System Assessment and Validation for Emergency Responders (SAVER)

Underwater Cameras Assessment Report

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FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercially available equipment and systems and develops knowledge products that provide relevant equipment information to the emergency responder community. The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency response equipment
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency response equipment.

SAVER Program knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?" These knowledge products are shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. As a SAVER Program Technical Agent, the Space and Naval Warfare Systems Center (SPAWARSYSCEN) Atlantic has been tasked to provide expertise and analysis on key subject areas, including communications, sensors, security, weapon detection, and surveillance, among others. In support of this tasking, SPAWARSYSCEN Atlantic developed this report to provide emergency responders with information obtained from an operationally oriented assessment of underwater cameras, which fall under AEL reference number 04MD-01-UCAM titled Camera, Underwater (Still/Video).

For more information on the SAVER Program or to view additional reports on underwater cameras or other technologies, visit www.firstresponder.gov/SAVER.

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EXECUTIVE SUMMARY

Underwater cameras are valuable tools used by public safety divers to document underwater accidents, crime scenes, and security inspections. In May 2015, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of underwater cameras.

Seven underwater cameras were assessed by public safety divers. The criteria and scenarios used in this assessment were derived from the results of a focus group of public safety divers with experience using underwater cameras. The assessment addressed 13 evaluation criteria in four SAVER categories: Capability, Deployability, Maintainability, and Usability. The overall results of the assessment are highlighted in the following table.

Product	Overall Score	Overall	Usability	Capability	Maintainability	Deployability
Olympus Corporation of the Americas TG-3		**4.1**	3.7	4.7	3.9	3.5
Canon USA Inc. PowerShot D30		**4.0**	3.9	4.2	4.0	3.9
Nikon Inc. COOLPIX AW120		**4.0**	3.7	4.4	3.8	3.6
GoPro Inc. HERO4 Silver		**3.9**	3.8	3.9	4.0	3.9
SeaLife DC1400		**3.8**	4.2	3.0	4.3	3.8
Intova EDGE X		**3.4**	3.3	3.1	3.9	3.5
Oregon Scientific Inc. ATC9K HD Action Camera		**2.5**	2.4	2.6	2.0	2.9
	0 1 2 3 4 5 Lower Higher					

1. INTRODUCTION

Underwater cameras are valuable tools used by public safety divers to document underwater accidents, crime scenes, and security inspections. In May 2015, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of underwater cameras. The purpose of this assessment was to obtain information on underwater cameras that will be useful in making operational and procurement decisions. The activities associated with this assessment were based on recommendations from a focus group of public safety divers with experience using underwater cameras.

1.1 Evaluator Information

Five public safety divers from various jurisdictions and with at least 10 years of experience using underwater cameras were selected to be evaluators for the assessment. Evaluator information is listed in Table 1-1. Prior to the assessment, evaluators signed a nondisclosure agreement, conflict of interest statement, and photo release form.

Table 1-1. Evaluator Information

Evaluator	Years	State
Law Enforcement, Dive Team Diver	20+	FL
Emergency Services, Marine Unit Diver	20+	TN
Law Enforcement, Dive Team Diver	16-20	WA
Law Enforcement, Search and Rescue Team Diver	11-15	AL
Law Enforcement, Dive Rescue/Swift Water Team Diver	6-10	WA

1.2 Assessment Products

Seven products were selected and purchased for the assessment based on market research and the focus group's recommendations. Final selection was based on how well each product met the product selection criteria identified by the focus group and listed below.

- Commercially available, removable storage media
- Depth rating of at least 40 meters
- Ability to capture still images
- User-replaceable battery
- Display screen
- Shock resistant.

A mix of compact digital and action cameras were selected for assessment with a maximum of one camera per vendor. Cameras that were waterproof to a depth of at least 10 meters with or without an included housing were considered for the assessment. The Intova® EDGE X and SeaLife® DC1400 were selected because they met all product selection criteria. The rest of the action cameras were selected because they had a display screen. The rest of the compact digital cameras were selected by

choosing one from each remaining vendor with the greatest depth rating since these cameras met all product selection criteria except a depth rating of at least 40 meters.

Table 1-2 presents the products that were assessed.

Table 1-2. Assessed Products

Vendor	Product	Product Image
Canon USA Inc.	PowerShot D30	
GoPro Inc.	HERO4 Silver	
Intova	EDGE X	
Nikon Inc.	COOLPIX AW120	
Olympus Corporation of the Americas	TG-3	
Oregon Scientific Inc.	ATC9K HD Action Camera	
SeaLife	DC1400	

2. EVALUATION CRITERIA

The SAVER Program assesses products based on criteria in five established categories:

- **Affordability** groups criteria related to the total cost of ownership over the life of the product. This includes purchase price, training costs, warranty costs, recurring costs, and maintenance costs
- **Capability** groups criteria related to product features or functions needed to perform one or more responder relevant tasks
- **Deployability** groups criteria related to preparing to use the product, including transport, setup, training, and operational/deployment restrictions
- **Maintainability** groups criteria related to the routine maintenance and minor repairs performed by responders, as well as included warranty terms, duration, and coverage
- **Usability** groups criteria related to ergonomics and the relative ease of use when performing one or more responder relevant tasks.

The focus group of public safety divers met in September 2014 and identified 13 evaluation criteria within four SAVER categories: Capability, Deployability, Maintainability, and Usability. They assigned a weight for each criterion's level of importance on a scale of 1 to 5, with 1 being somewhat important and 5 being of utmost importance. The SAVER categories were assigned a percentage to represent each category's importance relative to the other categories. The focus group discussed the Affordability category but did not identify any evaluation criteria for that category.

