Remotely-controlled docking and yard parking for large articulated vehicles (18-wheel tractor-trailers)

Patent Application for "Secure, Safe Remote Control Via Drone Imaging of Autonomous Articulated Vehicles (Tractor-Trailers), Delivery Trucks, Vans And Driverless Cars For Software-Driven Relocation, Loading/Unloading, Parking and Servicing in Confined Areas"

August, 2019

Patent Pending #62/783,482

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Version 1.90

Toward Level 5

"Driverless" or autonomous Class-8 tractor-trailers (aka "big rigs" or "18-wheelers") are in development now and safely road-testing in various states at **SAE Level 4**. With government sanction, they operate only on freeways and interstates with onboard, commercially-licensed “safety” drivers.

These tractor-trailers are being tested to eventually convey freight at **SAE Level 5** – safe, commercial operation (direct shipper to receiver) without the costs and Federal Hours of Service (http://tinyurl.com/jds4yko) restrictions of human drivers.

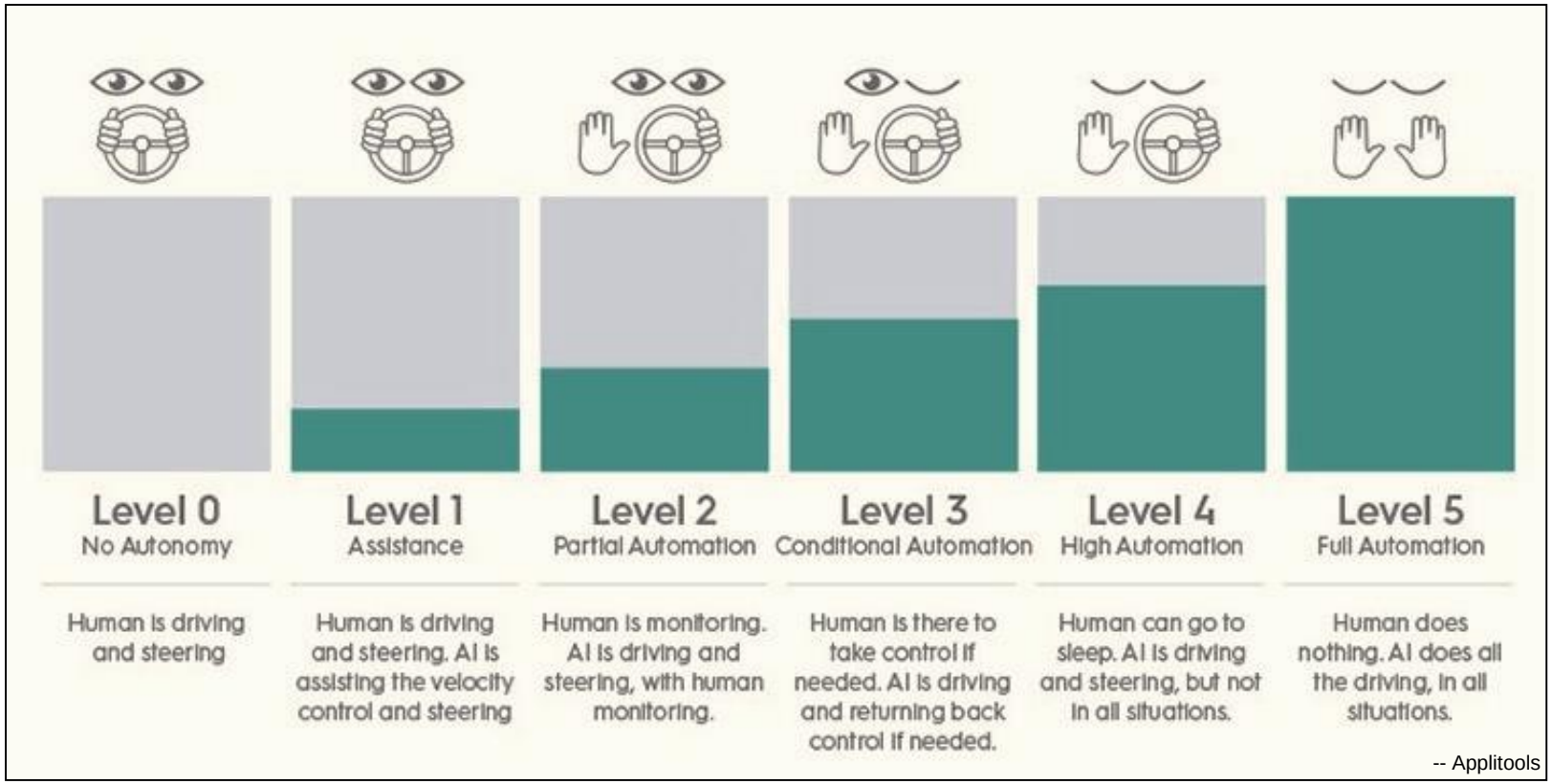
Current Level 4 technology limits autonomous trucks from safely maneuvering in confined areas for access to docks where their freight is loaded and/or unloaded -- the onboard driver must take control of the vehicle, backing the trailer into a dock or parking it in an assigned space.

To reduce costs, eventually eliminate the driver and operate the vehicle completely autonomously (transcending from Level 4 to 5 when proven safe and legal), the docking or parking procedure can be safely handled by a **remote** operator who is supported with drone imaging, custom software and high-speed telecommunication.

This drone and wireless software interface to the truck allows the remote operator to identify the parking place or loading dock which the vehicle must back into and commands the truck’s own self-driving components to safely do so. This technology is also applicable to automobiles and smaller Class 1-7, two and three-axle trucks.

Following is the solution to handling a fully autonomous Class-8 tractor-trailer at its shipper and receiver’s location.

Transitioning Driverless Vehicles from SAE Level 4 to 5



Society of Automotive Engineers Vehicle Automation Levels

http://bit.ly/saelevels

Startup Driverless Trucking Firms at, near or planning Level 4

	Videos/Articles
• TuSimple (San Diego, Tucson, Beijing)	http://tinyurl.com/y7u28rtq
• Daimler (Portland)	http://tinyurl.com/y3hamobz
• Kodiak Robotics (Mountain View, Dallas)	http://tinyurl.com/yb4tv895
• Pronto.ai (Bay Area)	https://youtu.be/XuOddn2gT08
• Ike Robotics (California)	http://tinyurl.com/y9r6aapa
• Starsky Robotics; San Francisco	https://tcrn.ch/2Wmpjxy, http://tinyurl.com/y85tr5g7
• Nuro (California)	https://nuro.ai/product/
• Waymo (Google)	http://tinyurl.com/y6cgxskn, http://tinyurl.com/yb43elao
• Volvo (North America)	http://tinyurl.com/ybx87qlo
• Plus.ai (California, China)	http://tinyurl.com/y575tk3x
• Einride/Ericsson/DB Schenker (EU)	http://tinyurl.com/yxfcpdc4
• Embark (San Francisco)	http://tinyurl.com/yaduvoh4
• Locomation (Pennsylvania)	https://youtu.be/RGJEymZ2dww
• Nikola Motor (Phoenix, said to be teaming with one of the firms above in 2019 per their CEO)	

"By the end of 2020 or early 2021 we think we think we can take the driver out of the cab on trucks," said Chuck Price, chief product officer of TuSimple. 5/2019

Why will Autonomous Trucking succeed?

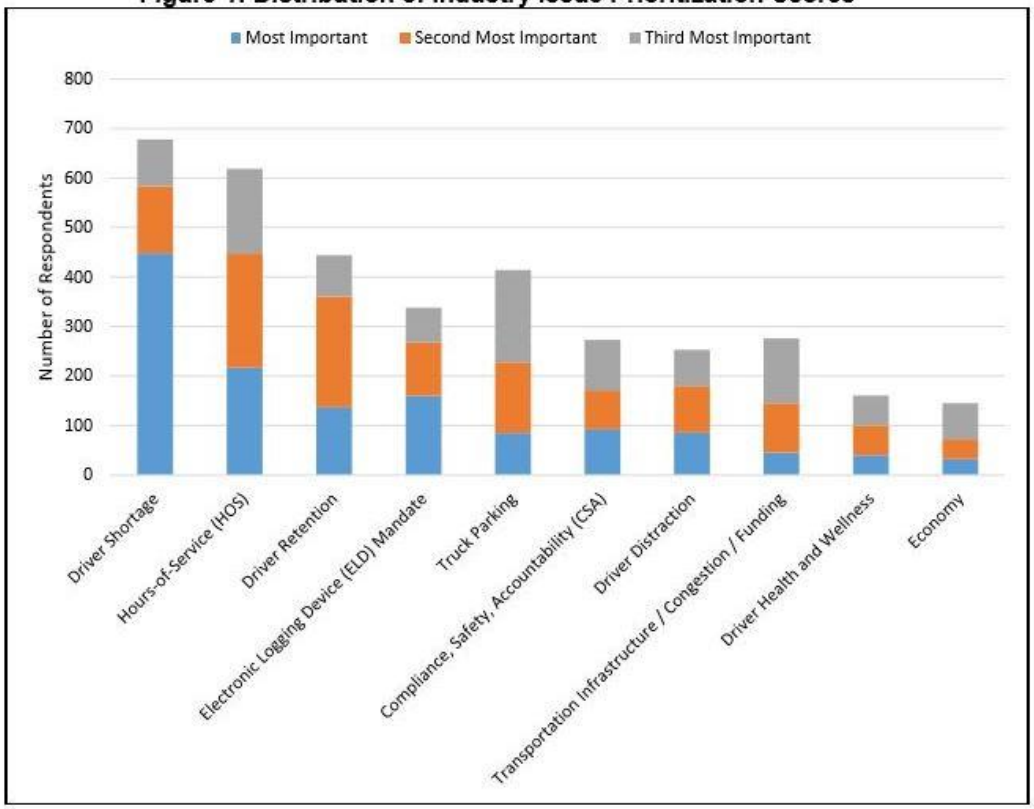
By 2030, autonomous trucking will dominate the truckload and LTL (less than truck-load) market for five essential reasons:

