El Faro: Developing a Digital Illustration of Hull Wreckage 15,400 Feet Below the Surface of the Atlantic Ocean

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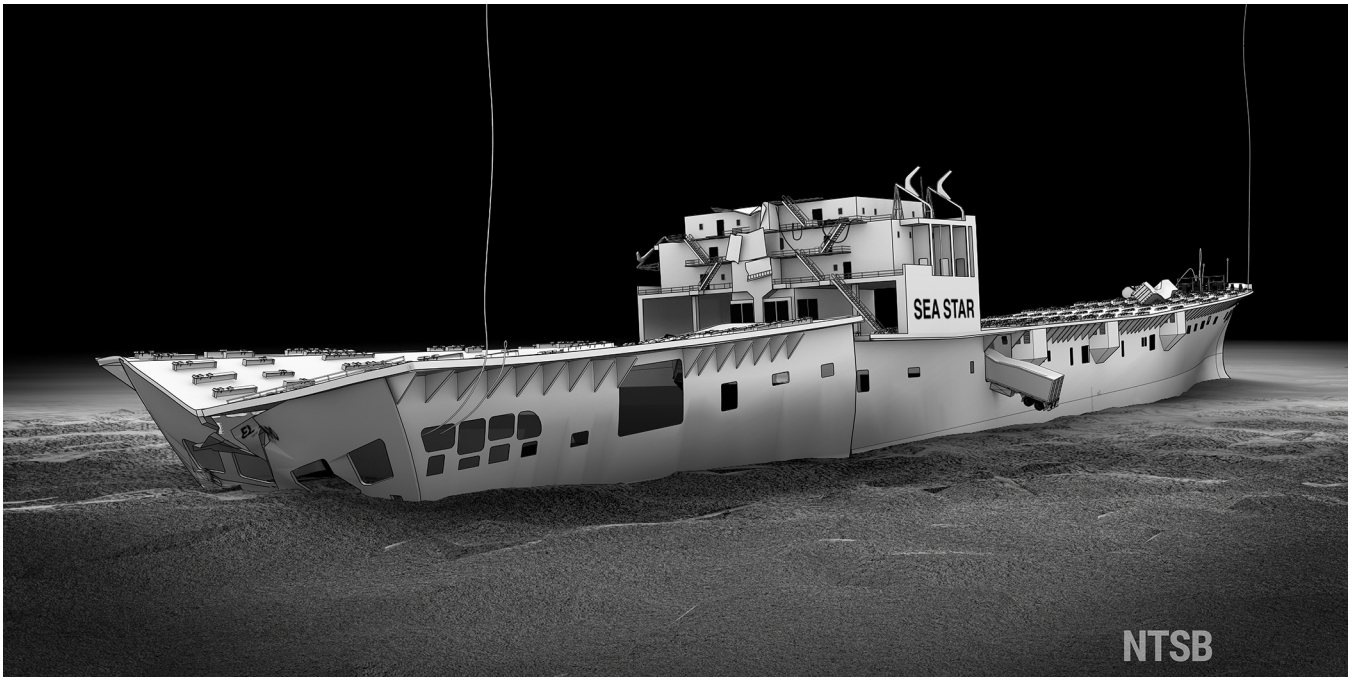

Figure 1: Digital illustration of *EL FARO*'s final position on the seafloor, 15,400 feet below the surface of the Atlantic Ocean.

ABSTRACT

The National Transportation Safety Board (NTSB) is an independent agency charged with determining the probable cause of transportation accidents and promoting transportation safety. We collect a large volume of highly complex and diverse data, which is often integrated into digital illustrations to help explain the accident events, probable cause, and relevant safety issues. One major accident investigation in which digital illustrations were key was our investigation into the sinking of the cargo ship *SS El Faro* in 2015. (Fig. 1)

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CCS CONCEPTS

• **Computing methodologies** → **Computer graphics**; *Scientific visualization*;

KEYWORDS

Visualization, accident reconstruction, digital illustration

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1 INTRODUCTION

On October 1, 2015, during Hurricane Joaquin, the 33,000 ton, 790-foot long US-flagged cargo ship *SS El Faro*, en route from Jacksonville, Florida, to San Juan, Puerto Rico, sank in the Atlantic Ocean near the Bahamas, killing all 33 people on board. [NTSB 2017] The National Transportation Safety Board's (NTSB's) Office of Marine Safety's Naval Architecture Group sought to develop a

complete image of the vessel's hull on the ocean floor to assist with forensic analysis of the sinking. Video and photographic footage of the hull were taken by remotely operated underwater vehicles (ROVs) during three missions to locate the wreckage, document the debris field, and retrieve the ship's voyage data recorder (VDR), 15,400 feet below the surface of the Atlantic Ocean.