Products were assessed against all 13 evaluation criteria. Table 2-1 presents the evaluation criteria and their associated weights as well as the percentages assigned to the SAVER categories. Refer to Appendix A for evaluation criteria definitions.

Table 2-1. Evaluation Criteria

SAVER CATEGORIES			
Usability	**Capability**	**Maintainability**	**Deployability**
Overall Weight 40%	Overall Weight 35%	Overall Weight 15%	Overall Weight 10%
Evaluation Criteria			
Ease of Use Weight: 5	**Still Image Quality** Weight: 4	**Durability** Weight: 5	**Ease of Setup** Weight: 4
Display Screen Weight: 5	**Video Quality** Weight: 4	**Ease of Maintenance** Weight: 4	**Attachment and Mounting Options** Weight: 3
Indicators Weight: 4	**Data Storage Options** Weight: 4		
Maintain Settings Weight: 4	**Frame Capture Quality** Weight: 3		
	Data Transfer/Playback Weight: 3		

3. ASSESSMENT METHODOLOGY

The products were assessed over four days. On the first day of the assessment, a subject matter expert (SME) and facilitators presented a safety briefing and an overview of the assessment process, procedures, and schedule to the evaluators. Each product was then assessed in two phases: (1) specification assessment and (2) operational assessment.

3.1 Phase I/Specification Assessment

During the specification assessment, evaluators assessed each product based on vendor-provided information and specifications. Product information was confirmed by vendors prior to the assessment.

3.2 Phase II/Operational Assessment

During the operational assessment, evaluators assessed each product based on their hands-on experience using the product after becoming familiar with its proper use, capabilities, and features. The SME and facilitators assisted the evaluators with product familiarization, and

evaluators had access to the reference material included with each product. The products were assessed in three scenarios: (1) setup scenario, (2) open water scenario, and (3) review scenario. Evaluators used the products one at a time and completed the assessment worksheets for each product before assessing the next product.

3.2.1 Setup Scenario

During the setup scenario, evaluators examined the cameras and included components for overall ruggedness, including O-rings, latches, locks, and hinges on their underwater housings, as well as the level of protection keeping the housings sealed (e.g., single or double locks on latches, double O-rings). To assess Ease of Setup, evaluators reviewed user manuals and/or quick-start guides, removed and replaced batteries and memory cards, and formatted memory cards. In addition, they installed the GoPro® Inc. HERO4 Silver and SeaLife DC1400 in their included underwater housings. Next, evaluators turned the cameras on/off, adjusted zoom and focus, changed exposure settings, switched between video and still, and turned flash, full automatic, and macro modes on/off to assess Ease of Use without dive gloves. They also inspected the cameras for visual and audible indicators to assess how easy they were to interpret. Evaluators examined the cameras for attachment points, included mounts, and features that could prevent unintentional adjustment of settings. They also intentionally changed a setting on the cameras, turned the cameras off, and turned the cameras back on to determine if the cameras saved the new setting.

3.2.2 Open Water Scenario

At the beginning of the open water scenario, evaluators prepared the cameras for a dive by performing pre-dive maintenance as specified in the user manuals. Evaluators put on dive gloves and turned the cameras on/off, adjusted zoom and focus, changed exposure settings, switched between video and still, and turned flash, full automatic, and macro modes on/off to assess Ease of Use while wearing dive gloves. If they were able to adjust these controls with the dive gloves on while outside of the water, they wore their dive gloves during the dive. Otherwise, they assessed the cameras underwater without wearing dive gloves. During the dive, evaluators captured still images and videos of three objects located along a dive line 15 to 35 feet underwater: a color wheel (15 feet), an inoperable handgun (25 feet), and an angel statue (35 feet), as shown in Figure 3-1 through Figure 3-3.

Figure 3-1. Color Wheel

Figure 3-2. Inoperable Handgun

Figure 3-3. Angel Statue

Images were captured in automatic and manual modes, and macro mode was used to capture images of the serial number on the inoperable handgun. While navigating the dive line and capturing still images and videos, evaluators observed the indicators to determine how easy they were to see, hear, and interpret. They also noted if the size of the cameras affected dive operations and observed the size and clarity of the display screen. After the dive, evaluators noted if any controls were unintentionally adjusted during the dive. As a group, they also performed post-dive maintenance as specified in the user manuals to assess Ease of Maintenance.

3.2.3 Review Scenario

During the review scenario, evaluators reviewed the various methods by which the files can be exported from the cameras and/or viewed on another device and transferred the files to a laptop to assess Data Transfer/Playback. Next, on a television with 1920x1080 resolution, they reviewed still images and videos captured during their dives as well as still images and videos captured by the SME. This allowed them to assess Still Image Quality and Video Quality. Using the vendor-provided software, evaluators captured and reviewed still images from videos to assess Frame Capture Quality. Lastly, evaluators inspected the cameras and included components to determine if any damage occurred during the assessment.

3.3 Data Gathering and Analysis

Each evaluator was issued an assessment workbook that contained vendor-provided information and specifications, assessment procedures, and worksheets for recording criteria ratings and comments. Evaluators used the following 1 to 5 scale:

1. The product *meets none* of my expectations for this criterion
2. The product *meets some* of my expectations for this criterion
3. The product *meets most* of my expectations for this criterion
4. The product *meets all* of my expectations for this criterion
5. The product *exceeds* my expectations for this criterion.

Criteria that were rated multiple times throughout the assessment were assigned final overall ratings by the evaluators. Facilitators captured advantages and disadvantages for the assessed products as well as general comments on the underwater cameras assessment and the assessment process. Once assessment activities were completed, evaluators had an opportunity to review their criteria ratings and comments for all products and make adjustments as necessary.

