Annex B Full Scale Test Results

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APPROVED BY:	AUTHOR	REVIEWER	MANAGING DEPARTMENT
D. Shepherd	A. Flores	M.L. Scatola	DART Engineering

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1. General

The primary objective of the test is to verify the results of the buoyancy analysis performed on the HEFS and to validate the performance characteristics of a prototype HEFS concept. The following test conditions were performed to make a direct comparison with the buoyancy analysis: Fully capsized no damage float bags, fully capsized main EFS float bag damaged, and fully capsized HEFS float bag damaged. Additionally, a partial capsized side floating attitude condition was evaluated to validate a stable floating attitude in this orientation.

The test fixture used for conducting this test is illustrated in Figure 1 and Figure 2. Both the primary EFS and prototype HEFS were mounted directly to the fixture. The fixture was constructed from welded steel tubing and was designed to be representative of the AW139 helicopter which includes a removable mock hoist, to observe the HEFS interacting with the hoist during capsize. Prior to the test, the test fixture was ballasted to achieve as close as practical to the buoyancy model's center of mass (CofM) and total weight.

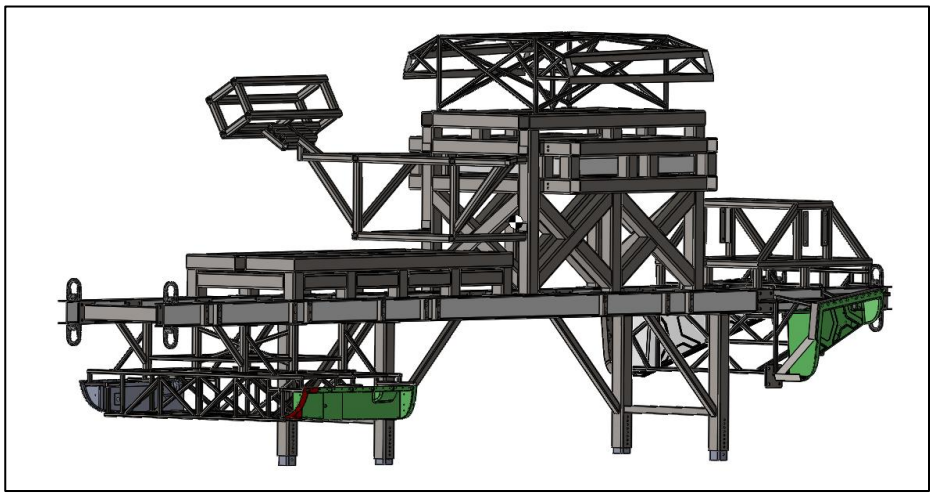


Figure 1 Test Fixture Model

Figure 2 Test Fixture

2. Results

During each test, once the fixture was in a stable floating attitude, the water line position was recorded using detailed photos.

The position of the "actual" waterline recorded during the full-scale test has been compared with the "simulated" waterline from the buoyancy analysis in order to validate the accuracy of the computer simulation. Subsequently, the "actual" waterline position was overlayed into the CAD model to determine the available air pocket.

Test Scenarios (in chronological order):

- Upright Floating Attitude (for reference only)
- Partially Capsize (Side floating attitude)
- Fully Capsized (Fully inverted attitude)
    - HEFS with one critical compartment damaged
    - EFS with one critical compartment damaged
- Forced Perturbation Test 1
- Forced Perturbation Test 2
- Forced Perturbation Test 3
- Forced Perturbation Test 4
- Forced Perturbation Test 5

The orientation of each test will be in reference to the illustration in Figure 3 and 4 with respect the fixture in its stable level attitude.
The float bags are omitted from the figures for clarity.

