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# **AUTONOMOUS TRUCKING: HOW DISRUPTIVE TECHNOLOGY WILL REDISTRIBUTE VALUE POOLS**

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# INTRODUCTION

In recent years the truck industry has experienced increasing pressure to change some of the fundamentals it had relied on for about one century.

**Climate change** requires turning away from fossil fuels, with the need to switch to zero-emission powertrains as quickly as possible. Connectivity and digitalization, which have been taken on rather slowly by the logistics sector, now enable a variety of new players and new business models to challenge the position of the incumbents.

Driverless operation is the most disruptive piece of this industry transformation. Autonomous trucking has long been a secondary field of action for car-focused tech players like Waymo and Aurora. In the meantime it has become common sense that autonomous trucking provides a more than tenfold opportunity compared to passenger mobility. It is the killer application of autonomous driving technology and the ultimate game changer for the whole trucking industry.

# BRIGHT PERSPECTIVES HAVE ATTRACTED BILLIONS OF DOLLARS

**The most** compelling argument for driverless truck operation is the severe driver shortage across the world. In the United States the gap is estimated to be around 80,000 drivers, and it will most probably double until the end of the decade. Autonomous trucking is the only sustainable relief for this bottleneck. 24/7 availability will boost capacity utilization of the installed fleet significantly. Moreover, enhanced fuel efficiency and unprecedented safe-

ty add to the benefits of autonomous trucks.

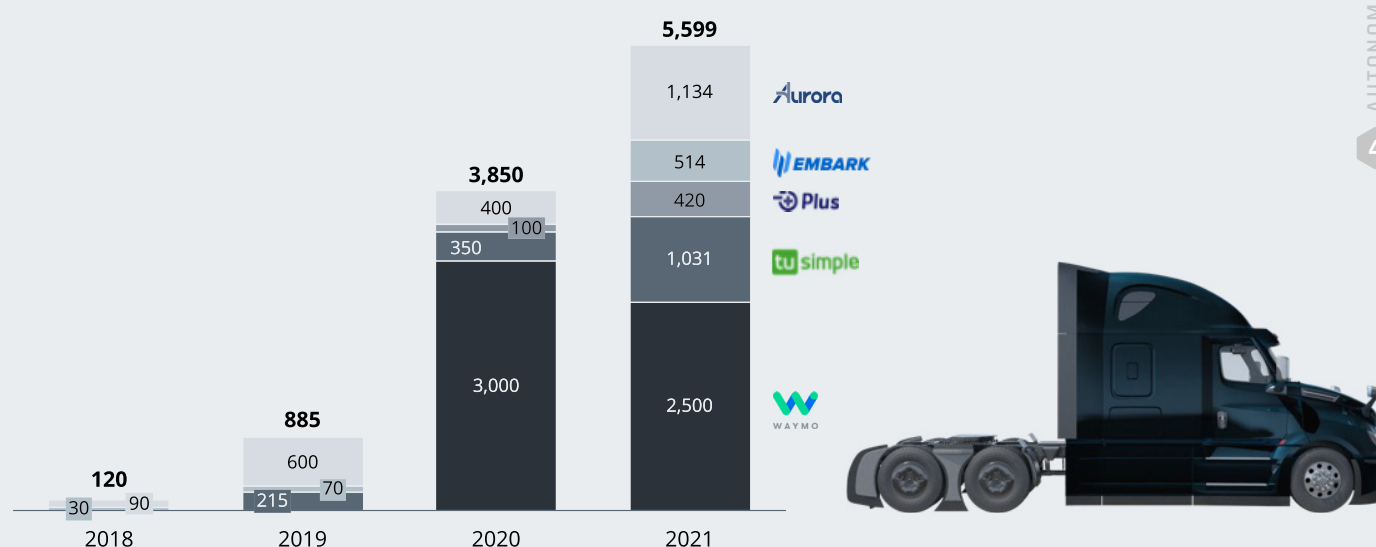
Those bright perspectives have attracted billions of dollars from various investors. The Top 5 autonomous trucking players in the U.S. alone have collected funds exceeding \$10 bn since 2018.