At the conclusion of the assessment activities, an overall assessment score, as well as category scores and criteria scores, were calculated for each product using the formulas referenced in Appendix B. In addition, evaluator comments for each product were reviewed and summarized for this assessment report.

4. ASSESSMENT RESULTS

Overall scores for the assessed products ranged from 2.5 to 4.1. Table 4-1 presents the overall assessment score and category scores for each product. Products are listed in order from highest to lowest overall assessment score throughout this section. Calculation of the overall score uses the raw scores for each category, prior to rounding; products with the same rounded overall score are in order based on the raw data.

Table 4-1. Assessment Results

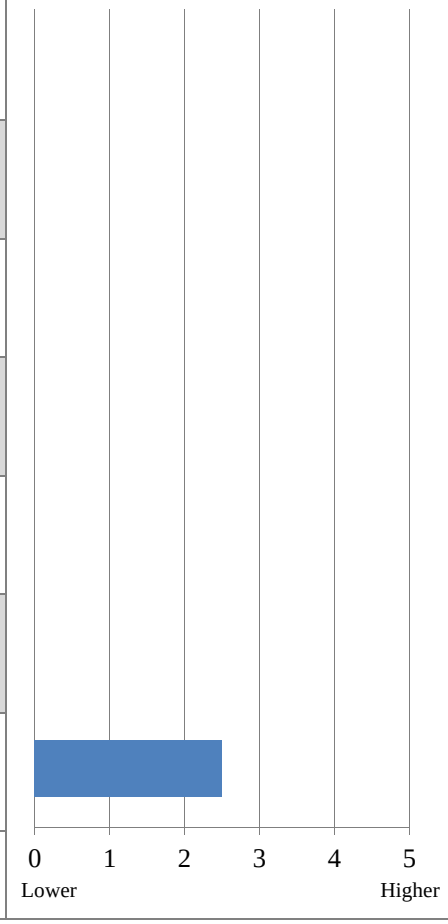
Product	Overall Score	Overall	Usability	Capability	Maintainability	Deployability
Olympus Corporation of the Americas TG-3		**4.1**	3.7	4.7	3.9	3.5
Canon USA Inc. PowerShot D30		**4.0**	3.9	4.2	4.0	3.9
Nikon Inc. COOLPIX AW120		**4.0**	3.7	4.4	3.8	3.6
GoPro Inc. HERO4 Silver		**3.9**	3.8	3.9	4.0	3.9
SeaLife DC1400		**3.8**	4.2	3.0	4.3	3.8
Intova EDGE X		**3.4**	3.3	3.1	3.9	3.5
Oregon Scientific Inc. ATC9K HD Action Camera		**2.5**	2.4	2.6	2.0	2.9

Table 4-2 presents the criteria ratings for each product. The ratings are graphically represented by colored and shaded circles. A green, fully shaded circle represents the highest rating. Refer to Appendix A for evaluation criteria definitions. All seven products received a green, three-quarter shaded circle for Maintain Settings. All of the cameras maintained their settings when they were turned off and back on, and no unintentional changes occurred during the dives.

Regarding Ease of Use, none of the cameras affected dive operations or dragged in the current. Data transfer was easily accomplished with all of the cameras. Table 4-3 presents vendor-provided key specifications for the assessed products. All of the cameras capture audio and include a 1-year warranty. In addition, they are powered by user-replaceable, rechargeable battery packs that are specific to the camera and may be available from multiple vendors. All of the cameras have a battery runtime of at least 75 minutes while capturing video. All of the compact digital cameras have a user-configurable flash, while none of the action cameras have a flash.

Table 4-2. Criteria Ratings

KEY Lowest Rating → Highest Rating							

Category	Evaluation Criteria	TG-3	PowerShot D30	COOLPIX AW120	HERO4 Silver	DC1400	EDGE X	ATC9K HD Action Camera
Usability	Ease of Use							
	Display Screen							
	Indicators							
	Maintain Settings							
Capability	Still Image Quality							
	Video Quality							
	Data Storage Options							
	Frame Capture Quality					Not applicable[1]	Not applicable[1]	
	Data Transfer/Playback							
Maintainability	Durability							
	Ease of Maintenance							
Deployability	Ease of Setup							
	Attachment and Mounting Options							

[1]Product does not support frame capture

Table 4-3. Key Specifications

Key Specification	TG-3	PowerShot D30	COOLPIX AW120	HERO4 Silver	DC1400	EDGE X	ATC9K HD Action Camera
MSRP	$350	$330	$300	$400	$530	$299	$250
Camera Type	Compact digital	Compact digital	Compact digital	Action	Compact digital	Action	Action
Dimensions (width x height x depth in inches)	4.4x2.6x1.2	4.3x2.7x1.1	4.4x2.6x1.0	2.6x2.3x1.1	5.3x3.7x2.8	3.3x2.8x2.4	1.9x2.3x4.3
Weight (ounces)	8.7	7.7	7.5	5.2	17.7	7.0	6.0
Display	3.0” LCD	3.0” TFT LCD	3.0” OLED	1.8” LCD Touch	3.0” LTPS TFT LCD	1.5” TFT LCD	1.5” TFT LCD
Depth Rating	50 feet	82 feet	59 feet	131 feet	200 feet	330 feet	66 feet
Buoyancy	Very negative	Very negative	Very negative	Very negative	Very positive	Slightly negative	Slightly positive
Maximum Image Resolution (megapixels)	16	12	16	12	14	12	5
Maximum Video Resolution (pixels)	1920x1080	1920x1080	1920x1080	3840x2160	1280x720	1920x1080	1920x1080
Still Image File Format	JPEG	JPEG	JPEG	JPEG	JPEG	JPEG	JPEG
Video File Format	AVI, MOV	MOV	MOV, MPEG-4	MPEG-4	AVI	MPEG-4	MOV
Storage Media	SD, SDHC, SDXC (class 10 or above)	SD, SDHC, SDXC (class 6 or above)	SD, SDHC, SDXC (class 6 or above)	Micro SD (class 10 or UHS-1)	SD, SDHC (class 6)	Micro SD (class 10)	Micro SD, SDHC (class 4 or above)
Maximum Removable Data Storage	128 GB[1]	No maximum[1]	128 GB[1]	64 GB[1]	32 GB[2]	64 GB[1]	32 GB[2]
Maximum Optical Zoom	4X	5X	5X	None	5X	None	None
Macro Mode	✓	✓	✓		✓		