- Simple economics – removing the driver from of the **vehicle reduces operational costs by 40-50%,** and enhances fuel economy by eliminating the paid-per-mile model, allowing slower speeds within schedules.
  - Per TuSimple's CFO re. overall trucking industry financials, gross margins are said to be 15%, EBITDA said to be 7% (given labor costs of 40% and fuel costs of 30%). If drivers are eventually displaced and retired by SAE Level 5 fully autonomous technology, margins could improve to nearly or more than 50%!
- No driver means no US DOT/FMCSA Hours of Service regulations – the vehicle can operate 24/7 less fueling, inspection and maintenance time. Truck utilization can dramatically increase, from about 50 to 80% per TuSimple's CPO.
- Today's significant driver shortage will gradually diminish as retiring drivers (who average 54 years old) are replaced by automation. Millennials have not been attracted to low-wage, 24/7/365 nation-wide driving.
- 24/7 operations reduces the need for truck and trailer parking that's increasingly scarce in American interstate/freeway infrastructure.
- Power units (tractors) should be less expensive to manufacture when human factors need not be supported.

"When the vehicle can operate truly driverless, it will be much more efficient," said Chuck Price, Chief Product Officer at TuSimple. "We think we complete a coast-to-coast run in two days, where today it takes five."

Most Critical Issues in the ($700B) Trucking Industry - October, 2018 (ATRI)

Figure 1: Distribution of Industry Issue Prioritization Scores



Driver Shortage Ranked 1st 29%, Ranked 2nd 9%, Ranked 3rd 6% Total Share 39%. (Industry Concern Index 100).

The Driver Shortage, a perennial top industry issue, ranked as the industry's top concern for the second consecutive year in 2018.

Growing demand for truck transportation over the past year has exacerbated industry capacity constraints as carriers continue to struggle with recruiting and retaining a qualified truck driver workforce.

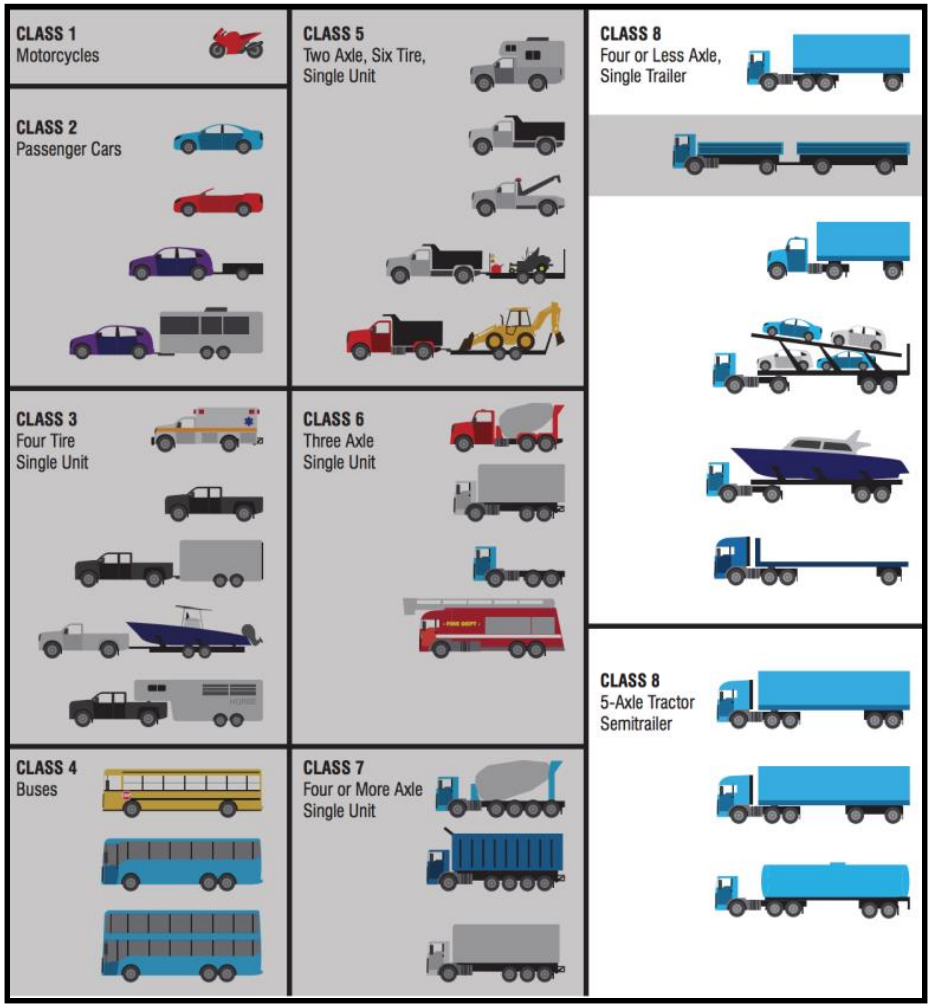
*The current driver shortage, which the American Trucking Associations (ATA) estimates to be over 50,000 drivers.**

Source: https://atri-online.org/wp-content/uploads/2018/10/ATRI-Top-Industry-Issues-2018.pdf

*Other estimates are closer to a 100k driver deficit.

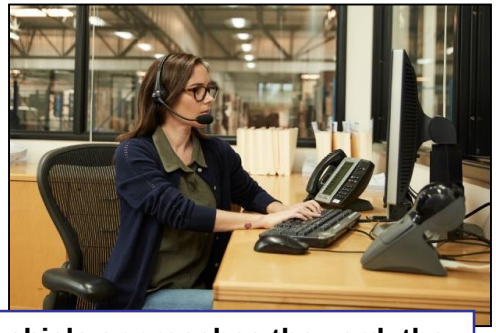
Truck Classifications

These methods, procedures and to-be-developed technology are primarily focused on Class-8 vehicles (3.6 million in 2016 per the ATA), however their application to smaller automated trucks and driverless automobiles is feasible.



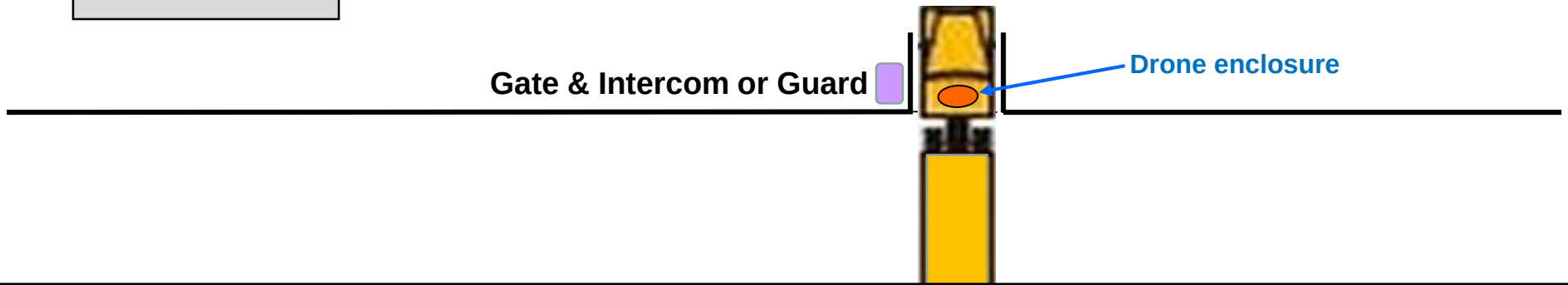
Everything You Need To Know About Truck Sizes & Classifications