It is obvious that Waymo – being backed by parent company Alphabet – has by

FIGURE 1

## FUNDING OF THE TOP 5 AUTONOMOUS TRUCKING PLAYERS

In million USD



far the best starting position with regards to funding. Two private funding rounds of more than \$2 bn each in 2020 and 2021 plus additional \$750 mn from external investors set the clear benchmark. But since Waymo is deve-

loping autonomous cars and trucks in parallel, it is impossible to say which share of the funding goes to trucks.

The rest of the crowd went public in the course of 2021 – or at least tried to

do so in the case of Plus. TuSimple made the start with its successful IPO on Nasdaq in April, resulting in net cash proceeds of slightly over \$1 bn. Aurora and Embark both followed the SPAC path to public funding. Aurora merged with Reinvent Technology Partners in November 2021, while Embark chose a combination with Northern Genesis II which was executed only a week later. Plus had originally also announced a SPAC merger. However, the deal was called off because of regulatory consequences of the increasing rivalry between the United States and China. Essentially for the same reason, TuSimple has in the meantime decided to sell its China division.

To understand the dimension and impact of the \$5.6 bn funding that the autonomous truck startups have piled up during 2021, a comparison to the net

cash flow of the “Big 4” global truck players is insightful. Daimler Truck, Traton Group, Volvo Group and Paccar have altogether achieved \$7.0 bn cash from operations in their industrial business during that period. In other words: It would have required 80% of their cash flow to match the funding of the start-ups. Even though they wouldn’t need to provide the full amount in a single year, this is hard to imagine, given that they are struggling with the transformation from fossil to electric at the same time.

So autonomous trucking attracted significantly more funding than the “Big 4” could have provided. But how likely will investors enjoy appropriate returns in the future? And how have the valuations of their investments developed so far?



FIGURE 2

## INDEXED STOCK PRICE DEVELOPMENT OF AUTONOMOUS TRUCKING PLAYERS



Sources: finance.yahoo.com, Berylls Strategy Advisors

# AUTONOMOUS TRUCKING - BOOM OR HYPE?

**Looking at** the current valuation of the publicly listed autonomous trucking players is quite disillusioning. Compared to the Nasdaq Composite or the more industry specific Berylls LeanVal Auto-mobility Leaders (AUTO100) index, they have underperformed in a dramatic way.

Both TuSimple and Aurora share prices have soared after the public listing with peak prices between 70% and 80% above initial offering. But these initial gains evaporated quickly and the share prices continued to drop far below the IPO prices. In absolute terms, Aurora, Embark and TuSimple have lost a cu-

mulated market capitalization of \$14.8 bn since their IPO or SPAC merger. During January 2022 alone, their share prices dropped between 48% and 58%. At the end of the second quarter, they arrived at all-time lows.

So what happened to investor sentiment? Have they lost faith in the bright future of 24/7 truck operation at halved total cost of ownership (TCO)? Or have they just realized that the way to driverless operation is much harder and longer than expected? And finally, how would we assess the progress of the different tech players?

Performance indicators like R&D spendings in percent of net revenue cannot be applied for companies that don't achieve any revenues yet. And enterprise values based on planned revenues as well as more or less realistic multiples are – well, more or less realistic. So when it comes to hard facts, only one metric is absolutely incorruptible: cash out. In tech startups, cash out is closely linked to R&D spendings.

According to their 2021 annual reports, the three startups have spent more than \$1 bn on research & development. The corresponding expenses

induced cash burn rates of up to 35% of the cash available at the beginning of the year. The resulting cash runways are between 2.9 and 5.2 years. If access to cheap capital has now dried up, they necessarily need to go to market and quickly ramp-up operations and revenues, because otherwise they will run out of cash.

