National Transportation Safety Board

Washington, DC 20594

Highway Accident Brief

Low-Speed Collision Between Truck-Tractor and Autonomous Shuttle, Las Vegas, Nevada, November 8, 2017

Accident Number:	HWY18FH001
Accident Type:	Collision involving automated test vehicle on public road
Location:	South 6th Street, Las Vegas, Nevada
Date and Time:	November 8, 2017, 12:07 p.m. Pacific standard time
Vehicle 1:	2006 International truck-tractor in combination with 2010 Utility refrigerated trailer
Vehicle 2:	2017 Navya Arma autonomous shuttle
Fatalities:	0
Injuries:	0

Crash Description

About 12:07 p.m. on Wednesday, November 8, 2017, a minor collision (figure 1) occurred on South 6th Street in downtown Las Vegas, Clark County, Nevada, between a truck-tractor combination vehicle, operated by a 48-year-old driver, and a 2017 Navya Arma autonomous shuttle, carrying 7 passengers and a 38-year-old attendant. The shuttle, manufactured by Navya and operated by Keolis North America, was on a 0.6-mile designated loop beginning and ending at a downtown shopping center known as Container Park (the buildings are repurposed shipping containers or modular cubes).[1] The combination vehicle, a 2006 International truck-tractor pulling a 2010 Utility refrigerated trailer, was backing into an alley west of South 6th Street while on a delivery route for US Foods when it struck the shuttle.[2]

[1] Navya is a French company headquartered in Lyon, France. Keolis North America operates public transportation services in the United States and Canada. Keolis runs local and express transit routes in Las Vegas for the Regional Transportation Commission (RTC) of Southern Nevada. The shuttle was operating under a special agreement between the RTC and Las Vegas and was not part of the company's normal service in the city. The parent Keolis company is based in Paris.

[2] US Foods is a trade name of E & H Distributing, LLC, an authorized for-hire interstate carrier of private property, including general freight, fresh produce, meat, chemicals, refrigerated food, beverages, and paper products.

Figure 1. Scene of minor collision between truck-tractor and autonomous shuttle in downtown Las Vegas (white car in foreground was not involved). (Source: KSNV News 3 Las Vegas)

The shuttle was a test vehicle, part of a pilot program in Las Vegas, and was on its first day of passenger-carrying operation (shuttle rides were free) when the collision occurred. The pilot program ran from October 2017 to October 2018. The city of Las Vegas, the American Automobile Association (AAA), and Keolis cooperated in the program. AAA sponsored the shuttle. In addition to handling day-to-day shuttle operations, Keolis tested the vehicle for 3 weeks before it was launched for public use on November 8 (the day of the collision).

At the beginning of the trip, the attendant boarded with the passengers at Container Park and started the shuttle in autonomous mode (see “Autonomous Operation” section). The shuttle followed one of its two designated routes (figure 2), both of which incorporated only right turns.[3] After leaving the shopping center, the shuttle traveled along Fremont Street, turned right onto South 8th Street, then right again onto East Carson Avenue. It stopped at an information kiosk at South 7th Street and East Carson Avenue, then turned north onto South 6th Street, where the truck was backing into the alley.

According to the manufacturer’s (Navya) incident report, the shuttle’s sensor system detected the truck at 45 meters (147.6 feet) and tracked the truck continuously while it backed up. The shuttle, which was programmed to stop 3 meters (9.8 feet) from any obstacle in its path, began to decelerate at a distance of 30 meters (98.4 feet) from the truck.

[3] The other route took the shuttle as far as Las Vegas Boulevard (see figure 2).