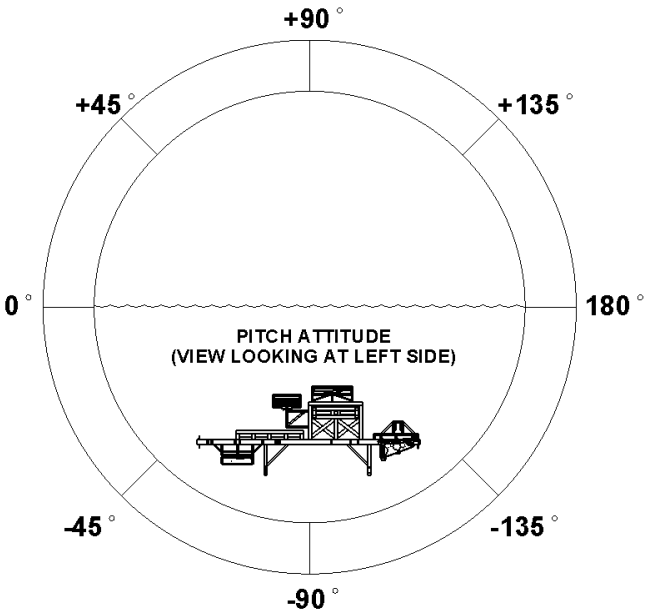


Figure 3 Attitude Reference (Pitch Attitude)

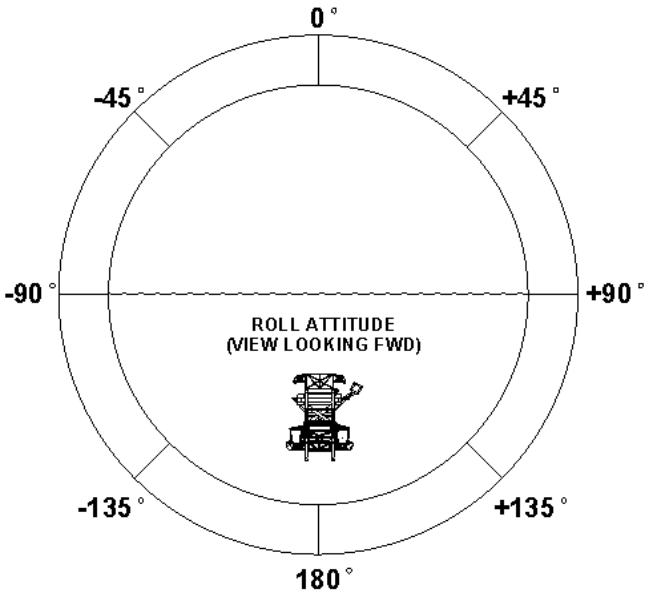


Figure 4 Attitude Reference
(Roll Attitude)

2.1 Upright Attitude Test Results

The fixture is stable in the upright floating attitude and rests at a position of +2° pitch and -3° roll. For reference, the stable floating attitude of the AW139 at max gross weight with forward-most CofG location is approximately 4.5° nose up and 0° roll. This test has been performed for reference only. Please refer to Figure 5 for reference.

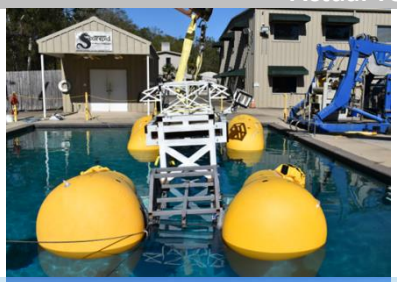
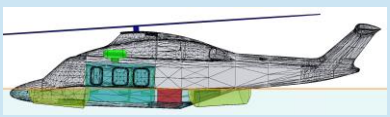
Buoyancy Analysis	Actual Test Results	
N/A to HEFS		N/A
		 AW139 at gross weight (N/A to HEFS, for reference only)

Figure 5 Upright Floating Attitude

2.2 Partially Capsize Attitude Test Results

It is necessary to confirm the attitude of the representative aircraft with HEFS when experiencing a partial capsize to determine if the presence of HEFS will provide a sufficient air pocket within the cabin to facilitate passenger egress in this scenario. In order to determine this, the primary EFS and the HEFS system were installed on the fixture and filled with shop air to approximately 1.75 psi, then the fixture was rotated into a partially capsized attitude before being submerged in water.