Investors should focus on the following questions: How big are the value pools that can be tapped by autonomous trucking? And what are the appropriate business models for sustainable success?

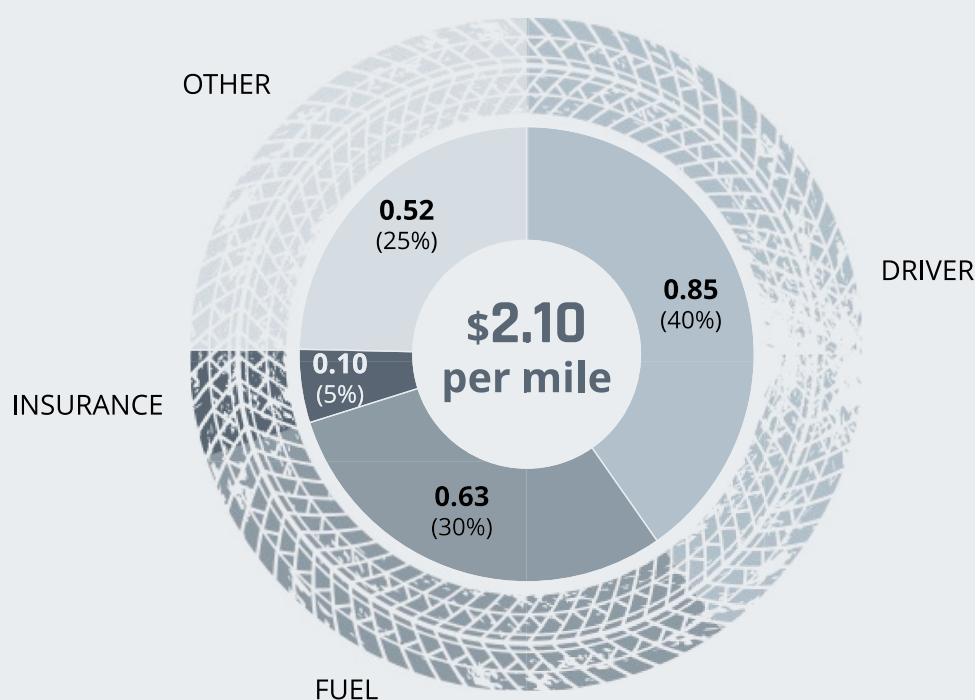
# CREATING VALUE WITH AUTONOMOUS TRUCKS

**Let's take** a look at the value pool that autonomous trucking provides in the case of a Class 8 heavy-duty vehicle. Based on the statistics of the American

Truck Research Institute (ATRI), we have projected the costs per mile into the year 2025, assuming Diesel will be at \$5.00 per gallon.

FIGURE 3

## COSTS PER MILE PROJECTION 2025, CLASS 8 HEAVY-DUTY LONG-HAUL TRUCK



Sources: ATRI, Berylls Strategy Advisors

The driver is by far the most expensive part! Including benefits, he will cost \$0.85 per mile by 2025, assuming linear extrapolation of the 3.9% annual cost increase between 2012 and 2020 (which is very conservative given the current inflation rate). Fuel will represent 30% of the total costs. This is the most volatile factor and might just as well be 25% (\$0.50 per mile) or 35% (\$0.75 per mile) three years from now. Insurance is the

third aspect being influenced by autonomous technology. More than 90% of truck crashes are caused by human factors, and insurance costs have increased by 4.1% annually over the last decade according to ATRI.

If we take the driver out of the equation, reduce fuel consumption by 10% and insurance premiums by 30%, we arrive at a potential reduction of \$0.95



per mile or 45% of the total. That's the value autonomous trucking will create. In absolute terms, applied on only 10% of the U.S. Class 8 truck fleet of 2.8 mn units, autonomous trucking will save \$25 bn every year.

How will truck operators benefit from this cost reduction? How much of the value pool will end up in the pockets of the autonomous trucking providers? And how will the truck OEMs participate in the game?