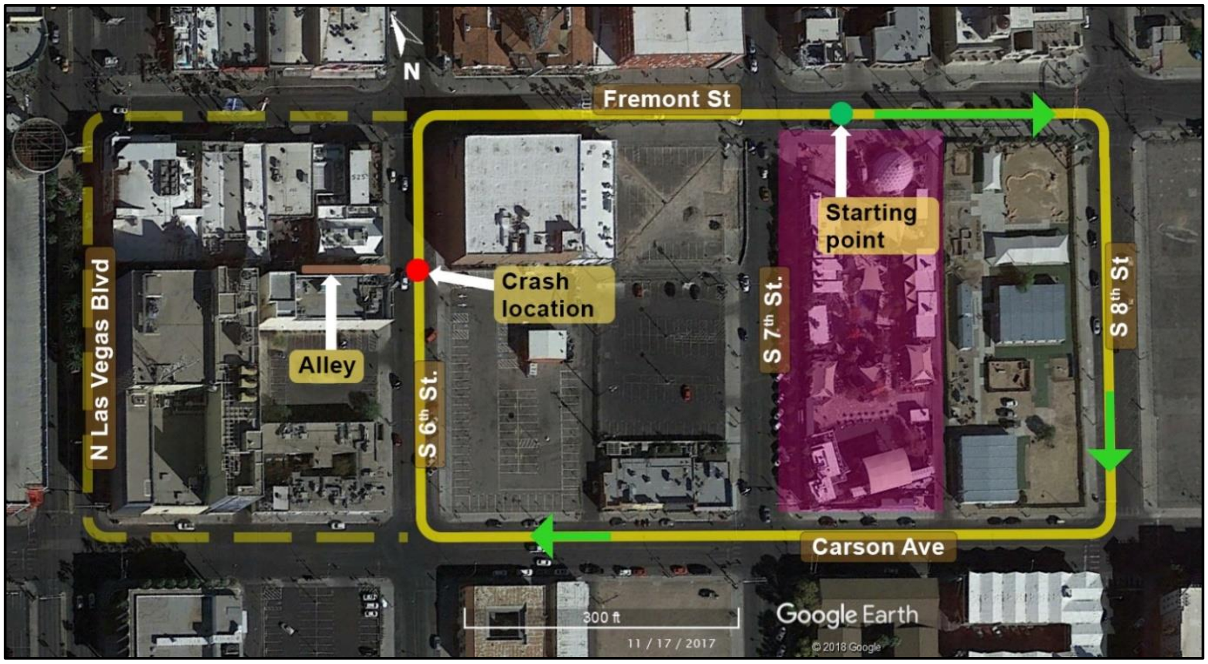

Figure 2. Shuttle's looped route on day of collision (solid yellow line), showing starting point at Container Park (shaded purple), direction of travel, and crash location, as well as alternate route to Las Vegas Boulevard (dashed yellow lines). (Adapted from Google Earth)

When the shuttle was 3.1 meters (10.2 feet) from the truck and at nearly a complete stop, the attendant pressed one of the emergency stop buttons on the wall opposite the loading doors.[4] Cameras inside the shuttle showed the attendant and passengers waving to the truck driver. The truck driver continued in reverse. Eleven seconds after the shuttle stopped, according to Navya's incident report, it was struck by the right front tire of the slow-moving truck.

The collision caused minor damage to the lower left front of the shuttle's body and a minor abrasion to the truck's tire (see photos later in this report, in "Truck" and "Autonomous Shuttle" sections). The shuttle passengers, the attendant, and the truck driver were uninjured. The shuttle and the combination vehicle remained in service after the collision.

Roadway

South 6th Street is a 14-foot-wide, two-way urban roadway running north and south in downtown Las Vegas. The surface is asphalt, marked with a solid yellow line separating the two lanes. The street is straight and level. Parking spaces are angled on the east side of the street and parallel on the west side. The posted speed limit is 25 mph. The weather was clear and the road was dry at the time of the collision.

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[4] According to Navya's report, the shuttle's speed was less than 1 mph (0.249 meters per second, or 0.56 mph) when the attendant pressed the emergency stop button.

Driver

Background

The 48-year-old male truck driver held a Nevada class A commercial driver's license that was due to expire in March 2018. He started working for US Foods in March 1995 and had been delivering to businesses in downtown Las Vegas for at least 15 years. He traveled the delivery route he was on at the time of the collision two or three times a week.

Collision Trip

The driver told investigators that on the day of the crash, he awoke at his usual time (about 3:40 a.m.), arrived at the US Foods warehouse at 4:40, and left by 5:20 to begin his deliveries. The delivery he was attempting to make when his truck hit the shuttle was his sixth or seventh of the day. The driver said that he was not in a hurry and did not have any issues with the truck. He also said that it was normal procedure to back into the alley—the truck was "too long" to enter the alley from Las Vegas Boulevard, and backing into the alley was the "only way . . . to be safe pulling out."

The driver told investigators that he activated his flashers as he pulled up to the alley. Two cars were behind him, which he waved past. When he began backing up, he saw the shuttle turn onto South 6th Street from Carson Avenue. He said that he knew the shuttle was automated and had seen it doing "test runs" on Fremont Street, but he had not previously seen the shuttle on South 6th Street. He said that he had no concerns about sharing a road with the shuttle.

The driver said that as he continued backing up, he paid particular attention to vehicles parked on the east side of South 6th Street so as not to strike them. He looked to the right and noted that the shuttle was halfway down the street. He stated that he assumed the shuttle would stop a "reasonable" distance from the truck. The driver said that he looked back to the left and saw a pedestrian in the alley. He waited until the pedestrian cleared and then turned his attention to the right, which was when his truck hit the shuttle.

Medical/Toxicology

The driver reported that he was in good health and did not have a primary care physician. He said that he was wearing his prescription glasses at the time of the collision and described his hearing as good. He said that he had never been diagnosed with a sleep disorder and reported being well rested before the incident.[5] He took no medications and did not drink alcohol on the day of the collision. Because no injuries were sustained in the collision and neither vehicle was towed from the scene, federal regulations did not require the driver's employer to test him postcrash for alcohol or other drugs.[6] An investigating officer from the Las Vegas Metropolitan Police

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[5] A sleep log was calculated for the driver from the times he told investigators that he went to bed and awoke during the 3 days before the crash. The log indicated that he had a sleep opportunity of almost 8 hours on each of those nights.

[6] Title 49 *Code of Federal Regulations* (CFR) 382.303 requires employers to perform postcrash testing of a commercial driver if a crash results in death, injuries that require medical treatment away from the scene, or damage that requires any vehicle to be towed from the scene.