Key Specification	TG-3	PowerShot D30	COOLPIX AW120	HERO4 Silver	DC1400	EDGE X	ATC9K HD Action Camera
Audio On/Off Capability	✓	✓	✓		✓	✓	✓
Compatible with External Lenses	✓				✓	✓	
Ability to Add External Filters	✓			✓		✓	
Shock Resistant	✓	✓	✓		✓	✓	✓
Operating Temperature	14° to 104°F	14° to 104°F	32° to 104°F	Unknown	33° to 110°F	14° to 140°F	32° to 104°F
Repair Facility Location	Contact vendor	Contact vendor	California, New York	No repair service	New Jersey	Hawaii	No repair service
Photo Extraction Software Included	✓	✓	✓	✓			✓
Integrated GPS	✓	✓	✓				✓

Notes:
✓—product is equipped with corresponding feature
Blank cell—product is not equipped with corresponding feature
Display—liquid crystal display (LCD); low temperature polysilicon (LTPS); organic light-emitting diode (OLED); thin-film transistor (TFT)
Video File Format—Audio Video Interleave (AVI); Apple Quick Time Movie (MOV), Moving Picture Experts Group (MPEG-4)
Storage Media—Secure Digital (SD), SD High Capacity (SDHC), SD Xtended Capacity (SDXC)
[1]Should be able to capture high resolution video and still images during standard-length dives
[2]May limit the amount of video and/or still images that can be captured on a high resolution setting

4.1 Olympus Corporation of the Americas TG-3

The TG-3 (Figure 4-1) received an overall assessment score of 4.1 and costs $350. A rechargeable battery, a USB cable, a wrist strap, an AC battery charger, a user manual on CD, a basic user manual, software, and a 1-year warranty are included with purchase.

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-1. TG-3

Usability

The TG-3 received a Usability score of 3.7. The following information is based on evaluator comments:

- It was simple to operate the camera, adjust settings, and operate macro mode. However, controls (Figure 4-2) were small, close together, and difficult to use with or without dive gloves, especially the power and record buttons.
- The display screen was a good size, clear, and easy to see.
- Visual indicators were easy to see and interpret. There was an audible confirmation when a function was selected; however, it was rarely heard during the dives.

Figure 4-2. TG-3 Controls

Capability

The TG-3 received a Capability score of 4.7. The following information is based on evaluator comments:

- Still image quality was exceptional. Still images were extremely clear with vibrant color and fine detail. Images of the serial number captured in macro mode were impressive.
- Video quality was also exceptional. Videos were sharp and clear with good color and great detail.
- Still images extracted from videos were very clear and as good as still images captured during the dives.
- Data transfer can be performed using a Secure Digital (SD) memory card, the included USB cable, or Wi-Fi®. The software for viewing images was impressive.

Maintainability

The TG-3 received a Maintainability score of 3.9. The following information is based on evaluator comments:

- The camera felt solid. The battery compartment door had a double lock, a good waterproof seal, and hinges that appeared sturdy. Although the camera was shock resistant, there was no lens cap and the display screen was unprotected.
- There were no pre-dive maintenance instructions. Post-dive maintenance instructions were detailed and easy to follow. They consisted of a combination of wiping the camera clean, immersing it in water, rinsing it under running water, and drying it with canned air and a soft cloth.

Deployability

The TG-3 received a Deployability score of 3.5. The following information is based on evaluator comments:

- The camera's operation was intuitive, and the camera could be set up without the use of manuals. In addition, when the camera was turned on, it had a tutorial that provided information/warnings on maintaining the water resistance of the camera. The battery and memory card were easily installed and removed; however, it was possible to install the battery incorrectly. A basic user manual, instructions on maintaining water resistance, and a more comprehensive user manual on CD was included with purchase. The comprehensive user manual could also be downloaded from the vendor's website. However, a quick-start guide was preferred.
- The camera included a wrist strap and standard tripod mount.

4.2 Canon® USA Inc. PowerShot D30

The PowerShot D30 (Figure 4-3) received an overall assessment score of 4.0 and costs $330. A rechargeable battery, a wrist strap, an AC battery charger, a basic user manual, software, and a 1-year warranty are included with purchase.

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-3. PowerShot D30

Usability

The PowerShot D30 received a Usability score of 3.9. The following information is based on evaluator comments:

- Control labels were easy to read. It was simple to turn the camera on/off and extremely easy to adjust settings without dive gloves. However, controls (Figure 4-4) were more difficult to use with dive gloves because they were small and close together.
- The display screen was large, clear, and easy to see.
- Visual indicators were large, clear, and easy to see and interpret. There was an audible confirmation when a function was selected; however, it could not be heard during the dives.