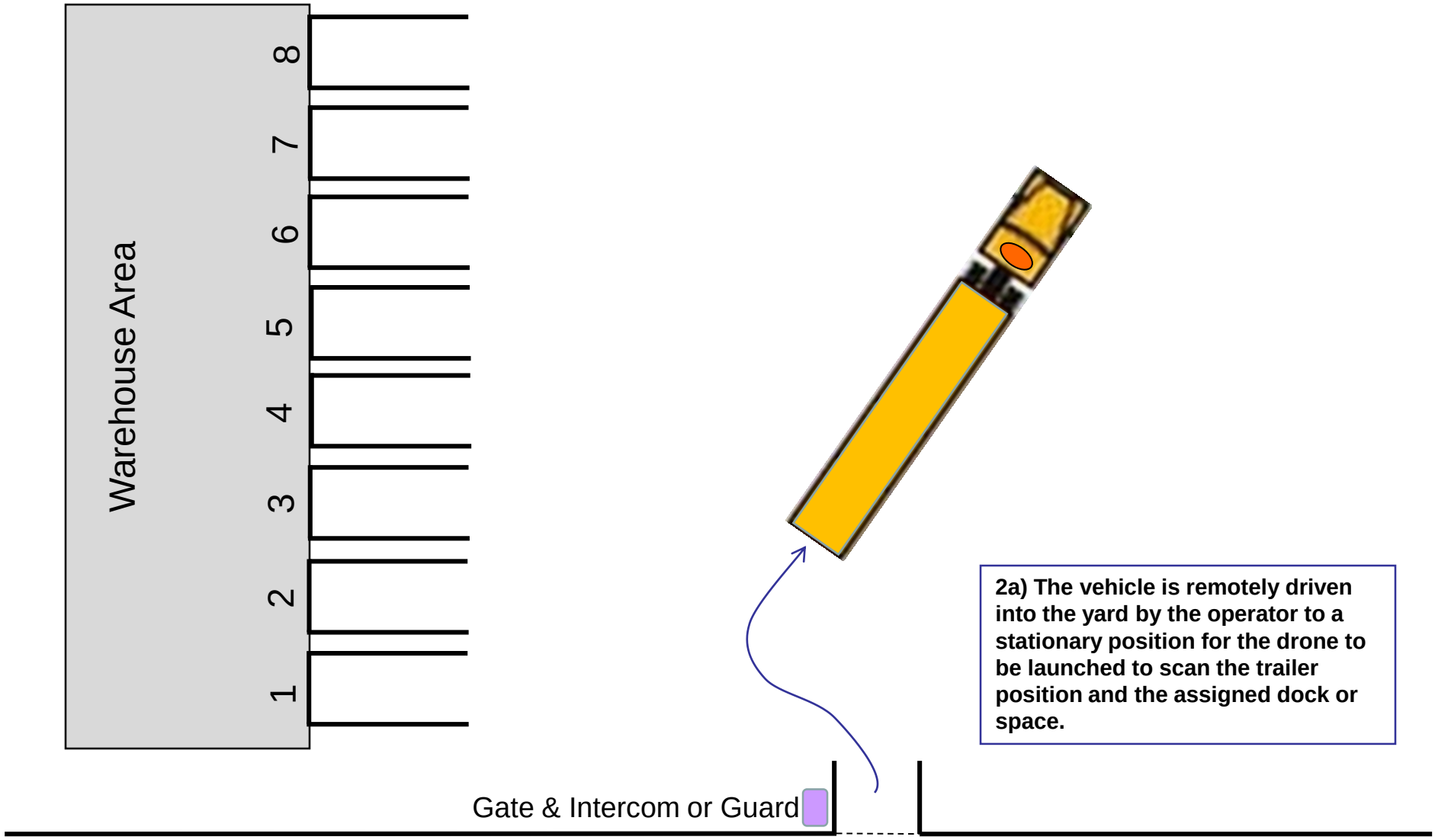
Step-by-Step Remote Docking Procedure



1) As the vehicle approaches the yard, the remote operator is aware via GPS and alerts yard personnel by phone or text that a) the vehicle is carrying an expected load per a standard Bill of Lading, b) needs access to the yard (if it is secured by a gate or guard) and c) instructions as to the disposition of the trailer (generally to back into a numbered dock or left at a parking location). The vehicle may also be pulling an empty trailer to be loaded.

2) Four-way flashers usually need to be toggled on for safety considerations. In addition to its throttle, steering and brakes, the remote operator will require control of all vehicle lights and its horn.




Warehouse Area
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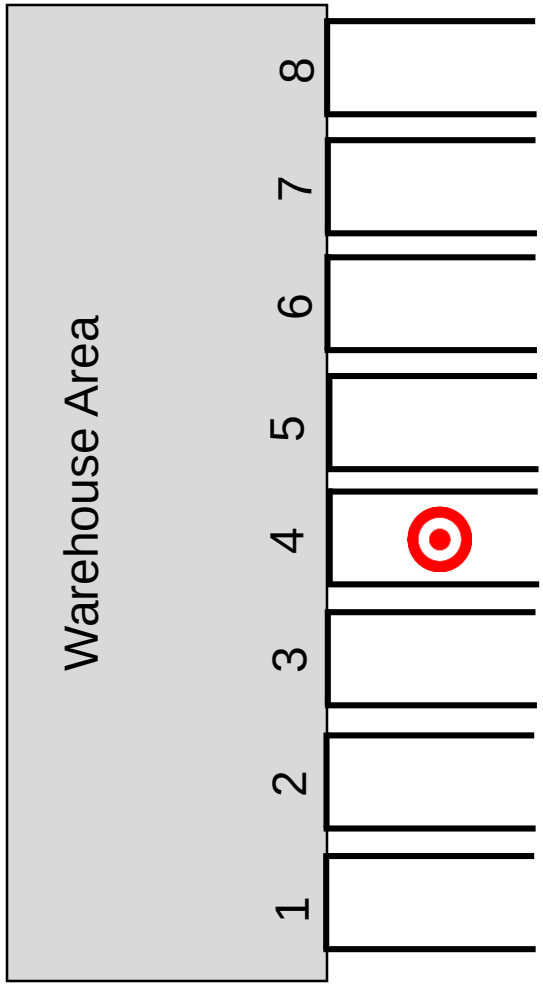
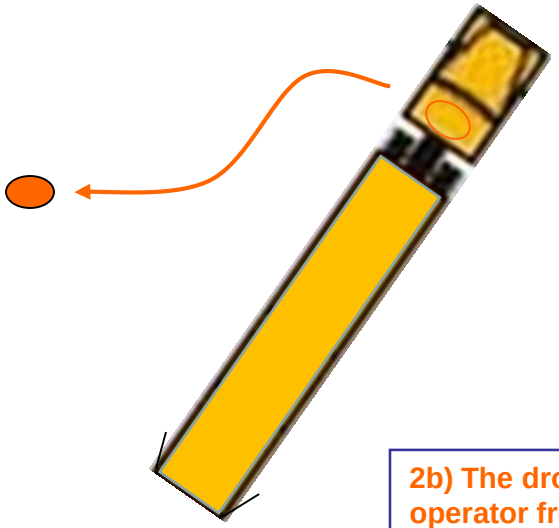
Gate & Intercom or Guard
2a) The vehicle is remotely driven into the yard by the operator to a stationary position for the drone to be launched to scan the trailer position and the assigned dock or space.

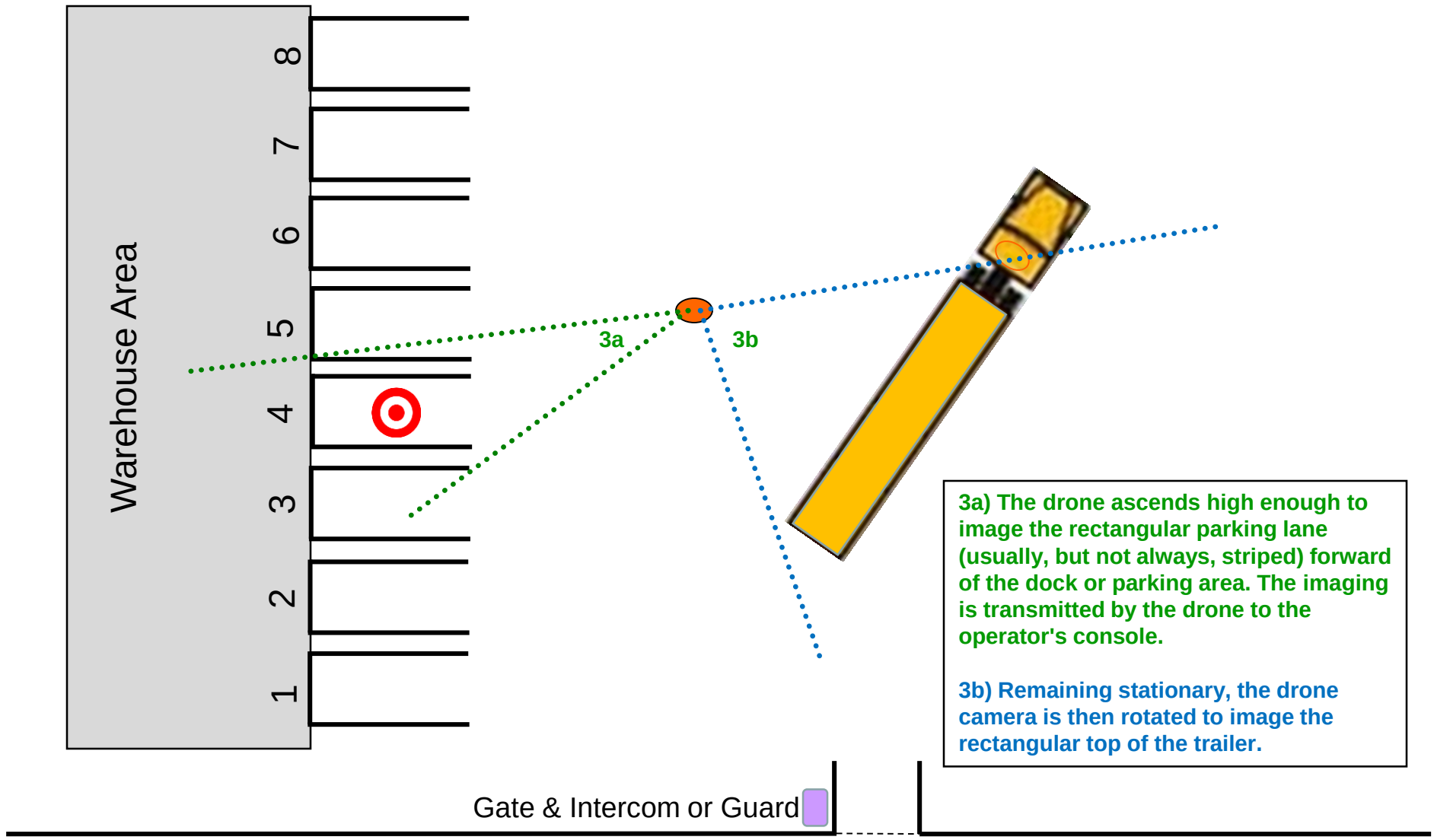
Note the docking procedure commences with the target in view from the driver's side of the cab. Only very rarely is a "blind back" approached from the passenger's side of the truck due to the driver's lack of vision to the space. This autodocking procedure will allow such a maneuver, greatly enhancing the flexibility of the vehicles, particularly in very tight and/or busy yards.