The results from the buoyancy analysis have determined that the fixture rests at a position of 4° pitch and -85° roll. The actual test has determined that the fixture is stable in the partially capsized attitude and rests at a position of -1.5° pitch and -105° roll.

The results of this test have demonstrated that the buoyancy analysis is relatively representative of each of the actual test results, however it is important to note that the buoyancy analysis is conducted with the float bags represented as rigid bodies whereas in the actual test, the float bags and restraint system tend to flex and deform based on the loading direction.

The ability for the HEFS float bags to flex and deform results in the fixture resting at a stable side floating attitude that is 20° more submerged than the buoyancy analysis and a lower overall waterline. It is anticipated that in a real-world situation, a fully developed HEFS design in addition to the support that would be provided by the fuselage structure and rotor mast would maintain the HEFS float bags in a much more rigid position than what was noticed during this test.

No damage to the EFS of HEFS was noticed either during or after the test despite being in direct contact with the fixture. Please refer to Figure 6 for reference.

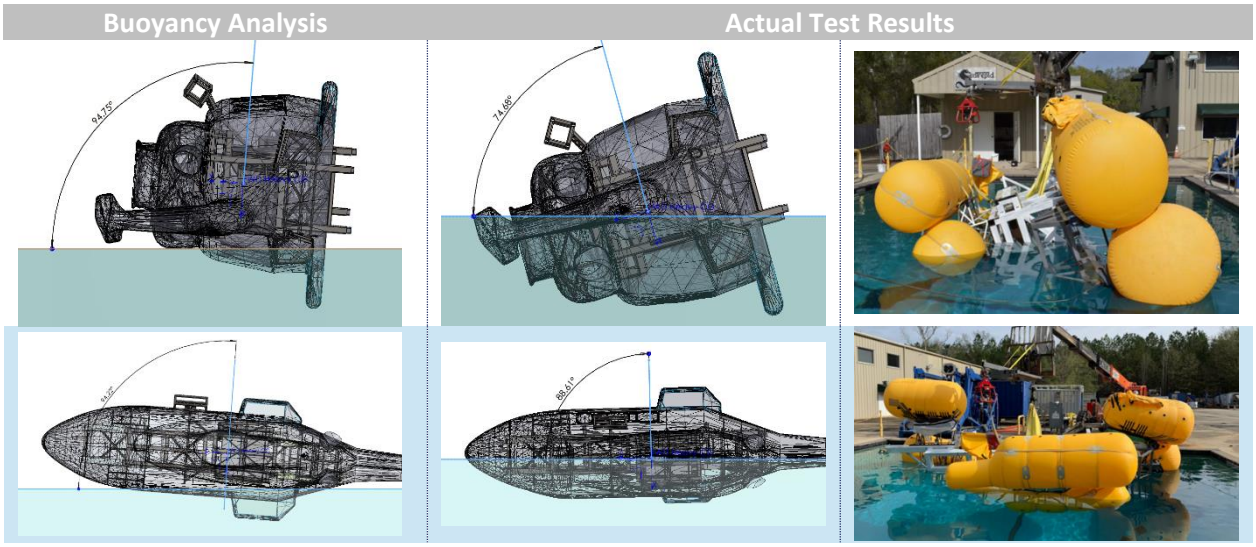


Figure 6 Partially Capsize Attitude

2.3 Full Capsized Attitude All Floats Inflated Test Results

It is necessary to confirm the attitude of the representative aircraft with HEFS when experiencing a full capsize to determine if the presence of HEFS will provide a sufficient air pocket within the cabin to facilitate passenger egress in this scenario. In order to determine this, the primary EFS and the HEFS system were installed on the fixture and filled with shop air to approximately 1.75 psi, then the fixture was rotated into a capsized attitude before being submerged in water.