Figure 4-4. PowerShot D30 Controls

Capability

The PowerShot D30 received a Capability score of 4.2. The following information is based on evaluator comments:

- Still image quality was great. Still images were extremely clear and showed fine detail. Images of the serial number captured in macro mode were impressive.
- Video quality was also great. Videos were sharp and clear with good color and great detail.
- Still images extracted from videos were crisp and clear, and the serial number was legible.
- Data transfer can be performed using an SD memory card. The software was easy to use.

Maintainability

The PowerShot D30 received a Maintainability score of 4.0. The following information is based on evaluator comments:

- The camera felt solid. The battery compartment door had a single lock and waterproof seal. Although the camera was shock resistant, there was no lens cap and the display screen was unprotected.
- Maintenance procedures were easily accomplished. Pre-dive maintenance consisted of inspecting the waterproof seal for debris. Post-dive maintenance consisted of rinsing the camera with fresh water and drying it with a cloth.

Deployability

The PowerShot D30 received a Deployability score of 3.9. The following information is based on evaluator comments:

- The camera was intuitive and easy to set up. The battery and memory card were easily installed and removed. A basic user manual was included with purchase, and a more comprehensive user manual was available for download from the vendor's website. However, a quick-start guide was preferred.
- The camera included a wrist strap and standard tripod mount.

4.3 Nikon® Inc. COOLPIX® AW120

The COOLPIX AW120 (Figure 4-5) received an overall assessment score of 4.0 and costs $300. A rechargeable battery, a USB cable, a neck strap, an AC battery charger, a cleaning brush, a user manual, software, and a 1-year warranty are included with purchase.

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-5. COOLPIX AW120

Usability

The COOLPIX AW120 received a Usability score of 3.7. The following information is based on evaluator comments:

- It was easy to turn the camera on/off and adjust settings without dive gloves. However, there were a lot of controls (Figure 4-6) that were small and close together, making it difficult to adjust settings with dive gloves.
- The display screen was a good size, clear, bright, and easy to see.
- Visual indicators were easy to see and interpret. There was an audible confirmation when a function was selected; however, it could not be heard during the dives.

Figure 4-6. COOLPIX AW120 Controls

Capability

The COOLPIX AW120 received a Capability score of 4.4. The following information is based on evaluator comments:

- Still image quality was exceptional. Still images were extremely clear with impressive color and fine detail. Images of the serial number captured in macro mode were impressive.
- Video quality was also exceptional. Videos were sharp and clear with good color and great detail.
- Still images extracted from videos were clear but not as sharp and clear as the still images captured during the dives.
- Data transfer can be performed using an SD memory card, the included USB cable, or Wi-Fi. The software was versatile and easy to download from the vendor's website.

Maintainability

The COOLPIX AW120 received a Maintainability score of 3.8. The following information is based on evaluator comments:

- The camera felt solid. The battery compartment door had a lock, a waterproof seal, and hinges that appeared sturdy. Although the camera was shock resistant, there was no lens cap and the display screen was unprotected.
- Maintenance procedures were easily accomplished. Pre-dive maintenance consisted of inspecting the waterproof seal for debris and cleaning it with the included brush. Post-dive maintenance consisted of rinsing the camera with fresh water, soaking it for 10 minutes, and then drying it with a cloth.

Deployability

The COOLPIX AW120 received a Deployability score of 3.6. The following information is based on evaluator comments:

- The camera was intuitive and easy to set up. In addition, when the camera was turned on, it had a tutorial that provided information/warnings on maintaining the water resistance of the camera. The battery and memory card were easily installed and removed. A detailed but shorter version of the user manual was included with purchase, and a more comprehensive user manual was available for download from the vendor's website. However, a quick-start guide was preferred.
- The camera included a neck strap and standard tripod mount. A wrist strap was preferred for diving applications.

4.4 GoPro Inc. HERO4 Silver

The HERO4 Silver (Figure 4-7) received an overall assessment score of 3.9 and costs $400. An underwater housing, a rechargeable battery, a USB cable, a quick-release buckle, a curved adhesive mount, a flat adhesive mount, a 3-way pivot arm, a quick-start guide, software, and a 1-year warranty are included with purchase. This product also includes interchangeable backdoors for the housing; however, they are not waterproof. The skeleton backdoor is used for access to camera ports, cooling, and optimal audio capture. The touch backdoor has a thin plastic layer across the back that allows use of the touch screen while in the housing.

Figure 4-7. HERO4 Silver

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-8. HERO4 Silver Controls – Side (left) and Top (right)

Usability

The HERO4 Silver received a Usability score of 3.8. The following information is based on evaluator comments:

- The camera had minimal, large, well-spaced controls (Figure 4-8). It was easy to turn the camera on/off and adjust settings with or without dive gloves. Settings were selected by scrolling through a menu. However, if the desired selection was passed, the entire menu had to be scrolled through again.
- The display screen was clear and bright but small.
- Visual indicators were easy to see and interpret; however, they were more difficult to see during the dives due to the size of the display screen. There was an audible confirmation when a function was selected; however, it was rarely heard during the dives.

Capability

The HERO4 Silver received a Capability score of 3.9. The following information is based on evaluator comments:

- Most still images were vivid and clear; however, fine details (e.g., serial number) in close-up images were not clear because there was no zoom or macro mode.
- Video quality was great. Videos were sharp and clear with good color and great detail, even though they were viewed on a television with a lower resolution than the video resolution of the camera.

- Still images extracted from videos were clear but not as sharp and clear as the still images captured during the dives.
- Data transfer can be performed using an SD memory card, the included USB cable, or Wi-Fi. The software was challenging to use.