Department (LVMPD) did not suspect impairment or intoxication and did not perform or request toxicological tests. The LVMPD cited the truck driver for improper backing of a vehicle—specifically, for backing into a one-way, out-only alley.

Truck

The combination vehicle consisted of a conventional, two-axle truck-tractor connected to a two-axle, 38-foot refrigerated semitrailer. The truck's gross vehicle weight rating (GVWR) was 32,000 pounds.[7] The truck was equipped with two rearview mirrors, as required, one mounted on each cab door, and two additional mirrors, one mounted on each front fender.[8] National Transportation Safety Board (NTSB) investigators inspected the truck and semitrailer 4 days after the collision at the US Foods warehouse. No body or mechanical damage was apparent. The truck's backup alarm and backup lamp were operational. The truck was equipped with light-emitting diode brake lights and turn signals. At the time of inspection, the brake lights, turn signals, and hazard warning signals were all operational.

For the inspection, the truck-tractor and trailer were placed in their approximate postcrash positions (figure 3). The truck's steering wheel was turned to the left. The offset distance from the right fender to the outboard tire shoulder on the truck's steer axle measured about 6 inches. The abrasion on the truck's right front tire extended inboard 1.75 inches from the outboard shoulder.

Figure 3. Truck-tractor after collision, with inset showing damage to right front tire (photo taken 4 days after collision).

[7] GVWR is the total maximum weight a vehicle is designed to carry when loaded, including the weight of the vehicle itself plus fuel, passengers, and cargo.

[8] Title 49 CFR 393.80 sets out federal requirements for rear-vision mirrors on buses, trucks, and truck-tractors.

Investigators conducted a line-of-sight analysis to assess whether the truck driver had an unobstructed view of the shuttle. After the truck and objects representing the height and width of the shuttle were placed in their approximate crash positions, an investigator sat in the driver's seat and checked the view on the right side of the truck. The analysis showed that parts of the surrogate shuttle were visible through the windows and in the mirrors on the right side.

Autonomous Shuttle

Overview

The 2017 Navya Arma shuttle was a two-axle, battery-powered automated test vehicle with a GVWR of 3,500 pounds.[9] As a vehicle designed primarily for autonomous operation, the shuttle did not have a steering wheel, a brake, or an accelerator pedal. Its design permitted manual operation, however, using a hand-held controller, as described below ("Manual Operation"). The highest speed at which the shuttle was allowed to operate at the time of the crash was 25 kilometers per hour (16 mph).

The shuttle had two symmetrical ends, either of which could serve as the front or the rear.[10] Passengers entered through double sliding doors on one side. The shuttle could carry 15 passengers, 11 seated and 4 standing. Eight seats were occupied at the time of the collision. All but three seats along one side of the shuttle were equipped with lap belts (figure 4); seats without belts were not occupied at the time of the collision.[11]

Figure 4. Seats equipped with lap belts, shuttle interior (photo taken 3 days after collision).

[9] In recommended practice SAE J3016, the Society of Automotive Engineers (SAE) defines six levels of driving automation, from no automation (level 0) to full driving automation (level 5).

[10] At the time of the collision, the shuttle's direction of travel was such that the passenger entry doors were curbside (on the vehicle's right when facing its direction of travel).

[11] Both the city of Las Vegas and AAA had requested that passengers use seat belts, which also conformed with Keolis's policy.

Two emergency stop buttons were installed on either side of the central window opposite the loading doors (figure 5). Pushing an emergency stop button would turn off the motor, activate three types of brakes, and turn on flashing hazard signals. The loading doors were equipped with emergency release handles. If the doors could not be used to evacuate the shuttle in case of emergency, a hammer could be used to break the central window, marked "emergency exit." A fire extinguisher and first aid kit were stored under the seats opposite the doors.