2b) The drone is launched by the operator from its locked, weather-proof enclosure on the top (or hood) of the tractor to locate the dock or parking location. In this example, the truck has been assigned to Dock #4 and its trailer doors would have been opened and secured.

Gate & Intercom or Guard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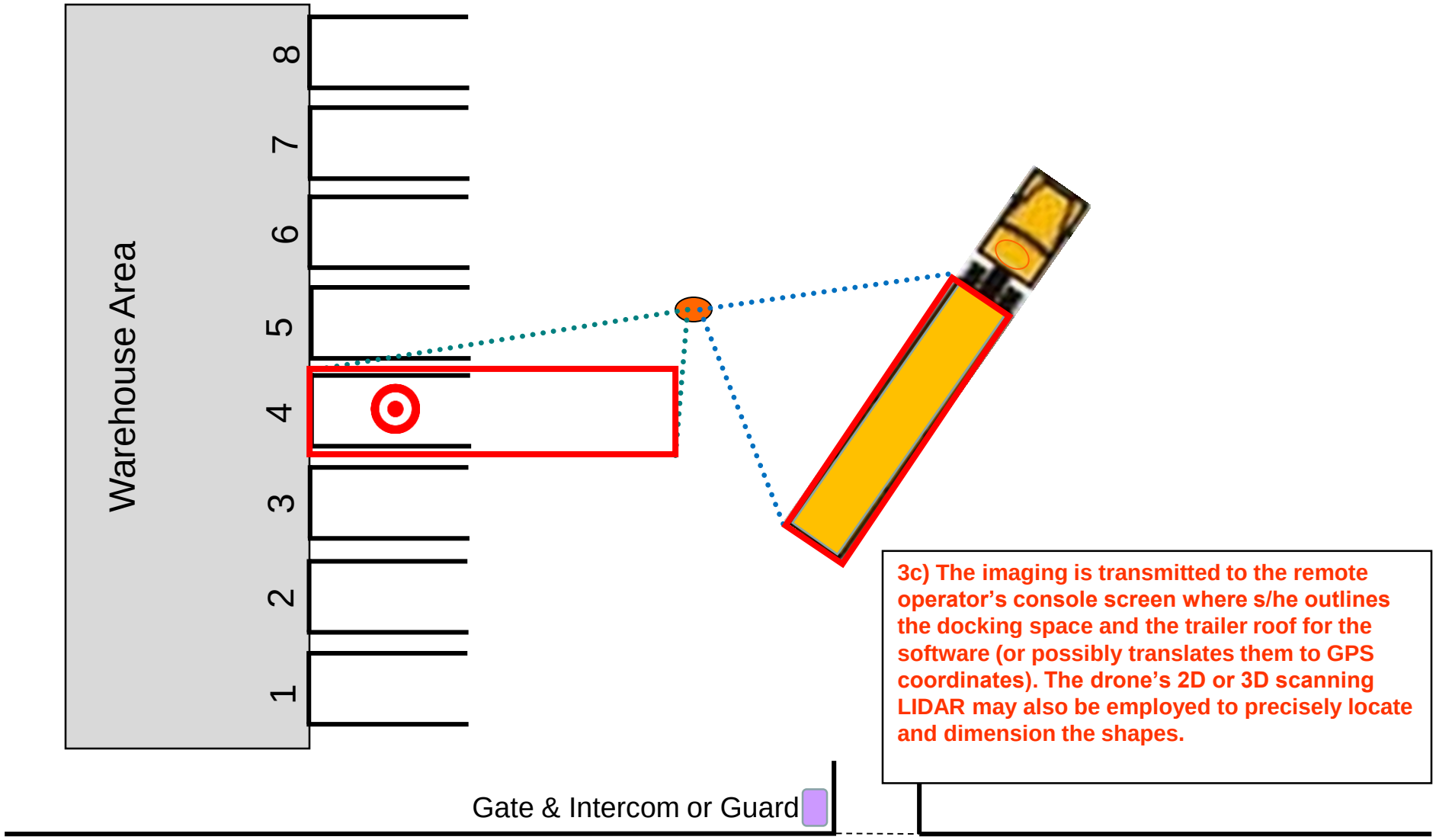
Gate & Intercom or Guard
3a) The drone ascends high enough to image the rectangular parking lane (usually, but not always, striped) forward of the dock or parking area. The imaging is transmitted by the drone to the operator's console.
3b) Remaining stationary, the drone camera is then rotated to image the rectangular top of the trailer.


Warehouse Area
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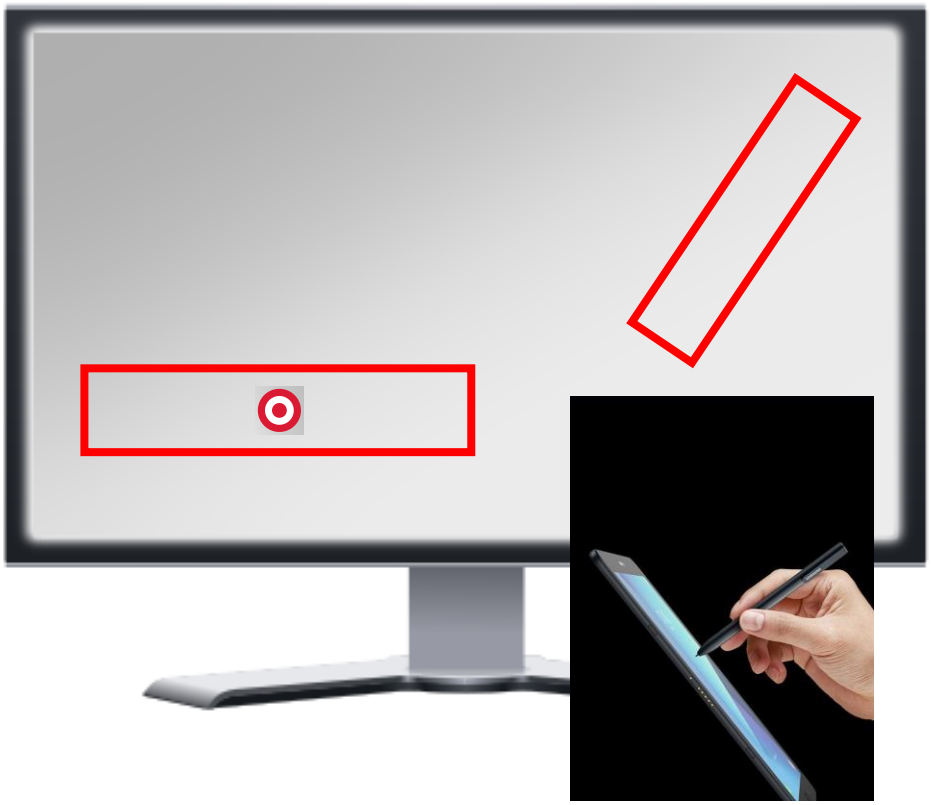
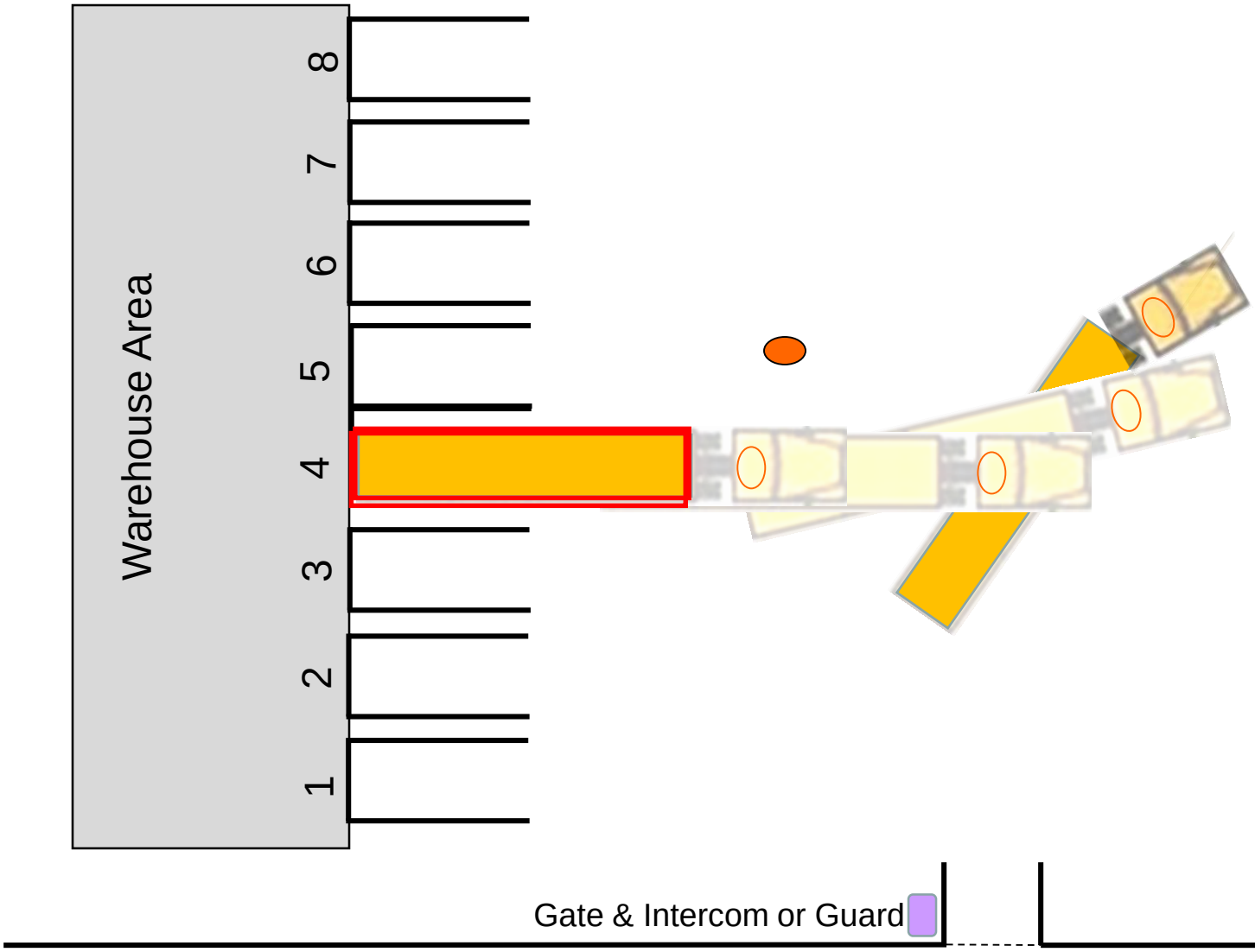
Gate & Intercom or Guard
3c) The imaging is transmitted to the remote operator's console screen where s/he outlines the docking space and the trailer roof for the software (or possibly translates them to GPS coordinates). The drone's 2D or 3D scanning LIDAR may also be employed to precisely locate and dimension the shapes.