Maintainability

The HERO4 Silver received a Maintainability score of 4.0. The following information is based on evaluator comments:

- Although the camera was not shock resistant, it came with a durable underwater housing that latched firmly shut. The O-ring on the housing appeared resilient, sealed the housing well, and was easy to inspect for damage. Outside of the housing, the dust cover on the camera's USB port was not attached and could be easily lost.
- There were no pre-dive maintenance instructions. Post-dive maintenance consisted of rinsing the housing with fresh water, wiping it dry, and then opening the housing to remove and rinse the O-ring, which was easily accomplished. Although not stated in the post-dive maintenance instructions, users should consider leaving the housing open so it can dry completely.

Deployability

The HERO4 Silver received a Deployability score of 3.9. The following information is based on evaluator comments:

- The camera was intuitive and easy to set up. The battery and memory card were easily installed and removed. A quick-start guide was included with purchase, and a comprehensive user manual was available for download from the vendor's website.
- The attachment points on the housing made it very versatile for mounting in a variety of ways; however, no wrist strap was included. While there were many mounting options available for an additional cost, there were no included mounting options for underwater photography or for mounting the camera on a standard tripod.

4.5 SeaLife DC1400

The DC1400 (Figure 4-9) received an overall assessment score of 3.8 and costs $530. A wrist strap for the camera, an underwater housing with a wrist strap and lens cap, a rechargeable battery, a USB cable, an audio/video (AV) cable, an AC battery charger, international plug adapters, a flash link optical cable adapter, a flash diffuser with strap, a camera pouch, a two-pack of moisture removal/drying agents, a cleaning brush, a lens cloth, a user manual, a quick-start guide, and a 1-year warranty are included with purchase.

Figure 4-9. DC1400

The following sections, broken out by SAVER category, summarize the assessment results.

Usability

The DC1400 received a Usability score of 4.2. The following information is based on evaluator comments:

- Controls (Figure 4-10) were large, clearly labeled, and very easy to see. It was easy to turn the camera on/off and adjust settings with or without dive gloves.
- The display screen was large, clear, bright, and easy to see.
- Visual indicators were large, clear, and easy to see and interpret. There was an audible confirmation when a function was selected; however, it could not be heard during the dives.

Figure 4-10. DC1400 Controls

Capability

The DC1400 received a Capability score of 3.0. The following information is based on evaluator comments:

- Still images were clear and showed fine detail. The serial number was legible in the still images captured in macro mode. Still images were a good representation of color as long as the red electronic filter, which is meant for use during deeper dives, was not used.
- Video quality was good. Videos were clear with good color as long as the red electronic filter was not used.
- Data transfer can be performed using an SD memory card or the included USB cable. No software was provided.

Maintainability

The DC1400 received a Maintainability score of 4.3. The following information is based on evaluator comments:

- The camera came with a sturdy, shock-resistant underwater housing that felt solid and latched firmly shut with a double-hinged lock. It also featured a lens cap that offered additional protection. The O-ring was large and easily accessible for inspection and replacement.
- Maintenance procedures were easily accomplished. Pre-dive maintenance consisted of inspecting the housing's O-ring for debris and cleaning it with the included brush. Annual O-ring replacement was recommended. Post-dive maintenance consisted of soaking the housing for 15 minutes in fresh water while manipulating the buttons to remove salt and sand, and then drying the housing with a cloth.

Deployability

The DC1400 received a Deployability score of 3.8. The following information is based on evaluator comments:

- The camera was intuitive and easy to set up. The battery and memory card were easily installed and removed. A quick-start guide and comprehensive user manual were included with purchase.
- The camera included a wrist strap and standard tripod mount. The underwater housing included a wrist strap and standard tripod mount. The clip on the housing's wrist strap was plastic, which may not be very durable.

4.6 Intova EDGE X

The EDGE X (Figure 4-11) received an overall assessment score of 3.4 and costs $299. A rechargeable battery, a USB cable, a float strap, an anti-glare hood, silicone grease, a quick-start guide, and a 1-year warranty are included with purchase.

Figure 4-11. EDGE X

The following sections, broken out by SAVER category, summarize the assessment results.

Usability

The EDGE X received a Usability score of 3.3. The following information is based on evaluator comments:

- The camera had minimal controls (Figure 4-12), but they were difficult to use with or without dive gloves because they were small and required significant force to press.
- The display screen was small and difficult to see.
- Visual indicators were easy to interpret. A flashing red light indicated the camera was recording, but otherwise the visual indicators were small and difficult to see. There was an audible confirmation when a function was selected; however, it could not be heard during the dives.

Figure 4-12. EDGE X Controls – Side (left) and Top (right)

Capability

The EDGE X received a Capability score of 3.1. The following information is based on evaluator comments:

- Still images were moderately clear. The colors were not very distinct, and differentiating between green and black was difficult at times. Fine details (e.g., serial number) in close-up images were not clear because there was no zoom or macro mode.
- Overall, video quality was good. The colors were better than those in the still images; however, green still lost some color at a distance and some videos captured in automatic mode appeared overexposed.
- Data transfer can be performed using an SD memory card, the included USB cable, or Wi-Fi. No software was provided.

Maintainability

The EDGE X received a Maintainability score of 3.9. The following information is based on evaluator comments:

- The camera was enclosed in a shock-resistant, non-removable underwater housing that was rubberized and rugged. The O-ring stayed in place well and was large and easy to inspect.
- Pre-dive maintenance consisted of inspecting and cleaning the O-ring and then applying the included silicone grease, which was easily accomplished. There were no post-dive maintenance instructions, which was not realistic since the camera should at least be rinsed with fresh water after use in salt water.