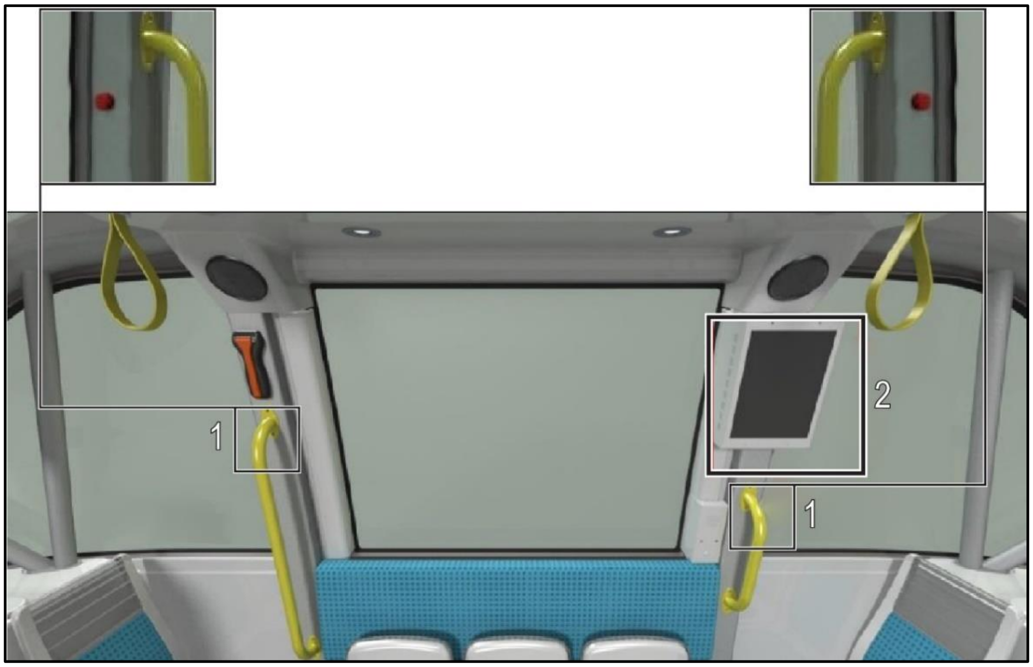

Figure 5. Rendering of shuttle interior showing locations of (1) emergency stop buttons (detailed in inset drawings) and (2) navigation touch screen. Emergency hammer (red) is shown in upper left. (Adapted from Navya owner's manual)

The shuttle was powered by two batteries, an 80-volt traction battery that stored the energy needed to operate the vehicle's electric motor and a 12-volt backup battery. The 80-volt battery was at one end of the shuttle, under a door that could be lifted from the outside for access. The 12-volt battery was stored in an enclosed space inside the passenger compartment (at the same end as the 80-volt battery). A navigation touch screen attached to the side opposite the loading doors, as shown in figure 5, displayed information such as the battery's charge status and the vehicle route.

Autonomous Operation

The shuttle could operate autonomously only on a predetermined path, on a route that had been fully mapped. The route was planned to minimize safety concerns by, for example, limiting the shuttle to right turns, which reduced potential conflicts with oncoming traffic. The shuttle traveled well below its maximum speed as another safety feature and did not operate in severe weather, a condition of its state license (see "Regulatory Considerations" section).

The travel route was planned by Keolis, Navya, and AAA, with input from the city. The path was mapped using the shuttle's external sensing devices, which, together with its telecommunication equipment, were used to guide the vehicle during autonomous operations (see figure 6). The sensing devices included eight lidar (light detection and ranging) sensors. The lidars measured the distance to other objects using a laser light and had a detection range of 40 meters under ideal conditions.[12] Two of the lidars were positioned on the roof to give a 360-degree view around the vehicle. The primary purpose of the lidar system was to detect obstacles, whether moving or stationary (cars backing out of parking spaces, motorcycles, bicycles, pedestrians, and so forth) on the roadway or sidewalk. The lidars were also used to verify the shuttle's location and path.

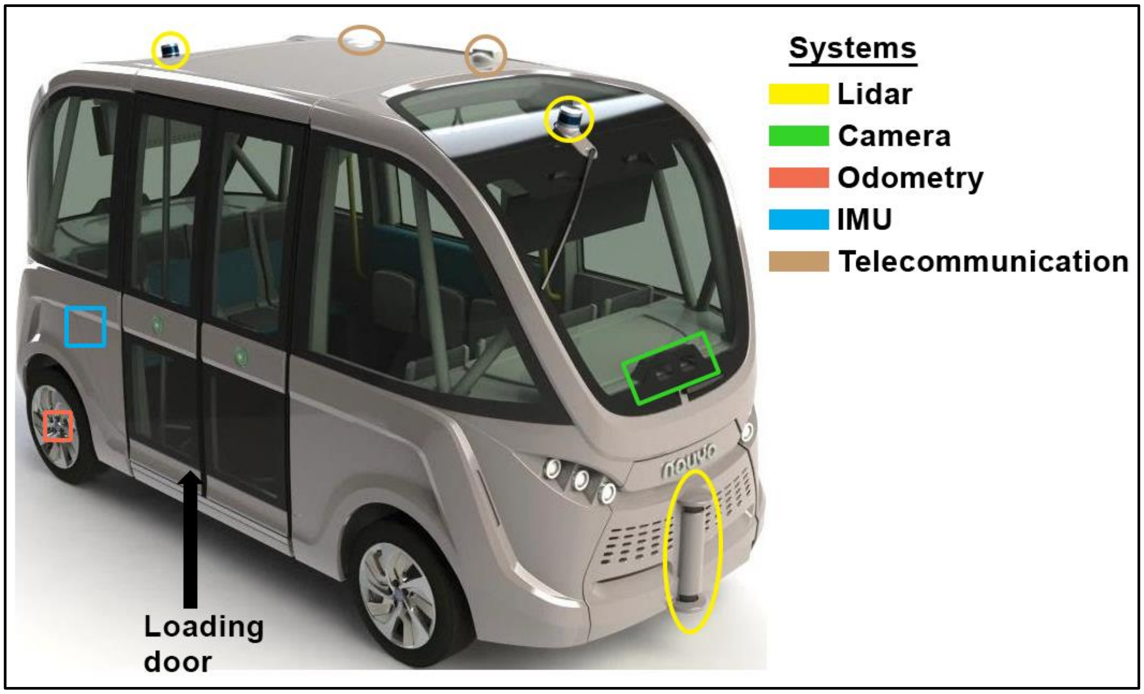

Figure 6. Location of external sensors and communication devices that guided shuttle's autonomous operation. (Adapted from Navya owner's manual)