Software Dimensioning and Route Mapping

With the drone stabilized in place and seeing both the rectangular space forward of the target dock or parking space and the trailer's roof, the remote operator might draw rectangles on the screen or a tablet with a stylus or mouse on her/his screen. The software interprets the relationship of the two rectangles either dimensionally or by their GPS or LIDAR coordinates. The software determines the path which the trailer must be forward or reverse guided by its tractor into the space, effectively overlapping the rectangles.

This path is transmitted to the truck as a command file (the positioning is not accomplished by the operator in real-time). The truck's guidance system then executes the command file slowly and under observation by the drone and operator should the operation require correction or need to be recalculated or aborted. The software will be designed, written and exhaustively tested -- first, on a 1/14th scale radio-control model and then on real trucks under controlled, safe conditions in unoccupied truck yards without competing traffic.

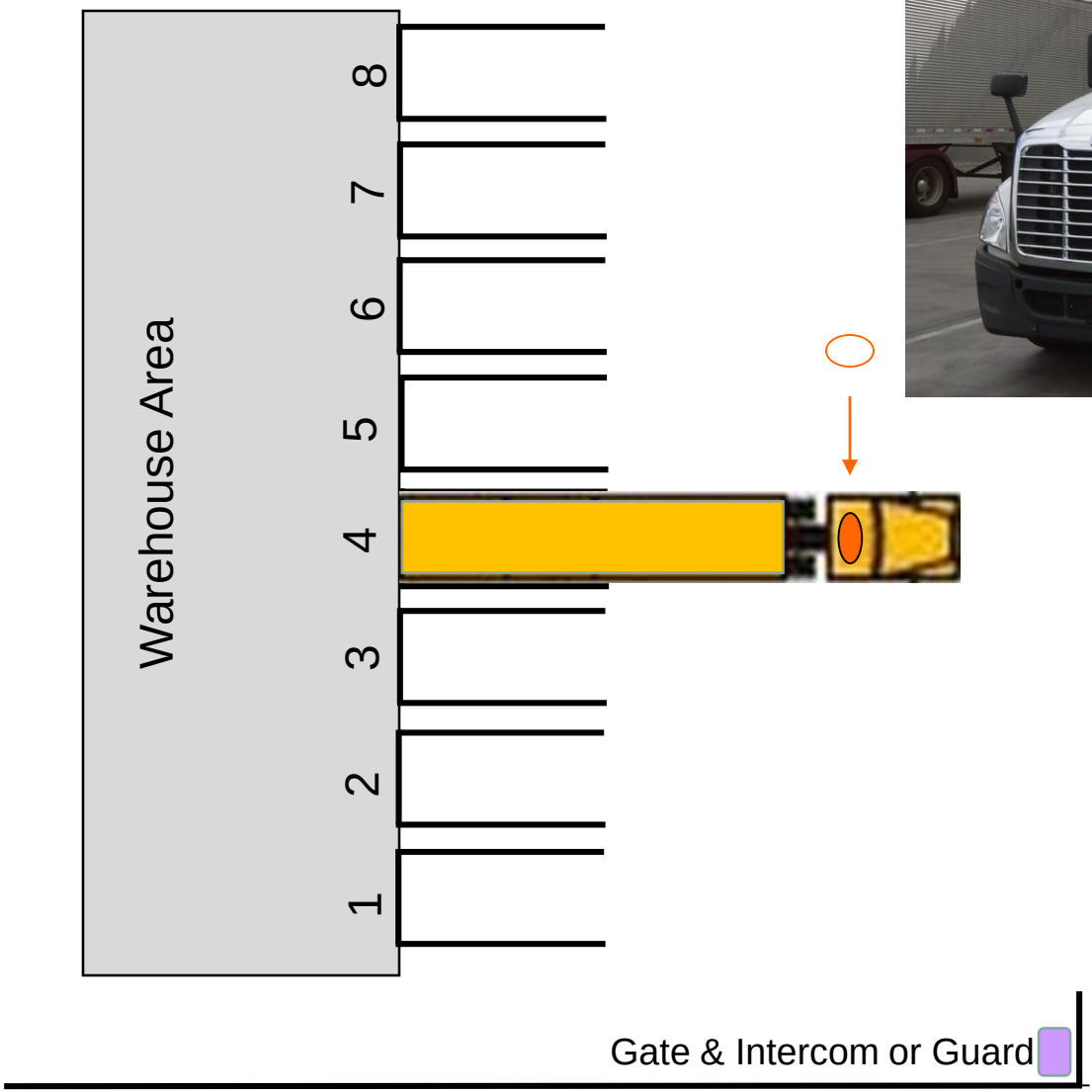




4) Backing a truck and trailer which can be up to 75-feet long and can weigh as much as 40 tons loaded is the most difficult skill to be mastered by a professional Class-8 drier.

There are two pivot points to consider – one at the fifth wheel and trailer king pin and again at the center of the dual trailer axles (aka the "tandems").

Wet or icy pavement is problematic. Yards may not be paved – dirt surfaces are common and can be slippery and rutted when wet.



5) Only after the truck is safely docked or parked is the drone returned to its enclosure.

6) When the remote operator is notified that dock personnel have finished unloading or loading the trailer, documentation will be exchanged by email, text or fax and trailer doors are closed. The truck may exit the yard to its next assignment or to complete its delivery.

7) It can be the case that a "drop and hook" is necessary. This is common for larger carriers where the trailer is uncoupled and left in a designated parking place in the yard for later unloading or loading. Another trailer belonging to the carrier is located on the yard, coupled (“hooked”) to the tractor and then taken to another destination. In this event, with no driver at Level 5, yard personnel will need to be engaged to physically couple or decouple the trailer, raise or lower its landing gear and disconnect or reconnect air brake hoses and trailer electrical cables.

Warehouse Area

8 7 6 5 4 3 2 1

Extreme, but common and workable, example parking situation

Trailer Parking

The control techniques illustrated here apply to any type of parking situation. Truck yards commonly have additional space for empty trailers or those awaiting loading or unloading.

Gate & Intercom or Guard

There will generally be a document exchange prior to the truck exiting the lot for its next destination (it may or may not be towing a trailer. It is also common for large truckload firms to exchange (swap) full trailers for empty ones, or vice versa.

Selected Training and YouTube Videos Demonstrating Tractor-Trailer Backing and Confined Area Maneuvering

- CR England Training - Proper Backing http://tinyurl.com/y7bt8tb2
- Alley Dock Backing - Tennessee Truck Driving School http://tinyurl.com/zwfmd6r
- Backing Up- Truck Driver Tips and Tricks http://tinyurl.com/ybg76esf
- Revised Alley Dock with pull-ups http://tinyurl.com/yb4u28km
- PARKING a TRACTOR TRAILER like a PRO! Tight Spot – Perfect http://tinyurl.com/ybyvc2dr
- Swift Academy Training -- Backing Tutorial http://tinyurl.com/ydhbhbvt
- Truck Backing3.mov http://tinyurl.com/jkk85r2
- Truck reverse CRE back http://tinyurl.com/y8uqzjsu
- 90-degree alley dock tandem towards the rear http://tinyurl.com/y8433nz6
- My Trucking Skills - Blind Side Back http://tinyurl.com/y7bpzb7z

- Semi truck parking – YouTube collection
  - http://tinyurl.com/ydhkrhhz

An excellent YouTube video via a Swedish PhD student
Illustrates the programmed movement of
an articulated vehicle: http://tinyurl.com/y3l5z28o