Deployability

The EDGE X received a Deployability score of 3.5. The following information is based on evaluator comments:

- The camera was fairly easy to set up. The battery and memory card were easily installed and removed. A one-page quick-start guide was included with purchase but was somewhat difficult to understand and lacked some basic information, such as an explanation of all the buttons and how to change between video and still image modes. A comprehensive user manual was available for download from the vendor's website.
- The camera included a float strap and standard tripod mount. It can also be used with a variety of mounts available at an additional cost.

4.7 Oregon Scientific® Inc. ATC9K HD Action Camera

The ATC9K HD Action Camera (Figure 4-13) received an overall assessment score of 2.5 and costs $250. A rechargeable battery, a USB cable, an HDMI cable, a long silicone strap, a long Velcro strap, a helmet grip (to attach silicone and Velcro straps), a handlebar mount, a tripod mount, a rubberized patch, a Velcro patch, a lens cap, a remote control, a carrying bag, a user manual, a quick-start guide, software, and a 1-year warranty are included with purchase.

Figure 4-13. ATC9K HD Action Camera

The following sections, broken out by SAVER category, summarize the assessment results.

Usability

The ATC9K HD Action Camera received a Usability score of 2.4. The following information is based on evaluator comments:

- Controls for capturing video and still images were large and easy to use; however, controls near the display (including the power button) were too small, close together, and difficult to use with or without dive gloves (Figure 4-14). They also had to be held down for several seconds to make a selection.
- The display screen was small, not very bright, and difficult to see. The color appeared washed out.
- Visual indicators were easy to interpret; however, they were difficult to see due to the size of the display screen. There was an audible confirmation when a function was selected; however, it was rarely heard during the dives.

Figure 4-14. ATC9K HD Action Camera Controls – Top (left) and Rear (right)

Capability

The ATC9K HD Action Camera received a Capability score of 2.6. The following information is based on evaluator comments:

- Still image quality was moderate. Still images were not very sharp or clear, and the colors were faded. Letters and numbers were legible, but the serial number was not clear because there was no zoom or macro mode.
- Overall, videos were not very clear and appeared grainy. In addition, the colors were somewhat faded.

- Still images extracted from videos were of average quality and representative of the video quality. They were somewhat blurry and grainy. The serial number was only partially legible.
- Data transfer can be performed using an SD memory card or the included USB cable. The software was difficult to use.

Maintainability

The ATC9K HD Action Camera received a Maintainability score of 2.0. The following information is based on evaluator comments:

- Water intrusion occurred during the dives. While the camera remained functional, the lens became foggy and resulting still images and videos were compromised. In addition, although it was shock resistant and featured a lens cap, the camera was constructed of plastic that did not appear very durable.
- There were no pre-dive or post-dive maintenance instructions, which was not realistic since the camera should at least be rinsed with fresh water after use in salt water.

Deployability

The ATC9K HD Action Camera received a Deployability score of 2.9. The following information is based on evaluator comments:

- The camera was easy to set up. The battery and memory card were easily installed and removed. A quick-start guide was included with purchase, but some of the print and diagrams were small, making it difficult to read.
- The camera included an attachment for a standard tripod mount. It also included several mounting options that were not very useful for diving applications. The mounting brackets on the camera appeared fragile and therefore not very secure. In addition, there were no attachment points on the camera for connecting a strap or other means of tethering the camera to a diver.

5. SUMMARY

Evaluators prefer underwater cameras that are simple to use with large buttons, display screens, and visual indicators. Clear, bright images and good macro capability is important. Evaluators really liked Wi-Fi capability and simple pre- and post-dive maintenance, as well as a variety of mounting options. A wrist strap and/or other attachment point are important for tethering the camera to a diver so it does not get lost. Durability is also important as wear and tear can be expected for this application. The advantages and disadvantages for the assessed products are highlighted in Table 5-1.

Emergency responder agencies that consider purchasing underwater cameras should carefully research each product's overall capabilities and limitations in relation to their agency's operational needs.

Table 5-1. Product Advantages and Disadvantages

Vendor/Product	Advantages	Disadvantages
 Olympus Corporation of the Americas TG-3 MSRP: $350 Overall Score: 4.1	• Wi-Fi capability • Visual indicators are easy to see and interpret • Underwater, underwater macro, and underwater super macro modes • Exceptional still image and video quality • Warnings/Tutorial on camera at startup • Very clear frame capture quality	• Non-replaceable seal • Controls are small, close together; and difficult to use while wearing dive gloves • Battery can be installed incorrectly
 Canon USA Inc. PowerShot D30 MSRP: $330 Overall Score: 4.0	• Large, clear display screen • Visual indicators are large, clear, and easy to see and interpret • Underwater and underwater macro modes • Durable • Great still image and video quality • No maximum SD memory card storage size • Good zoom capability	• No Wi-Fi capability • Easy to cover lens in upper corner with fingers • Non-replaceable seal • Controls are small, close together, and difficult to use while wearing dive gloves
 Nikon Inc. COOLPIX AW120 MSRP: $300 Overall Score: 4.0	• Wi-Fi capability • Visual indicators are easy to see and interpret • Underwater and underwater macro modes • Exceptional still image and video quality • Warnings/Tutorial on camera at startup • Versatile software • Indicates depth	• Easy to cover lens in upper corner with fingers • Non-replaceable seal • Controls are small, close together, and difficult to use while wearing dive gloves • Included neck strap has limited use for diving applications
 GoPro Inc. HERO4 Silver MSRP: $400 Overall Score: 3.9	• Wi-Fi capability • Durable, separate underwater housing • Great video quality • Wide range of mounting options (additional cost) • Touch screen • Compact and lightweight	• No zoom, adjustable focus, or macro mode • No integrated flash • No manual mode