Two stereoscopic cameras were mounted on the shuttle to monitor the outside environment as well as to analyze signs and traffic signals.[13] The shuttle's telecommunication equipment included a differential global positioning system that helped the vehicle keep to its designated path. The shuttle also had a dedicated short-range communication system and a long-term evolution antenna that communicated with traffic signals along the route. An inertial measurement unit (IMU) measured the shuttle's acceleration and angular rate to refine its position and verify its location. An odometry device measured the speed of the wheels to estimate changes in the vehicle's position.

During the map-making stage, the lidar and camera systems recorded environmental features such as roadway markings, curbs, stop lines, traffic signals, signs, road grade and

[12] Lidars compute distance from the time between the pulsing of a laser beam toward an object and the return of the beam's reflection from the object.

[13] Another camera (fish-eye) was mounted on the ceiling of the shuttle to monitor passengers.

curvature, and certain nontraffic static objects such as buildings. The map included vehicle telematics and roadway curvatures associated with locations along the route. As the shuttle traveled along the mapped coordinates of its path, the various systems continuously scanned the environment and verified that the detected objects (such as stop signs) and roadway features (such as grade) matched those on the mapped route at those specific locations.

Navya could monitor the shuttle's performance in real time from its control center in Lyon, France, by observing the vehicle telematics or viewing the video from the shuttle's cameras.[14] The control center operated 24 hours a day, 7 days a week.

Manual Operation

A trained driver (attendant) could use manual control to operate the shuttle outside the vehicle's predetermined path (for example, to move it from a storage location to its mapped route or to navigate around stationary objects). A hand-held controller was required to operate the shuttle in manual mode (figure 7).

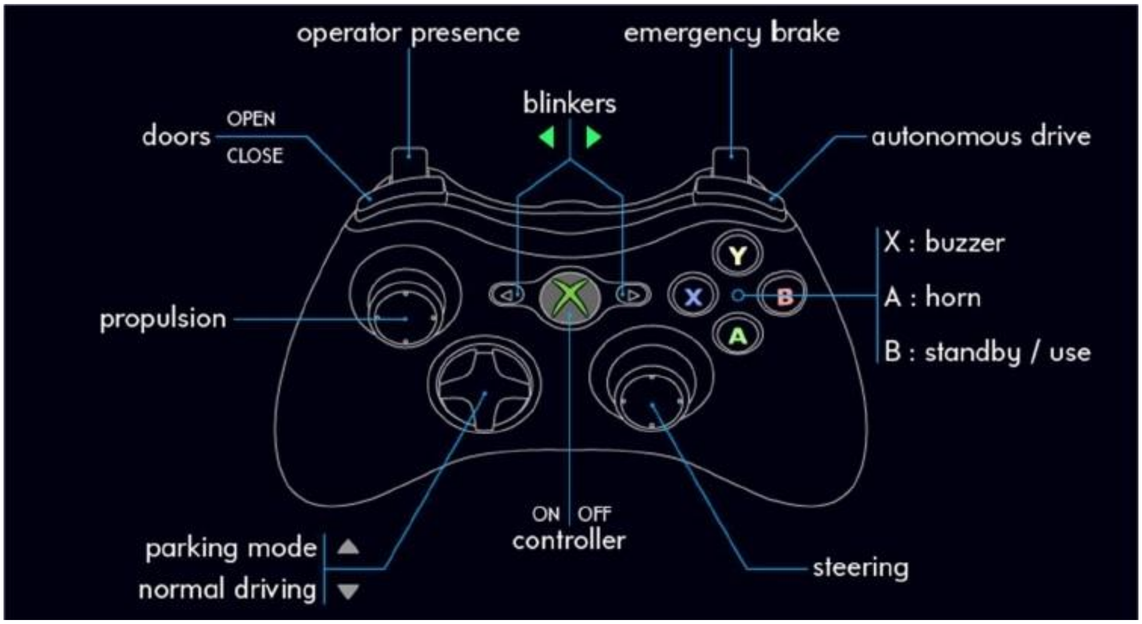

Figure 7. Schematic of controller used to operate shuttle in manual mode or return it to autonomous mode. (Source: Navya operator training booklet)

Pressing the "operator presence" button on the controller would activate manual mode. In addition to steering the shuttle, the controller could engage the emergency brake, horn, or buzzer; open or close the doors; or activate the turn signals (blinkers).[15]

Pressing both turn signal buttons would activate the hazard warning lights. Releasing the control button (green X at center of controller) would activate the emergency brake. Pressing the

[14] It was also possible for Navya to control the shuttle remotely from Lyon, but network time delay would make such an operation unsafe, so it was not performed.

[15] The headlights and rear lights illuminated automatically, according to which direction the shuttle was traveling.