2 LOCATING THE WRECKAGE AND VOYAGE DATA RECORDER

It took three voyages and collaboration with four organizations—the US Navy Superintendent of Salvage and Diving (SUPSALV), Woods Hole Oceanographic Institution (WHOI), the National Science Foundation, and the University of Rhode Island's Inner Space Center—to locate the *El Faro*'s wreckage and retrieve its VDR (for details on the search and recovery, see NTSB Report No. MAR-17/01, *Sinking of US Cargo Vessel* SS El Faro *Atlantic Ocean, Northeast of Acklins and Crooked Island, Bahamas* [NTSB 2017] and NTSB Report No. SPC-18/01, *Sinking of the US Cargo Vessel* El Faro *Illustrated Digest* [NTSB 2018]).

3 DEVELOPING THE DIGITAL ILLUSTRATION

Photography and sonar imaging challenges meant we were left without a full-hull mosaic or high-resolution sonar image of the hull, so we decided to produce a simpler rendition of the main hull using an illustrative style inspired by NTSB's report on the 1975 sinking of the *SS Edmund Fitzgerald* in Lake Superior. [NTSB 1978] We reviewed the video footage and photographs from all three missions to the seafloor, then culled it to include only pertinent footage of the vessel wreckage. We also obtained and reviewed archival photographs and drawings of *El Faro* and its sister vessel, *El Yunque*.

3.1 Collating and verifying the data

On the mission to image the hull, WHOI obtained high-resolution side-scan (850 kHz) and multibeam images for the debris field areas of interest; however, neither could be attained for the main hull because the vessel's mooring lines were streaming up from it, which forced the underwater vehicle to fly above the maximum heights for high resolution 850 kHz and multibeam imagery (10 and 30 meters, respectively). Therefore, WHOI made a dense multibeam survey of the hull from a safe height of a constant 100 meters above the seafloor. The coverage angle was reduced to improve return beams, resulting in complete profiles with superior geometry. Researchers at WHOI postprocessed the dense survey multibeam (bathymetric) data and created a final view of the hull surface and the surrounding seafloor as point cloud data. WHOI researchers reconfigured the data, at our request, to place the origin of the point cloud on the hull surface. The point cloud data would later be used to model the seafloor and fit an accurate three-dimensional (3D) model of *El Faro* relative to the seafloor based on the position of the hull surface in the point cloud.

The NTSB's Office of Research and Engineering verified that the bathymetric hull surface was relatively precise and suitable for an accurately scaled 3D illustration by showing that the 3D ship model could be fitted to the bathymetric hull surface.

3.2 Creating the digital illustration

The Coast Guard Marine Safety Center had produced an accurate 3D hull model of *El Faro* in Rhino. We imported the Rhino model into Autodesk Maya software, along with the bathymetric point cloud data of the ship's hull and seafloor, and created a computer-generated 3D environment of the wreckage scene, which allowed us to add additional details to the vessel and render it from several different viewpoints.

The ship's navigation bridge deck and lower navigation bridge deck were removed from the ship's house because they had separated from the hull when the vessel sank. The boat deck, cabin deck, and two upper decks were also remodeled so further details could be added that represented the damage we observed from hours of video and thousands of photographs. The seafloor was modeled and rendered using an image processed from the multibeam data. The damaged *El Faro* model was then placed into the seafloor rendering using the origin position data from the hull point cloud.

Toon shading was added to develop the illustrative look, and the vessel's name, draught marks, and Plimsoll marks were texture mapped onto the hull and stern. Several render passes were developed and tested using Maya's software and vector renderers, as well as the Arnold renderer. Four views of the 3D scene were rendered in an illustrative style then composited using Adobe Photoshop, and finally imported into Adobe Illustrator, where the vector render pass was added and artistically refined to achieve the final look of the digital illustration.

4 CONCLUSION

The NTSB investigates accidents in all modes of transportation, and each case presents its own challenges for investigators. Creating a 3D environment to develop a digital illustration is a useful way of integrating and correlating data analysis to convey visual aspects of the accident scene. The rendered illustrations provide a means of explaining complex concepts to a wide range of audiences. Via visual representations, the NTSB can better support its recommendations to improve the safety of the nation's transportation system.

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