Vendor/Product	Advantages	Disadvantages
 SeaLife DC1400 MSRP: $530 Overall Score: 3.8	• Visual indicators are large, clear, and easy to see and interpret • Large, clear display screen • Controls are easy to use • Durable, separate underwater housing • Can auto-slave an external strobe • Lens cap	• No Wi-Fi capability • No software available to capture stills from video • Big and bulky • Plastic clip on housing's wrist strap does not seem durable • Exposure not user adjustable
 Intova. EDGE X MSRP: $299 Overall Score: 3.4	• Wi-Fi capability • Durable – camera is built into the underwater housing • Compact and lightweight • Can auto-slave an external strobe	• No zoom, adjustable focus, or macro mode • No integrated flash • No manual mode • Controls are difficult to press • No software available to capture stills from video • Small display screen
 Oregon Scientific Inc. ATC9K HD Action Camera MSRP: $250 Overall Score: 2.5	• Compact and lightweight • Gyroscope provides information on the camera's orientation in the water • Lens cap	• No Wi-Fi capability • No zoom, adjustable focus, or macro mode • No integrated flash • No manual mode • Controls are small, close together, and difficult to use • Controls may be accidentally activated due to location • Small display screen • Not durable (water intrusion) • Video quality is grainy • No strap mounting point • Included mounting options are not diver relevant

APPENDIX A. EVALUATION CRITERIA DEFINITIONS

The focus group identified 13 evaluation criteria, which are defined as follows.

USABILITY

Ease of Use refers to how easy it is to turn the camera on/off and adjust camera settings (e.g., adjust zoom and focus; change exposure settings; switch between still and video; turn the flash, macro mode, and full automatic camera mode on/off), with and without dive gloves. This may be affected by the number, location, and size of controls. Ease of Use also refers to the effect the size of the camera has on dive operations (e.g., drags in current).

Display Screen refers to the camera featuring a display screen that is large and clear enough to view the video/still image.

Indicators refers to how easy it is to interpret the camera's visual and audible indicators (e.g., battery, camera status [recording, camera mode, optical zoom, digital zoom]). Indicators also includes how easy it is to see, hear, and interpret the indicators during a dive.

Maintain Settings refers to how well features of the camera prevent unintentional adjustment of settings during a dive or after the camera is turned off and then on again.

CAPABILITY

Still Image Quality refers to the clarity and sharpness of still images, including those captured in macro mode, in low-light conditions, and when the integrated flash is used.

Video Quality refers to the clarity and sharpness of recorded video, including in low-light conditions.

Data Storage Options refers to the capacity and type(s) of storage media that are compatible with the camera. Focus group participants noted a preference for multiple and expandable data storage options, as well as removable media that are commercially available.

Frame Capture Quality refers to the clarity and sharpness of stills extracted from previously captured video.

Data Transfer/Playback refers to how easy it is to transfer and/or view files on another device as well as the different methods by which this can be performed (e.g., Wi-Fi®, USB, removable media).

MAINTAINABILITY

Durability refers to the overall ruggedness of the camera and included components, as well as the camera being shock resistant.

Ease of Maintenance refers to how easy it is to conduct standard field maintenance based on vendor recommendations (e.g., special tools required to replace O-rings).

DEPLOYABILITY

Ease of Setup refers to how easy it is to prepare the camera for deployment (e.g., installing batteries, installing a memory card, formatting the memory card, placing the camera in the underwater housing) and if setup is intuitive. Ease of Setup also includes the comprehensiveness of the user manual as well as if a quick-start guide is included.

Attachment and Mounting Options refers to the methods by which the camera can be secured to a diver.

APPENDIX B. ASSESSMENT SCORING FORMULAS

The overall score for each product was calculated using the product's averaged criterion ratings and category scores. An average rating for each criterion was calculated by summing the evaluators' ratings and dividing the sum by the number of responses. Category scores for each product were calculated by multiplying the average criterion rating by the weight assigned to the criterion by the focus group, resulting in a weighted criterion score. The sum of the weighted criterion scores was then divided by the sum of the weights for each criterion in the category as seen in the formula and example below.

Category Score Formula

$$\frac{\sum\left(AverageCriterionRating \times CriterionWeight\right)}{\sum\left(CriterionWeights\right)} = Category\ Score$$

Category Score Example[1]

$$\frac{\left(4.3\times 4\right)+\left(5\times 4\right)+\left(4\times 3\right)+\left(4.5\times 3\right)+\left(4.5\times 3\right)}{4+4+3+3+3} = 4.5$$

To determine the overall assessment score for each product, each category score was multiplied by the percentage assigned to the category by the focus group. The resulting weighted category scores were summed to determine an overall assessment score as seen in the formula and example below.

Overall Score Formula

$$\sum\left(Category\ Score \times Category\ Percentage\right) = Overall\ Assessment\ Score$$

Overall Score Example[1]

Capability	*Usability*	*Affordability*	*Maintainability*	*Deployability*	
$\left(4.0\times 33\%\right)$	+ $\left(4.2\times 27\%\right)$	+ $\left(4.2\times 20\%\right)$	+ $\left(3.8\times 10\%\right)$	+ $\left(4.5\times 10\%\right)$	= 4.1

[1]Examples are for illustration purposes only. Formulas will vary depending on the number of criteria and categories assessed and the criteria and category weights.