"standby" button would disable propulsion. Pressing two buttons on the controller ("operator presence" and "autonomous drive") would return the shuttle to autonomous mode.

Before the crash, the controller was stored in an enclosed space at one end of the passenger compartment. The attendant did not retrieve the controller during the event. After the crash, Keolis put in place a new company policy to make the controller more accessible. Attendants were now to remove the controller from its storage space at the beginning of a trip and keep it available throughout the trip.

Data Recording

The shuttle was equipped with a Lytx DriveCam, installed by Keolis. The DriveCam is a monitoring and recording device that tracks driving metrics (such as following distance) and records telematic information triggered by critical events (such as hard braking or activation of electronic stability control).[16] The DriveCam was mounted on the windshield at one end. It consisted of a dual-channel video recorder, forward- and interior-facing cameras, and a microphone. The data were stored locally, on the device.

NTSB investigators reviewed images and audio recorded by the DriveCam and images recorded by the shuttle's three cameras (two outside and one inside) and stored in its computer.[17] Based on video from the interior cameras (shuttle and DriveCam), the DriveCam was activated moments before the crash, when the attendant struck the window with his palm while trying to capture the truck driver's attention. The DriveCam's outward-facing camera recorded 12 seconds of video data, beginning with images of the truck-tractor. On the simultaneous audio recording, an auditory signal is heard, followed by a crashing sound 6 seconds into the video. The truck then stops and is immobile for the rest of the video.

The DriveCam's inward-facing camera and microphone also recorded 12 seconds of data, showing the passengers seated and the attendant standing, then the attendant waving his hands to get the truck driver's attention. Eleven seconds into the recording, one passenger says, "Oh, he [the truck driver] can't see this." The rear-facing shuttle camera recorded 33 seconds of data; 25 seconds into the video, the camera shakes, indicating the time of impact. NTSB investigators found that data from the DriveCam and the shuttle's cameras confirmed Navya's incident report.

The shuttle's operation, whether in autonomous or manual mode, was recorded on two computers inside the passenger compartment. Combined, the system had a storage capacity of at least 12 hours and recorded all data, including telematics, sensor data, and camera video.

[16] The threshold for triggering a hard-braking event is a 9-mph deceleration in 1 second, and for a stability control event, lateral acceleration of at least 0.4 g (gravitational force). The system records vehicle telematics within a 20-second window of the triggered event—10 seconds before and 10 seconds after.

[17] The shuttle's cameras did not record sound.

Damage

NTSB investigators examined the shuttle 3 days after the collision. The left front fiberglass panel on the body was displaced to the left, creating a gap (measuring from 1.375 inches at the bottom to 1.125 inches at the top) between the panel and the access door at one end of the shuttle (figure 8).[18] Investigators also observed black transfer marks on the fiberglass.

Figure 8. Closeup of damage to lower left front of shuttle (photo taken 3 days after collision).

Shuttle Attendant

Although the shuttle could operate autonomously, Navya, AAA, and the city of Las Vegas required an attendant to be on board to supervise and intervene if necessary. According to Navya's operator training booklet, the attendant's duties included receiving passengers on board, checking that the vehicle functioned properly, reporting errors to the supervision center, maintaining the security of passengers inside the vehicle and of pedestrians outside, and reporting damage or injuries. The attendant also initiated the shuttle's autonomous operation (the system determined when it was safe to depart) and would request stops at designated locations and open and close the doors. In the event of an unexpected or erroneous action by the shuttle's autonomous system, the attendant could notify Navya by pressing an intercom button on a speaker next to the navigation touch screen. Activating the intercom would connect the attendant to the control center in France.

Part of the attendant's regular duties included using the hand-held controller to load the shuttle on and off a tow truck (to take it to and from its route location), to maneuver the shuttle in the yard where it was stored, and to pull the shuttle into parking spaces. The attendant could also

[18] The door at this end of the shuttle (the front end, in the travel configuration for its Las Vegas route) gave access to the electric motor and other parts. The door at the other end gave access to the 80-volt battery.

intervene and operate the shuttle manually if an obstacle blocked its path (the shuttle could not deviate outside its designated path, for example, to go around a stopped vehicle). In such situations, the attendant would use the controller to maneuver the shuttle around the obstacle and then return it to its path. The attendant would then reengage autonomous mode.

Investigators interviewed the attendant after the collision. He told investigators that in January 2018 he trained on the shuttle for 10 days with an engineer from France and representatives of Keolis, testing the vehicle from Fremont Street to Las Vegas Boulevard. Three weeks before the collision, he joined the shuttle team in Las Vegas for further training with French engineers. He said that previously, he drove 40-foot motorcoaches in Utah for about 3 years and that he held a class B commercial driver's license.

The attendant told investigators that on the day of the collision, he noticed a delivery truck backing up ahead of the shuttle as it moved along South 6th Street. He felt the shuttle slow as the vehicles neared each other. Just before the shuttle stopped, the attendant said that he hit the emergency button as a precaution. The truck kept moving, and the attendant and the passengers waved to get the driver's attention. The attendant told investigators that several seconds passed after the shuttle stopped before the truck collided with it. The attendant believed the shuttle was visible to the truck driver in the right-side mirror from the time the shuttle stopped until the collision. The attendant said that he considered switching to manual mode to move the shuttle, but that he had very little time. He further stated that manual mode was not designed or intended to be used as an emergency mode. That statement was consistent with Keolis policy, as reported to NTSB investigators.