"GOAL" – Get Out and Look

Example aerial images of remote operator's console views

Under consideration: DJI Phantom 4 Drone

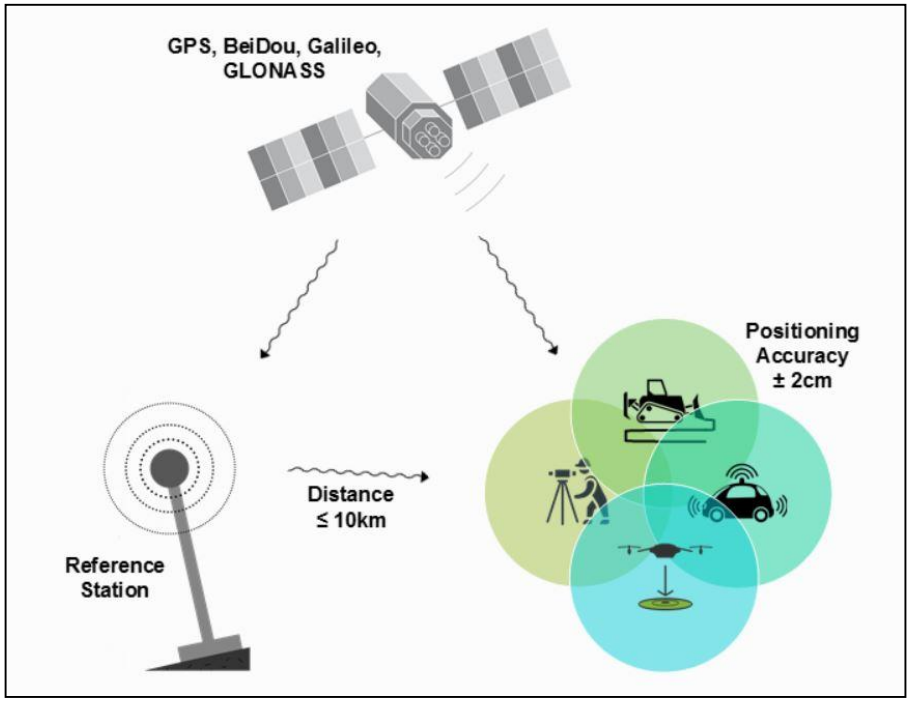
Pertinent Specifications

The DJI Phantom 4 Pro quadcopter is a serious flying camera capable of 4K video at high frame rates and extra-sharp 20MP stills at high burst rates. That's ground camera performance adapted to aerial videography and photography. The Phantom 4 Pro+ enhances control with an extra-bright 5.5-inch LCD built into the remote controller, eliminating the need for a connected smartphone or tablet. Both Phantom 4 Pros use a high-capacity battery for long flight time and advanced sensors for precise control over an extended range. The drone can also be mounted with a second sensor, e.g. 2D or 3D LIDAR.

Every Phantom 4 Pro offers:

- 30 minutes of flight time on one battery
- 4.3 miles of range
- Resistance to interference from 4G cell towers and WiFi
- GPS for precise positioning and return to previous location
- Five-dimensional sensing; four-dimensional obstacle avoidance
- Draw, which allows waypoint mapping
- ActiveTrack to recognize, follow and keep a moving subject in the frame
- TapFly, which directs the drone with a finger tap
- Safe Return to Home

Under consideration: Yuneec H520RTK via Fixposition



High precision

Our technology is able to provide high precision self-localization of any object in all outdoor environments. Combining satellite signals received on two or more different objects, e.g. provided by GPS, our algorithm offers you centimeter-level positioning accuracy even in obstructed environments.

High reliability

It is important to get a reliable positioning service to be able to plan safely. Our technology achieves high reliability using our novel RTK engine. Optionally enhanced by our highly reliable, fast and low power wireless communication technique, all major components for your high precision application are in place.

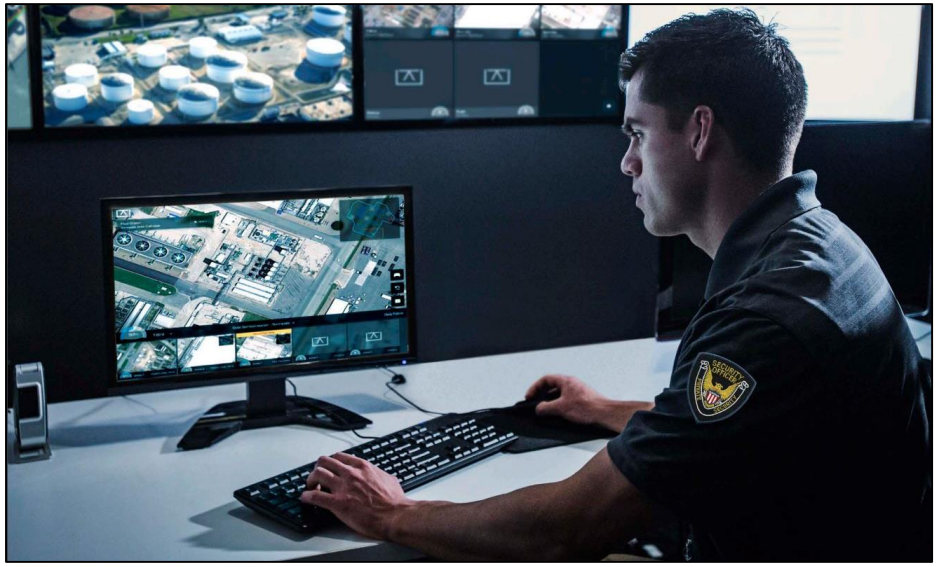
Low Latency

To be able to react fast, your device needs to know its position as close to real-time as possible. Our technology provides its high precision solution with very low latency and is therefore optimized for all moving objects even deployed in high dynamic environments.

Under consideration: Remote Operations Providers

- Nightingale Security (San Francisco)
  - Has FAA approvals to operate out of visual range, at night
  - Proven remote operations for drone flying
  - Proprietary drone enclosure unsuitable for application to heavy trucks
- Phantom Auto (Mountain View)
  - Video
  - Unproven with drones
- Designated Driver
  - Unproven with drones
- Scotty Labs (Menlo Park, acquired by Door Dash, 8/19))
  - Funded by Gradient Ventures, Google's AI fund

Phantom Auto Teleoperation

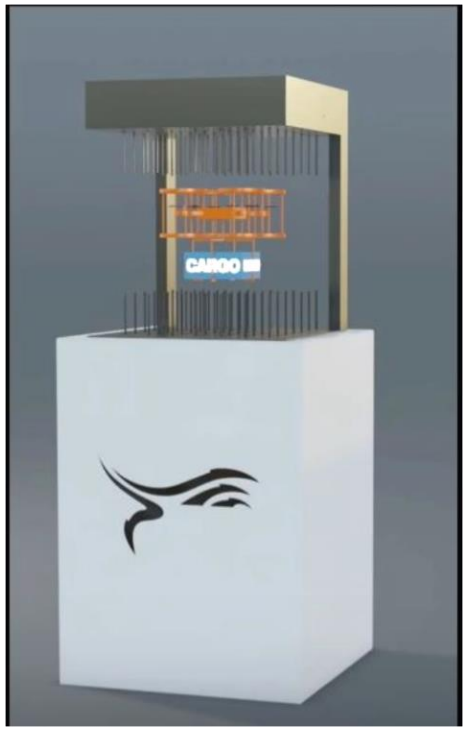


Nightingale Security Officer monitoring drone

Operator responsibilities for unloads, swaps:

- Advises receiving yard when X miles out, confirms appointment
- On gate arrival, exchanges Bill of Lading documentation
- Requests location to dock/park trailer
- Requests yard personnel to break seals, open trailer doors
- If necessary, yard personnel will adjust tandem axles
- Launches drone, monitors maneuvering to assigned dock/park space, retrieves drone to enclosure
- If 'Drop & Hook', requests yard personnel to uncouple trailer, requests location and number of next trailer to attach
- After cab's positioning at new trailer, requests yard personnel to couple, attach all hoses, raise landing gear
- Exits yard after inspection for next destination
- Can also proceed for contracted inspection, refueling
- Follows up with yard for satisfaction, any compensation due

Under consideration: Target Arm *Talon* Drone Launch and Recovery Platform/Enclosure



Talon Videos:

Prototype for military applications

Actual OTR Prototype Testing

Egg Shell Test "Breech" demonstration shows the capability of gently capturing a target object with no damage

Launch and Retrieve

7/16/18 News Release

Target Arm's ***Talon*** Drone Enclosure can be built into a Class-8 cab's rooftop air fairing and wired to its AC/DC electrical system. It will be remotely opened and closed from the stationary semi to launch and retrieve the drone (note the lightweight add-ons on the aircraft to protect the rotors) and inductively charge it. We anticipate the final prototype will be cylindrical for better aerodynamics. It is infeasible to mount the drone and enclosure on the trailer as they are not consistently mated with their tractors (i.e. they are often swapped or left behind). Neither is it feasible to mount cameras or sensors on trailers.

Competition?

In May, 2017, Tom Berg at TruckingInfo.com wrote of an Eaton project called it Auto Dock, though its official name is Dock Assist. It uses GPS locating with sensors on the tractor and a transmitter on the dock that tell on-board controls where to drive the truck. The engine, automated transmission and electric-over-hydraulic steering gear get instructions and maneuver the rig accordingly, and electronically controlled brakes (if the tractor has them) stop the rig as needed.

After a thorough patent search and careful research, no other solution for “autodocking” has been found. The Eaton solution was never placed in the market and was apparently dropped.

Its primary deficiency was likely the need for sensors at the loading dock – an impractical and expensive solution which, in practice, would have required such equipment at every dock in a shipping yard. **It is important, however**, that the vehicle was able to be controlled in 2017 such that it could be accurately guided to its target and caused no damage while backing at the referenced very slow speed.

Potential Other Uses in Trucking for Drone Videography, LIDAR & Still Imaging

- Scouting for parking places in yard or truck stop
  - Lack of truck parking is a significant national issue
- Vehicle Inspection (not to replace a professional driver's eyeball inspection)
- Locating empty trailers (a significant problem and time waster for large firms which seed trailers in customer lots)
- Accident, damage documentation
- Capture weigh station axles loads from outdoor displays
- Capture fuel price displays off interstates and at truck stops (ala Gas Buddy)
- Daily in-yard trailer inventory, asset locating, reefer status (e.g. temperature, fuel remaining)
- New driver training, safety instruction
- LIDAR sensing, mapping
  - Is mapping data or imagery marketable?
- Traffic analysis, reporting
- Marketing

Typical external Reefer Control Panel @ eye level with temperature display, start/stop controls

Situations where drone operation is inappropriate and/or unsafe

- Extreme wind, rain or inclement weather
- Near airports (where government restricted)
- Where otherwise illegal (although restrictions are relaxing)
- Near complete darkness
- Overhead power lines, cables
- Where not allowed per shippers, receivers, insurance issues
- No telecommunications, poor cellular coverage, lack of 5G?