The results from the buoyancy analysis have determined that the fixture rests at a position of -23° pitch (inverted) and °180 roll. The actual test has determined that the fixture is stable in the capsized attitude and rests at a position of -21° pitch (inverted) and 180° roll at relatively the same waterline position. The results of this test have demonstrated that the buoyancy analysis is accurately representative of test results. No damage to the EFS of HEFS was noticed either during or after the test despite being in direct contact with the fixture. Please refer to Figure 7 for reference.

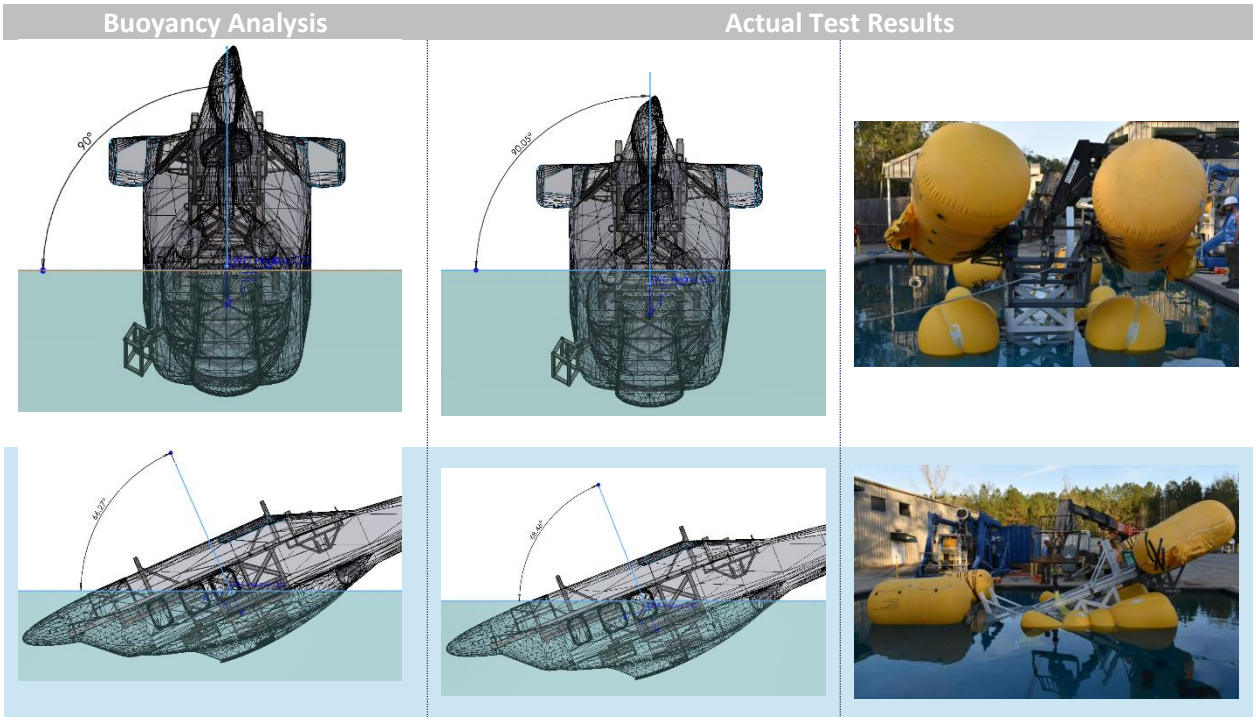


Figure 7 Capsized Attitude

2.4 Full Capsized Attitude Simulated EFS Damaged Test Results

It is necessary to confirm the attitude of the representative aircraft with HEFS when experiencing a full capsize with a critical EFS compartment damaged to determine if the presence of HEFS will provide a sufficient air pocket within the cabin to facilitate passenger egress in this scenario. In order to determine this, the primary EFS and the HEFS system were installed on the fixture and filled with shop air to approximately 1.75 psi with the exception of the forward most compartment on the left hand EFS (all air evacuated), then the fixture was rotated into a capsized attitude before being submerged in water.

