it recognizes that success relies upon a well-written standard. The standard must encourage compatibility and reconfigurability, provide a common language to describe functional capabilities, and enable meaningful quantitative performance evaluation.

1.2 The scope of this guide includes those characteristics in a UUV system which, when implemented in a detailed design, result in a UUV that is capable of operating for extended periods of time without external intervention. Implicit in this statement is the requirement that the UUV execute its designated sortie plan. Non-expendable UUVs must also return to a rendezvous point for recovery. The top level concept of such an autonomous system is presented in Fig. 3. The functional relationships identified in this block diagram will be discussed further in Section 4.

1.3 This guide contains a table of terminology so that autonomy and control can be described within the context of a common language, where all terms have consistent and clearly defined meaning. As introduced in Fig. 3, this guide defines high level functional capabilities of the autonomy controller, the vehicle controller, and the payload controller. Correspondingly high level interfaces are also defined.

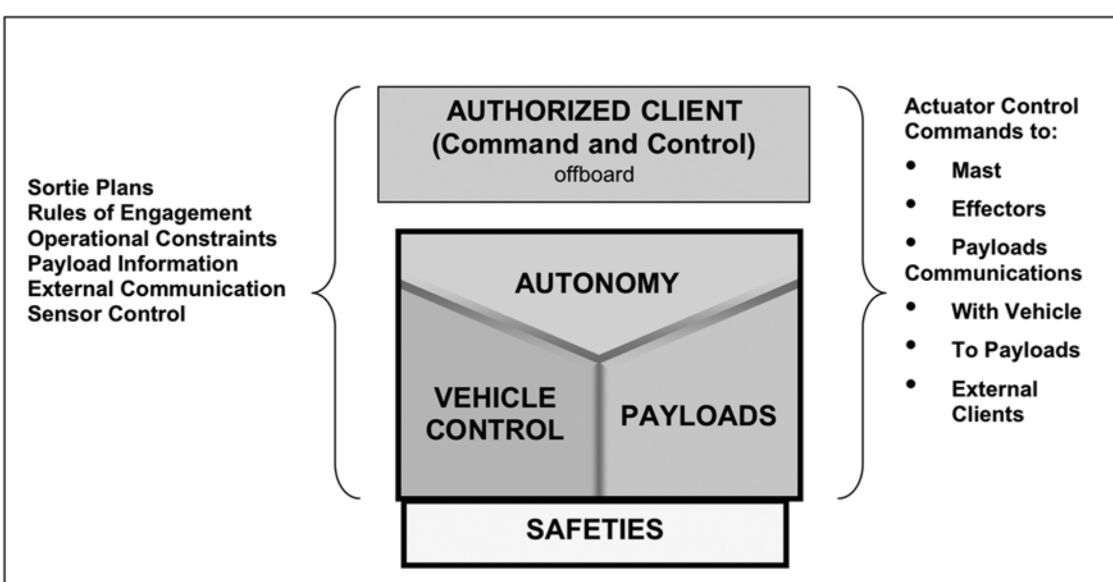
1.4 Section 5 presents the capabilities that an autonomous system is required to have. The table in this section concentrates on the functional capabilities of the total system, as opposed to the capabilities of the component controllers. A method for verification of the capability is also presented.

1.5 Section 6 presents a set of tables that index the system autonomy capabilities according to three criteria: Situational Awareness, Decision-making, Planning, and Control, and External Interactions. Such a set of qualifiers determines a Level of Autonomy (LOA) measurement for each of the three criteria. No attempt is made to combine these disparate measures into a single index.

1.6 The following are outside the scope of this guide and no part of this guide should be construed to prescribe requirements associated with these areas.

Payloads—outside of the generic functions of the Payload controller and the top level interfaces, the design and implementation of payload subsystems are not addressed in this guide.

Vehicles—outside of the generic function of the Vehicle controller and the top level interfaces, the design and implementation of the vehicle subsystems are not addressed in this guide.



NOTE 1—Internal boundaries between autonomy, vehicle control, and safeties are fuzzy, and different systems will have slightly different boundaries.

FIG. 2 Autonomy and Control Module External Interfaces