Fact Sheet – Small Unmanned Aircraft Regulations (Part 107): https://goo.gl/LwCeFJ

The legalities re. operating drones outdoors are rapidly evolving as they're proving their value in inspection, life safety and delivery situations. We expect law will evolve to allow their remote operation as described here in a safe and professional manner. Note these recent news stories:

- Here's everything you need to know about Amazon's drone delivery project, Prime Airdhl drone.JPG — http://tinyurl.com/yc6luqr7
- Amazon's delivery drone team will like the sound of this significant FAA decision — http://tinyurl.com/y9ao8zxs
- How Delivery Drones Can Help Save The World (Forbes, 2/2018) — http://tinyurl.com/y9tqplds
- Uber Ambitiously Eyes 2021 for Food-Delivery Drones Launch — http://tinyurl.com/y9tqplds
- FAA Proposes More Commercial Drone Operations at Night and Over People (1/14/19) — http://tinyurl.com/jcc7hum
- Amazon just got FAA approval to fly drones for deliveries (7/11/19) — http://tinyurl.com/yyb7mxlb
- With First-Ever FAA Waiver U.S. Closes In On True, Commercial BVLOS Operations (8/14/19) — http://tinyurl.com/y6rn8qq5

Pertinent Other Information

- Tractors must have automatic transmissions (now common and dominating new truck sales)
- Backing “doubles” and “triples” (2x & 3x trailers) commonly used by FedEx, UPS, XPO, Old Dominion and SAIA is infeasible
- Tractors and trailers will likely require “calibration” – i.e. observation from the drone to precisely record and track turning while reversing. This capability will vary between tractor types and trailers due to minor variations in steering, suspension, wheel alignment and tire wear.
- Rollup trailer doors (common to grocery deliverers) could be motorized and remote controlled to eliminate the need to manually open, close and lock them.
- To overcome current FAA stipulations that the drone must be in sight of the operator, it may be feasible to share its video or still imagery to PCs or tablets at the shipper/receiver with the potential of aborting the backing or parking operation. The FAA has made exceptions to these rules for stone drone security firms.

Supplemental: FAQs I

- **Why can not autonomous semis dock or park themselves?** Docking and most ordinary parking requires the vehicle and trailer to, usually, be *reversed* into a space. Autonomous truck video generally looks only forward or to the sides. A camera or sensor looking to the truck's rear is not sufficient to see *all* that's necessary to safely move the vehicle to a space, and when the trailer begins to turn, it immediately blocks a side camera's view of the target. This rearward movement must also be very precise as the trailer is being guided in a manner similar to pushing child's wagon backwards, but a higher degree of accuracy (in inches) is required.
- **Would cameras mounted on the trailer be adequate?** No. In the trucking business, trailers are treated like red-headed step children. They are simply dumb boxes – relatively inexpensive assets with no onboard power or intelligence. Mounted cameras require connection to the tractor's computer by cable for power, and would need frequent alignment and protection from theft. Trailers are often swapped and left idle for days or weeks at a time, then not utilizing any attached hardware and exposing it to damage or loss. Trailer cameras would not have the perspective required that an aerial drone provides.
- **Why not use cameras at the docks themselves?** Each dock would require at least one camera – thousands of them would be required with adequate connections to servers for every shipping yard wishing to accommodate Level 5 trucks. There is no incentive for the yard owner or operator to do this. Installation, communications, maintenance and alignment issues would be significant, especially in inclement environments.
- **Why a Drone?** The software we're developing must have visual or sensor references to the 1) location of the truck's trailer and 2) the target dock or parking place it is to go. As it is not fixed, the drone camera can be maneuvered per the truck's position and its destination to place both locations in view from its aerial perspective dozens or more feet above. Software then plots the path the vehicle must be steered to overlap the objects. This imaging cannot likely be accomplished from fixed-position cameras, or from a telescoping mast. We expect the drone must fly 100 or more feet above the objects. It would likely support a zoom camera for maximum flexibility.
- **Does the operator remotely drive the vehicle?** Not necessarily. Docking/parking is accomplished by the vehicle's onboard guidance software and its interface to the tractor's steering and braking components in either real time or by sending its computer an executable file with computed vectors and distances. Once the docking/parking maneuver is underway, the drone operator will continue monitoring the vehicle and its surroundings for people and other vehicular traffic. The operator is not anticipated to need a simulated steering wheel, accelerator, transmission shifting or braking controls, but will need control of the truck to possibly enter and exit the yard and move it to temporary positions.
- **Drone aircraft are heavily regulated by the FAA. What issues does this cause?** A number. The operator will likely need to be licensed (not difficult or costly). However, the FAA *now* requires the drone operator to be visually in-sight of the aircraft. We believe that sufficient testing of the concept will allow a future exception to this Regulation – especially as very large firms like Amazon are working with remote drone delivery operations (in Canada for now). The drones will also be operating over private property and might be geofenced to not cross its boundaries. Drone operations near airports may not be possible – the operator will be aware of locational issues with apps like https://www.airmap.com/.

Daimler Freightliner "Level 2" Cascadia announced 2019

Supplemental: FAQs II

- **Isn't this risky?** Perhaps. Most truck and trailer accidents (+90%) occur in constrained areas like truck stops and parking lots per the firms we've driven for – in their training, backing and yard maneuvering are stressed far more than OTR (over-the-road) driving.
- **Could the drone be operated from the shipping yard?** Yes, only a high-end, dedicated PC with the software, flat screens and proper communications capability is required. The operator will need to be an FAA licensed drone operator and trained in the application. This is unlikely to be cost-justifiable for the average yard and until Level 5 vehicles begin to dominate truck traffic.
- You've diagrammed operations on a dual-axle (10-wheel) power unit with a sleeper and a 53' trailer. **Is there any difference in using a short wheelbase day cab (no sleeper) and a 53' reefer or even shorter trailer or flatbed or tanker?** No, as long as both the trailer and the target location it is to be placed can be scanned by the drone. The tractor will always carry the drone onboard, in its enclosure, and not on a trailer. There also would be no issue in parking just a tractor (aka a "bobtail") using its drone.
- **How long should a docking or parking procedure take?** Likely not much longer than it takes a skilled professional driver, especially with 5G communications. Flight and hover time for the DJI Phantom drone approximates 25-30 minutes – more than enough time to safely dock the vehicle. The drone will be inductively charged in its cab-mounted enclosure.
- **Will a remote operator always be required?** Predictions for complete and safe 'hands-off' Level 5 truck operations range from five to 10 years, so the answer today is *probably.* Insurability and the government will dictate this as much as technology. L4T could also operate remote docking/parking as a 3rd-party service as it will for its own Class-8 fleet. From a financial standpoint, the retirement of the truck's driver is the long-term goal here, saving far more than the cost of a remote operator
- **How will government react to autonomous trucking?** We believe more sophistication and liberalization of the law will overcome these restrictions over time given the very useful applications that are being developed for drones. Drone operators will likely still require FAA licensing. Generally, the US government has been amenable and willing (reference AV Start legislation) to accommodate truck automation as it promises significant improvements in safety (40k lives are lost annually on American highways), lessened property damage and diminished environmental impacts (e.g., a paid-per-mile driver will not drive at the most truck's most fuel-efficient speed (generally accepted to be about 45 mph). Importantly, said Chuck Price, COO of TuSimple in The Drive recently: "We mostly are working with individual states. States tend to compete with each other for business so they are motivated to work with autonomous technology companies. We're finding that there's a lot of positive movement at the state level," said Price. "We've also found that the federal DOT is actually quite supportive and positive. There are certain non-governmental organizations that have put up some resistance to autonomous trucks." We suspect the latter comment may refer to unions (about 17% of American drivers are unionized).
- **Will 5G Wireless be necessary?** It certainly won't hurt, but it's improved latency isn't necessarily advantageous as the two objects we're trying to overlap with software aren't moving when their imaging occurs. Here's a good reference from Axios: 5G investment needs to scale up for AVs to reach full potential. Per this article, 5G will required 400K new towers, so we'd think this an opportunity for shipping yards to lease space for transmission towers as well.