The results from the buoyancy analysis have determined that the fixture rests at a position of -26° pitch (inverted) and -172° roll. The actual test has determined that the fixture is stable in the capsized attitude and rests at a position of -22° pitch (inverted) and -178° roll at relatively the same waterline position. The results of this test have demonstrated that the buoyancy analysis is accurately representative of test results. No damage to the EFS of HEFS was noticed either during or after the test despite being in direct contact with the fixture. Please refer to Figure 8 for reference.

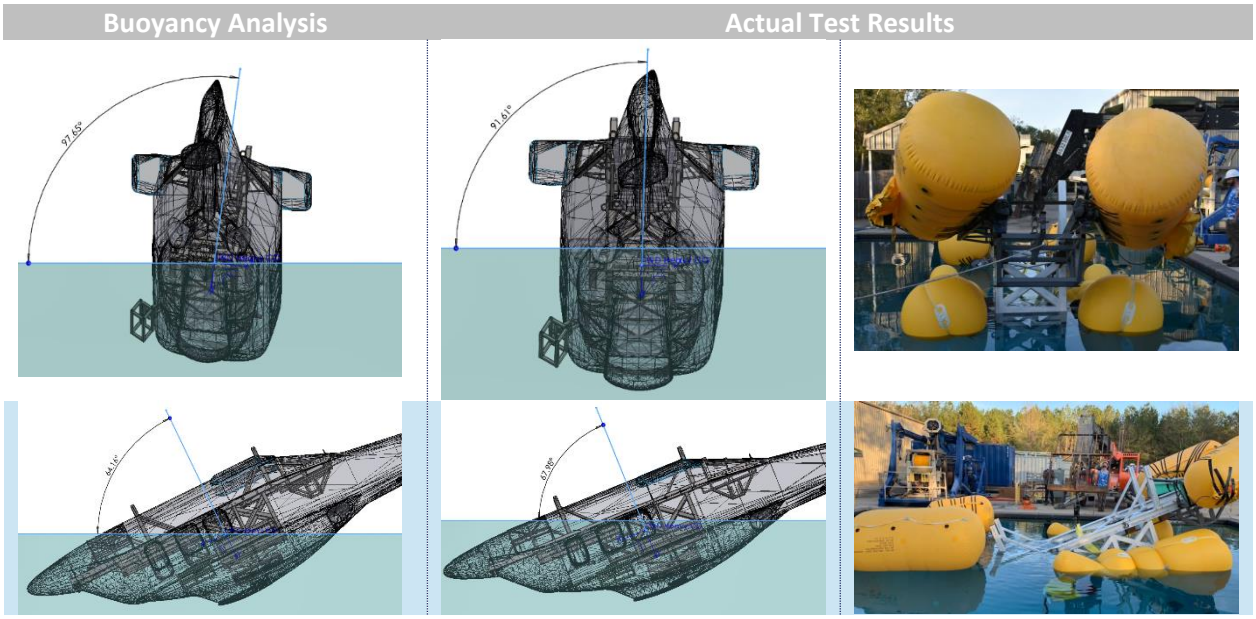


Figure 8 Capsized Floating Attitude, EFS Compartment Damaged

2.5 Full Capsized Attitude HEFS Damaged Test Results

It is necessary to confirm the attitude of the representative aircraft with HEFS when experiencing a full capsize with a critical HEFS compartment damaged to determine if the presence of HEFS will provide a sufficient air pocket within the cabin to facilitate passenger egress in this scenario. In order to determine this, the primary EFS and the HEFS system were installed on the fixture and filled with shop air to approximately 1.75 psi with the exception of the forward most compartment on the left hand HEFS (all air evacuated), then the fixture was rotated into a capsized attitude before being submerged in water.