Regulatory Considerations

Nevada Autonomous Vehicle Licensing

On August 2, 2017, Keolis applied for an autonomous vehicle testing permit from the Nevada Department of Motor Vehicles (DMV). The form required an applicant to affirm the safety of the test vehicle, and that in case of a technology failure, the vehicle "has a system to safely alert the operator to take control"; or if no operator is in the vehicle, it "can achieve a minimal risk condition."[19]

On August 7, 2017, the DMV issued Keolis a license ("autonomous business plate certificate") with an expiration date of August 7, 2018. The license authorized the shuttle to operate only in an urban environment. Excluded were complex urban environments, interstate or state highways, residential areas, and unpaved or unmarked roads. The license prohibited operation of the vehicle under foggy, snowy, or icy conditions. Night driving and operation in rain were

[19] Nevada law defines *minimal risk condition* as "a condition in which an autonomous vehicle operating without a human driver, upon experiencing a failure of its automated driving system that renders the autonomous vehicle unable to perform the dynamic driving task, achieves a reasonable safe state which may include, without limitation, bringing the autonomous vehicle to a complete stop."

permitted. The DMV issued the shuttle a special red license plate identifying it as an autonomous vehicle.

Nevada Requirements

Nevada was the first state to authorize the operation of autonomous vehicles on public roads (Assembly Bill 511).[20] The law defined an autonomous vehicle as “a motor vehicle that uses artificial intelligence, sensors and global positioning system coordinates to drive itself without the active intervention of a human operator.” The DMV adopted regulations pertaining to the operation of autonomous vehicles as Chapter 482A of the Nevada Administrative Code (NAC).

Section 130 of NAC 482A required at least one human operator to be present in an autonomous vehicle being tested on Nevada roads. On June 16, 2017, the governor of Nevada signed into law Assembly Bill 69, which, among other provisions, allowed a fully autonomous vehicle to be tested or operated on a state highway without a human operator inside if it met minimal risk conditions (thereby nullifying NAC 482A.130). Nevada revised the regulations applying to autonomous vehicles after Assembly Bill 69 was signed into law. The revised regulations came into effect in November 2018.

Federal Requirements

Passenger cars, trucks, buses, and other motor vehicles in the United States are subject to the requirements of the *Federal Motor Vehicle Safety Standards* (FMVSSs), codified at 49 CFR Part 571. The FMVSSs do not explicitly address automated vehicle technology and do not prevent the development, testing, sale, or use of automated driving systems in vehicles with traditional controls. However, the Navya Arma autonomous shuttle does not have traditional driving controls such as steering wheels, brakes, or accelerator pedals. Therefore, it does not meet all applicable FMVSSs. Vehicles that do not meet federal requirements can, however, be temporarily imported under the provisions of 49 CFR Part 591 (“Importation of Vehicles and Equipment Subject to Federal Safety, Bumper and Theft Prevention Standards”).

The regulations require importers to file a declaration about a vehicle’s eligibility for importation. On August 3, 2017, Keolis applied for permission to import a specific Arma shuttle for use in its proposed pilot testing program in Las Vegas and filed the required declaration (form HS-7) with the National Highway Traffic Safety Administration (NHTSA).[21] The form indicated (by a checkmark in box 7) that the company was seeking to import the shuttle “solely for the purpose of research, investigations, demonstrations or training, or competitive racing events.”[22]

[20] Nevada passed the legislation on June 17, 2011. Twenty-nine states and the District of Columbia have since passed legislation related to autonomous vehicles, as reported by the National Conference of State Legislatures.

[21] NHTSA recognizes that it is restricted in its ability to apply requirements to certain manufacturers that test vehicles on public highways if the manufacturers agree not to sell or offer for sale those vehicles at the conclusion of testing (see 49 *United States Code* 20112[b][10]).

[22] That is, under the provisions of CFR 591.5j.

As part of its application, Keolis supplied NHTSA with a detailed description of the proposed pilot program, including the dates (October 16, 2017, through October 14, 2018), the location (a three-block area of downtown Las Vegas that would not be closed to public traffic), the purpose of the project, and the training and role of "drivers" (the attendants).[23] The company reported to NHTSA that drivers who had been trained in all aspects of the vehicle's operation would be in the vehicle whenever it was being operated and that they would be located in a position where they could take control if needed. The company also reported that the vehicle was fully equipped for such use in manual mode.

Federal Approval

On September 18, 2017, NHTSA sent Keolis a letter approving the shuttle for import into the United States as a "show, pilot testing, demonstration, R&D, training" vehicle. The letter noted that Keolis had already obtained a testing permit from the Nevada DMV. It also listed conditions for the shuttle's entry into the country, including, among other items, that Keolis had to comply in full with the requirements of the states and cities where the shuttle would be delivered and where it would be exhibited.