TuSimple is operating manned Level 4 trucks now in limited commercial service

Supplemental: FAQs III

- **Where is Tesla re. autonomous trucking?** Tesla has announced their fully electric Semi power unit (tractor) and has been testing it, mostly in the Bay Area and hauling freight to/from its Nevada battery plant. We follow them closely, but there's been no strong indication that they'll offer any automation beyond what's currently available from other manufacturers; e.g. lane keeping, collision avoidance, adaptive cruise control, etc. To our knowledge, they've not produced any Level 4 technology for their recently announced semi-truck (which has no delivery date). A video is found here.
- **What is the potential market for this concept?** Please see Slide #28. FreightWaves, "the leading provider of news, data, and commentary for the freight market", references the NHA and NHTSA as counting ***3.8 million Class-8*** tractors in the US. The potential of driverless tractors seems to indicate that any of these trucks having automatic transmissions might be converted to autonomous hardware and software as the current developers have already accomplished (Slide #18). Tractors with manual transmissions cannot be automated, and have rapidly lost market share as automatics are proven to deliver 10-15% better fuel mileage and are far easier to drive.
- **Could the drone be launched and retrieved from inside the truck's cab?** That's an interesting idea and might be possible if the drone can 1) still be recharged in the cab and 2) reliably clear the power window on either side of the vehicle. The enclosure we've proposed might be eliminated in this case – it will likely need to be custom built and cost more than the drone. We're working on a design where a flat platform might be extended out the passenger window, and then launch, retrieve and charge the drone. We're also very encouraged that a Connecticut firm can supply a drone enclosure which can be mounted through the cab's top air fairing.
- **Can the tractor be either a "day cab" or a sleeper?** Yes. **Single or double rear axles?** Either and either. Driverless trucks will eventually require no cab at all (below). **Is there a preferred brand?** Yes, the existing driverless ventures (Slide #18) appear to use Peterbilt 579s. We are also impressed with Volvo VNLs are they're using very sophisticated automation technology (e.g. lane keeping, adaptive cruise control). Daimler Freightliner is also committed to autonomous technology and enjoys the largest market share for tractors in the United States (Slide #28). Daimler is fully committed to autonomous technology.
- **Could cameras mounted on the loading dock be enough to achieve automated docking?** Again, not likely, and in very large Amazon-like yards, dozens would be required. They would need to communicate a *standard* set of software instructions to any brand or fleet of trucks. And it's unlikely they'd have to necessary perspective of the yard and space to direct the truck, especially in reverse. PACCAR (Kenworth) has told us this has been unsuccessful in their trials of an automated docking procedure. See also the Competition slide.

Volvo "Vera" Cabless, Driverless Tractor

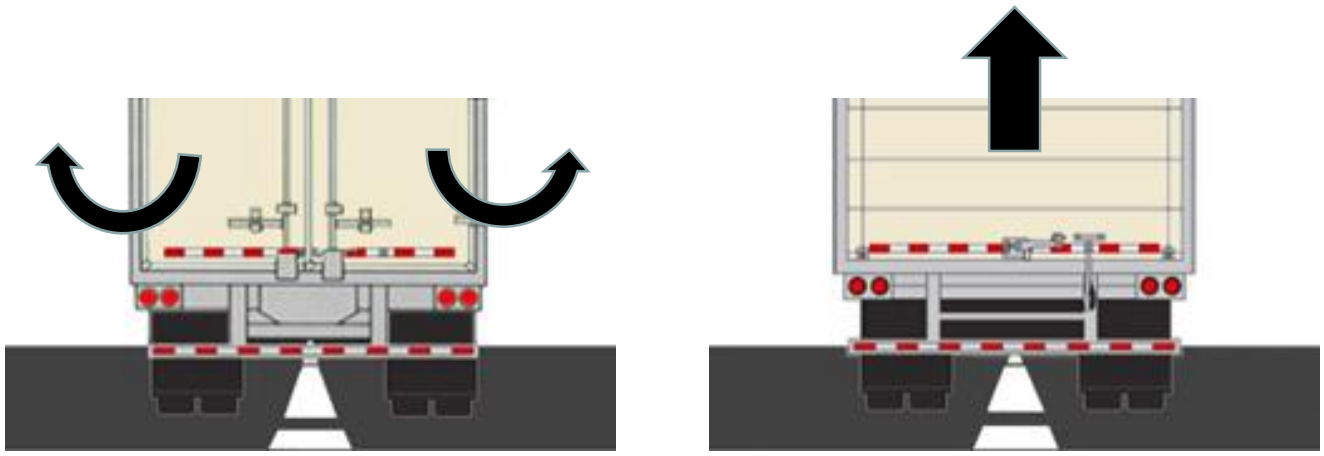
Supplemental: FAQs IV

- **Can the remote operator eventually be eliminated?** Yes, but we can't count on that for a number of years.
- **What about platooning?** We're not very interested in it as we don't see it makes much business sense. The technology is to be respected, but in practice, based on our years of Class-8 driving experience, multiple truck loads never go to the same place at the same time. A truck platoon is analogous to a freight train -- just as inflexible, but pulling less cargo (one railroad box car has about four times the dry cargo capacity of a truck trailer). Per Google, our American economy depends on trucks to deliver nearly 70 percent of all freight transported annually in the U.S. We'd argue that's because tractor-trailers get to the end-user far more efficiently than a box car. Neither do we see that touted 4% fuel savings from platooning will be significant to justify its use. All platooning trucks still require CDL drivers. However, there is excellent potential of our drone concept for a driverless platooned truck as it could *autonomously* leave the platoon and be sent directly to its receiver. The huge truck manufacturer, Daimler, will also not pursue platooning.
- **Will trucks drivers be put out of work?** Yes, over time. We believe with the enormous five to six figure driver shortage that's growing in the US, automated trucks will simply and *gradually* displace those open positions. Drivers average 54 years of age, so natural attrition will also displace them as they retire or leave the business. Further, millennials are not choosing driving, especially over-the-road -- as a profession as it's simply too low-paid, needs a 24/7 commitment and requires too much time away from home and family.
- **When will this tech not work?** Drone operation is currently limited by the FAA to daylight periods, yet many yards (particularly Amazon, UPS and FedEx) operate 24/7/365 – perhaps their external lighting would be sufficient for the drone and the FAA. Other potential FAA restrictions are covered elsewhere in this presentation.
- **Would a tethered drone work?** Potentially yes. We're researching the potential as there are no distance issues in flying the aircraft only above the truck and recharging would probably be unnecessary. A tethered aircraft might also be exempted from certain FAA requirements.

Freightliner Cascadia with sleeper unit, modern aerodynamic fairings, trailer skirts (mandatory in California for fuel economy) and long-mandatory rear "California bumper" to be prevent more serious read-end collisions

Supplemental: FAQs V

- **Will this system work for a flatbed trailer?** Yes, but flatbeds are never docked. They could be guided by a drone to a parking place if they're driverless.
- **Can the drone enclosure be mounted on the trailer?** No, for the same reasons that cameras should not be trailer-mounted. The enclosure could not increase the vertical dimension of the trailer (generally 13'-6") due to low clearance situations, and it could not be mounted on the front face of the trailer as it would likely interfere with the aerodynamic fairing atop the tractor cab and the refrigerator unit of a 'reefer' trailer.
- **Has automatic coupling and de-coupling of the tractor from the trailer been accomplished?** Jost International and Walmart are purportedly working on such a process, but very little is known about it. Called "automated drop and hook", the concept uses powered landing gear which would raise and support the trailer, would need to automatically connect and disconnect air, electrical cables and the 5th wheel. It would likely be very expensive and maintenance-intensive.
- **Are there any special advantages with the system for alternative fuel vehicles (e.g. natural gas, hydrogen, electrics):** None we can see, although refueling these vehicles at ordinary truck stops will be designed differently than the diesel stalls.
- **Is there such a thing as a *motorized* roll-up trailer door that can be remotely operated?** Yes, see Whiting Door and illustrations below. Another good video from TKO is here.
- **What else should we know?** Snow and ice will be a challenge for autonomous semis for some time. Traction will be unpredictable and not easily or safely handled by onboard computers or sensors. Winter weather often causes chains to be required – they are cumbersome and must be manually mounted and dismounted by an experienced driver. We see no way to avoid these conditions. One partial solution might be the use of Wavesense technology to monitor pavement conditions and cause the vehicle to be re-routed or temporarily placed out of service when road conditions are sensed to be unsafe.

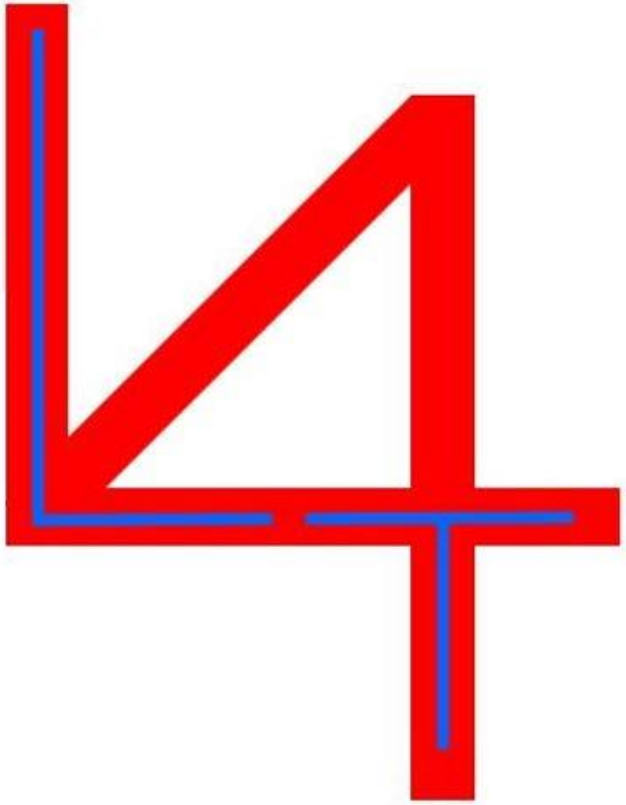


Via Whiting Door (http://whitingdoor.com/), swing doors on the left are extremely common and must be manually opened and secured. Roll-up doors on tracks (right) can be motorized and remotely opened and closed, particularly *after docking*..

Supplemental: FAQs VI

- **Your solution seems too ‘cut and dried’ – how do you completely eliminate the driver?** Slide 27 discusses those situations where a driver, OR a substitute for him or her is necessary to physically deal with the truck or its cargo. E.g., in a docking situation, trailer doors must to open before backing to a dock, and then closed when dock personnel is finished with it. Door seals must be checked and cut open, or applied. For the driver not be involved here, there are two solutions: 1) use a motorized rollup door when the remote operator can unlock, open and close or 2) involve the local dock personnel and cause them handle the doors before the trailer is docked.

Tesla Semi Concept introduced in 2018



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