The results from the buoyancy analysis have determined that the fixture rests at a position of -21° pitch (inverted) and -171° roll. The actual test has determined that the fixture is stable in the capsized attitude and rests at a position of -22° pitch (inverted) and -170° roll at relatively the same waterline position. The results of this test have demonstrated that the buoyancy analysis is accurately representative of test results. No damage to the EFS of HEFS was noticed either during or after the test despite being in direct contact with the fixture. Please refer to Figure 9 for reference.

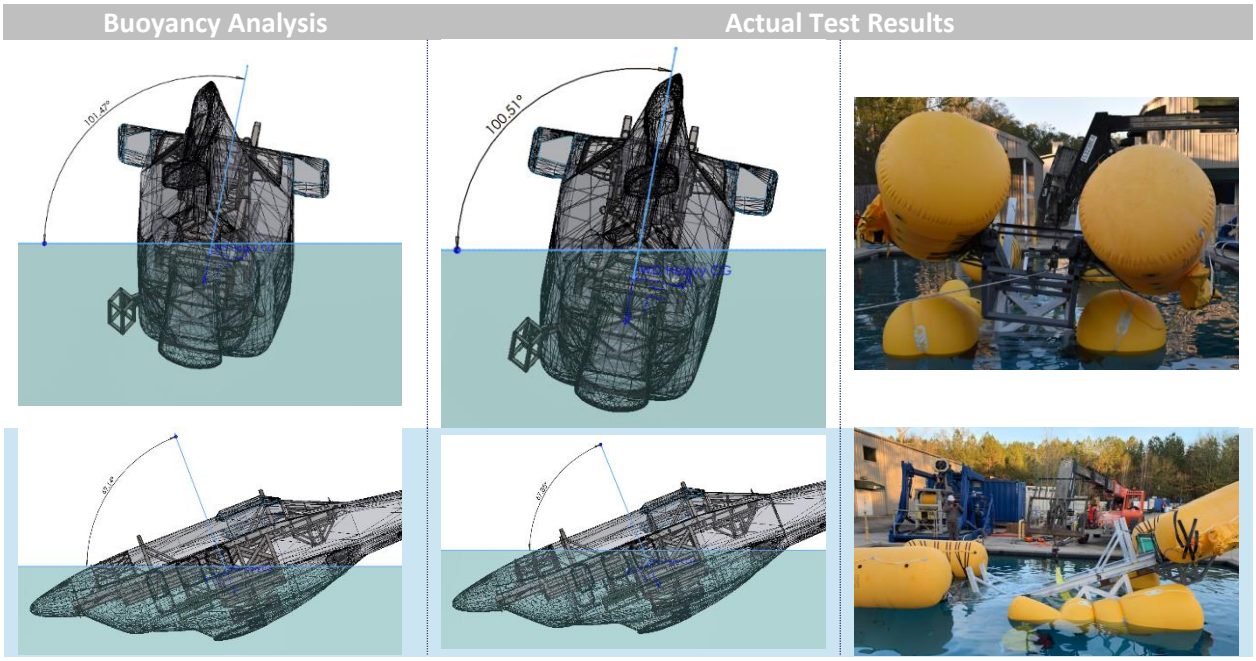


Figure 9 Full Capsized Attitude, HEFS Compartment Damaged

2.6 Forced Perturbation Test Results

The objective of this test was to assess the dynamic stability and roll direction of the test fixture when influenced by forced perturbations (external loads). The test fixture was incrementally raised from the partially capsized attitude by means of a strap secured to the top of the fixture to varying perturbation roll angles. Once the desired roll angle was achieved the fixture was quickly released using a helicopter remote cargo hook. A total of five forced perturbation tests were sequentially conducted from a starting / drop attitude of -97° roll (11° of roll to stable floating position) all the way to -45° roll (63° of roll to stable floating position) as illustrated in Figure 10a/b/c/d/e.

The results of this test have demonstrated that the HEFS is able to repeatedly return the fixture to the stable partially capsized floating attitude. It is also worth noting that during the fifth test the inertia of the dropping fixture is sufficient enough to fully submerge the left hand and partially submerge the right hand HEFS to a -125° roll attitude as illustrated in Figure 10f.