NHTSA stipulated that a label was to be affixed to the interior and exterior of the vehicle, warning prospective and actual occupants that the vehicle did not comply with all applicable federal safety standards. Further, NHTSA stipulated that Keolis notify the agency within 24 hours when the vehicle was involved in a crash or in other incidents, "including near misses and difficult edge cases that the system could not handle without further modification."[24] NHTSA also required Keolis to provide documentary proof that the vehicle had been exported or destroyed not later than 30 days after the end of the period for which it had been admitted to the United States. The temporary importation was valid only until October 14, 2018, but an extension could be requested. Keolis planned to continue the Las Vegas pilot program and reapply for certification.

Autonomous Shuttle Pilot Programs in United States

The year-long pilot program in Las Vegas was the first in the country to operate an autonomous shuttle in live traffic and open to the public. According to AAA, the shuttle operated for 1,515 hours and carried 32,827 riders in total during the program.[25] Las Vegas is planning another pilot program involving autonomous shuttles, the GoMed project, which would operate four autonomous shuttles on a fixed route from the downtown transit center to the Las Vegas Medical District.

Autonomous shuttles are operating on an experimental basis in several other US cities. For example, in April 2018, a Navya shuttle carried passengers on test rides for 2 days around the campus of the University of Wisconsin at Madison, with longer demonstration projects being

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[23] Nevada law defines *driver* for purposes of an autonomous vehicle as the person who causes the automated driving system to engage.

[24] *Edge cases* are problems or situations that occur only rarely.

[25] As reported on the AAA website devoted to the self-driving shuttle pilot program.

planned on the campus and in the city center. In 2016, the US firm Local Motors demonstrated its autonomous shuttle Olli, made up of 3D-printed parts, on private roads around National Harbor, Maryland, and in January 2019, received permission from the state for Olli to begin carrying passengers on public roads in the same area. In 2018, Sacramento State University in California won an Olli challenge and is operating two Olli shuttles on its campus for 90 days in early 2019. Officials in Washington, DC, are seeking a company to run a pilot program using an autonomous shuttle to connect the Smithsonian museums to the nearby Potomac waterfront.[26]

In October 2018, NHTSA issued an advance notice of proposed rulemaking seeking public comments on the factors that should be considered in designing a national pilot program for the safe on-road testing and deployment of vehicles with "high" and "full" driving automation.[27]

Discussion

This section considers the factors that could have led to the truck driver's continuous backing up and eventual collision with the autonomous shuttle.

Truck Driver Licensing and Experience

The truck driver was properly licensed for the vehicle he was driving at the time of the crash. He had years of experience as a commercial driver. He was familiar with the vehicle and with the delivery route. In addition, investigators determined that the driver's fatigue, medical condition, and alcohol or other drug use were not causal or contributing factors in the crash.

Visibility/Driver Expectations

Investigators confirmed through interviews that the truck driver was aware of the autonomous shuttle operation and that he saw the shuttle approaching as he started backing into the alley. Sight-line evaluations showed that the shuttle was visible to the truck driver at the time of the crash, considering the approximate location of both vehicles.

Autonomous Shuttle Operation

Navya and Keolis had the required state license and federal approval to test the autonomous shuttle. The shuttle had built-in redundancies for, among other purposes, verifying its location and integrating its movement with traffic signals and other features along the designated route. An attendant was inside the vehicle and activated the emergency button moments before the collision. The autonomous shuttle decelerated and stopped. However, the attendant did not have easy access to the manual controller, which limited his ability to, for example, activate the horn—to more effectively attract the truck driver's attention. After the crash, Keolis implemented a policy to make

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[26] For further information on the pilot programs mentioned in this paragraph, see news articles about actual or planned projects in Las Vegas, on the Madison campus, in downtown Madison, at National Harbor, in Sacramento, and in Washington, DC.

[27] *Federal Register* 83, no. 196 (October 10, 2018): 50872. According to NHTSA's notice, "high driving automation" means a vehicle can perform most aspects of the driving task under certain conditions; "full driving automation" means a vehicle can perform all aspects of the driving task under all conditions.

the controllers more accessible. Attendants were to remove the controller from its storage space at the beginning of each trip and keep it available throughout the trip.

Pilot testing of highly automated vehicles on public roads is under way at various locations in the United States. The NTSB will monitor the development of those vehicles to better understand their potential safety impacts and any unintended consequences.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision between the truck-tractor and the autonomously operated shuttle in Las Vegas, Nevada, was the truck driver's action of backing into an alley, and his expectation that the shuttle would stop at a sufficient distance from his vehicle to allow him to complete his backup maneuver. Contributing to the cause of the collision was the attendant's not being in a position to take manual control of the vehicle in an emergency.

Report Date: July 8, 2019

For more details about this accident, visit the NTSB public docket and search for NTSB accident ID HWY18FH001. The docket includes such information as police reports, photographs, manuals, and interview transcripts.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, "accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties . . . and are not conducted for the purpose of determining the rights or liabilities of any person" (Title 49 *Code of Federal Regulations*, Section 831.4). Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code*, Section 1154[b]).