No damage HEFS was noticed either during the test despite being in direct contact with the fixture however, approximately 30 seconds following the last test the second (from front) chamber on the aft left hand standard EFS leaked air and could not maintain standard operating air pressure which resulted in a stable floating attitude at a slightly lower waterline.

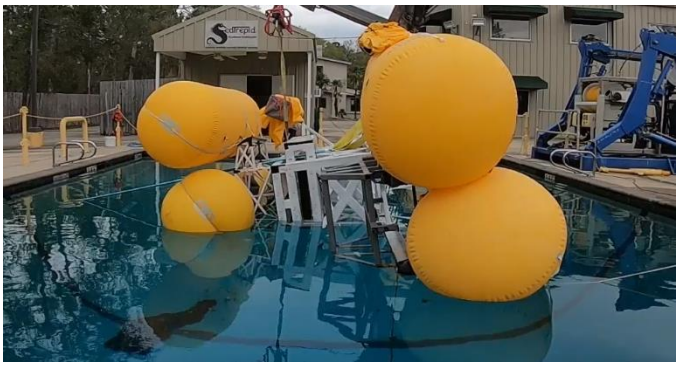


Figure 10a Forced Perturbation Test 1
(Actual, view looking fwd)

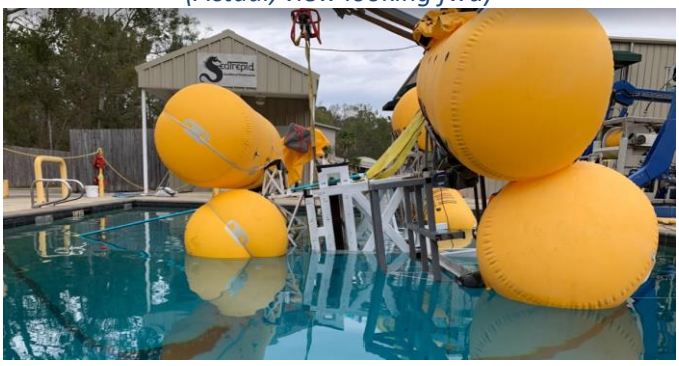


Figure 10b Forced Perturbation Test 2
(Actual, view looking fwd)

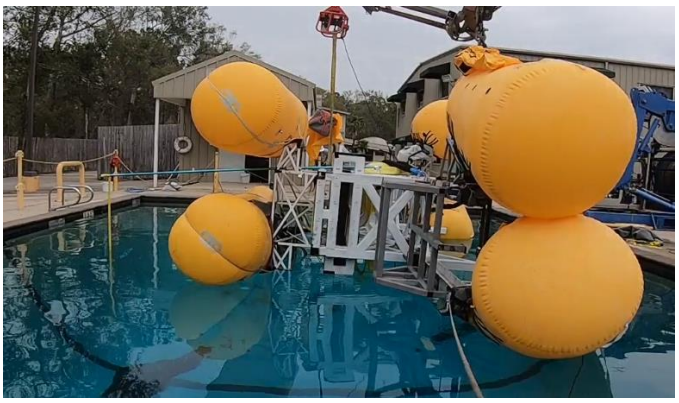


Figure 10c Forced Perturbation Test 3
(Actual, view looking fwd)

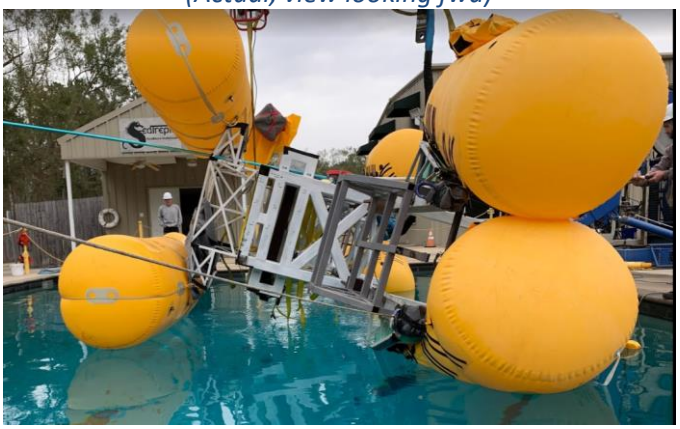


Figure 10d Forced Perturbation Test 4
(Actual, view looking fwd)

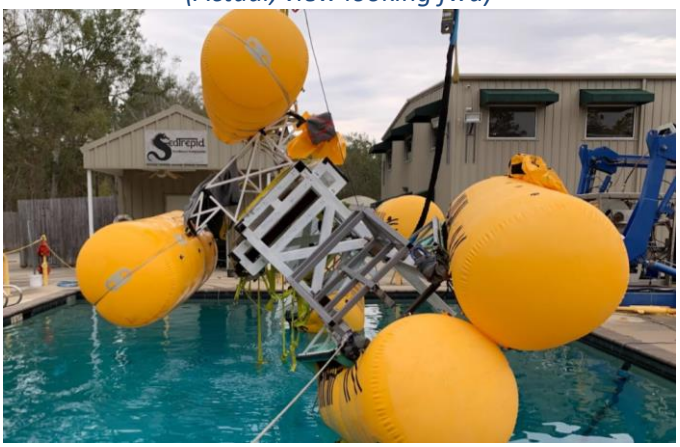


Figure 10e Forced Perturbation Test 5
(Actual, view looking fwd)

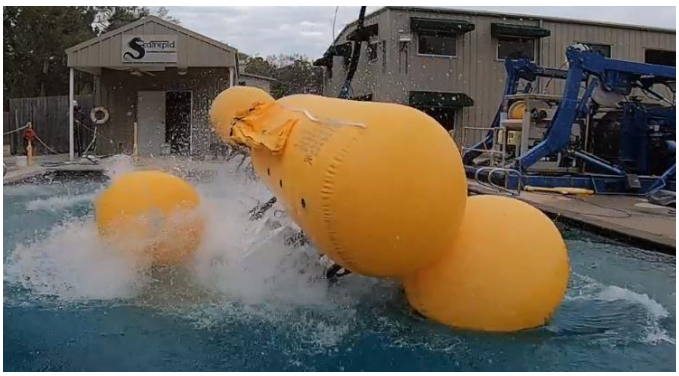


Figure 10f Forced Perturbation Test 5 at Most Submerged Attitude (Actual, view looking fwd)

2.7 Conclusion

The results of this test campaign have demonstrated that the buoyancy analysis is sufficiently representative of the majority of the test results. This specific test campaign has observed that significant forced perturbations (in roll angle) will result in the fixture returning to the stable partially capsized roll attitude.
The minor, but predictable delta between the buoyancy analysis and the actual test results is primarily due to the deflection of the prototype HEFS float bags and standard EFS float bags during the actual tests. A better constrained and fully developed HEFS is expected to produce test results that are much more similar to a buoyancy analysis.

Due to the fact that the observed waterline during testing was slightly lower than the (computer simulated) buoyancy analysis, DART conducted the air pocket assessment as part of the research based on the waterlines observed during testing which produced more conservative results.

It should also be noted that the primary EFS system is not generally designed to be loaded in the capsized or partially capsized position, therefore it is critical that the primary EFS is evaluated in parallel to a HEFS. Despite this test campaign demonstrating that the test fixture is stable in the partially capsized and capsized floating positions, it is essential to evaluate future designs to account for all likely ditching attitudes and capsizing scenarios.

European Union Aviation Safety Agency

Konrad-Adenauer-Ufer 3
50668 Cologne
Germany

Mail EASA.research@easa.europa.eu
Web www.easa.europa.eu

An Agency of the European Union