Truck operators will try to get the autonomous technology as cheap as possible, maximizing the net effect of the

cost reductions described above. They will benefit from competition between the various autonomous trucking providers. Medium term, we will observe not only a battle around the best technical solution, but also around cost competitiveness of the autonomous trucking system.

In our opinion, the fight for the value pool will mainly affect autonomous trucking providers and truck OEMs. The incumbents are under pressure from two sides: they must defend the potential to differentiate from competition technologically. Currently it looks rather as if the tech stack will be provided by the tech players, not the truck OEMs. Secondly, the incumbents must defend the access to their customers. That battle is primarily a question of the respective business models. Who will supply whom in the future?

# IT'S ALL ABOUT THE BUSINESS MODEL

**When looking** at the planned business models of autonomous trucking, two things stand out in particular: First of all, four out of five major tech players rely on subscription models and do not plan to sell their technology to their customers. They are directly targeting truck operators with what they call driver-as-a-service. Only Waymo is not yet clear about the intended business model and sees both OEMs and fleet owners as potential customers.






Secondly, the pricing the autonomous trucking providers are planning to implement, ranges from \$0.38 to \$0.65

per mile, which equals between 40% and 70% of the total value pool calculated above. The tech players are very confident to achieve gross margins around 80% and thus amortize their investments in a reasonable interval after go-to-market. Between \$0.30 and \$0.57 would remain in the pockets of carriers or shippers, synonymous to TCO savings between 14% and 27%. So autonomous trucking will be a win-win solution!

Let's take a closer look at the different players and the specifics of their business models.

FIGURE 4

## BUSINESS MODEL CHARACTERISTICS OF MAJOR AUTONOMOUS TRUCKING PLAYERS

					
<b>BUSINESS MODEL</b>	Driver-as-a-Service	Software-as-a-Service	Driver-as-a-Service	Capacity-as-a-Service	n/a
<b>SAE LEVEL</b>	L4	L4	SL4/L4	L4	L4
<b>VALUE PROPOSITION</b>	<ul style="list-style-type: none"> <li>» Increased operating hours</li> <li>» Driver access</li> <li>» Network efficiency</li> <li>» Safety</li> </ul>	<ul style="list-style-type: none"> <li>» Fuel efficiency</li> <li>» Delivery speed</li> <li>» Safety</li> <li>» Alleviated driver shortage</li> </ul>	<ul style="list-style-type: none"> <li>» Utilization</li> <li>» Cost efficiency</li> <li>» Carbon emission reduction</li> <li>» Safety</li> </ul>	<ul style="list-style-type: none"> <li>» Capacity increase</li> <li>» Safety</li> <li>» Higher fuel efficiency</li> </ul>	<ul style="list-style-type: none"> <li>» Safety</li> <li>» Greater efficiency</li> <li>» Reliable performance</li> <li>» Reduced costs</li> </ul>
<b>CUSTOMER</b>	Fleet owner/ operator	Carrier	Fleet owner	Carrier or shipper	OEM/fleet owner
<b>REVENUE MODEL</b>	Fee per mile	Fee per mile	Upfront + annual payment	Subscription fee or freight rate per mile	n/a
<b>PRICING</b>	\$0.45 – 0.65 per mile	\$0.38 per mile	\$30k upfront + \$35k – 50k annually	n/a	n/a
<b>USP</b>	Partners with Paccar and Volvo Group (~ 45% SoM)	Platform-agnostic approach, transfer hub concept	Collection of AD miles in commercial operation (SL4)	Autonomous freight network with own capacity offering	Unmatched autonomous driving experience

Sources: Investor Presentations, Company Websites, Berylls Strategy Advisors

# AURORA – DRIVER-AS-A-SERVICE OFFERING FOR PACCAR AND VOLVO GROUP PRODUCTS

**Aurora Innovations**, founded in 2017 by the former CTO of Google Self-Driving Cars, Chris Urmson, acquired Uber's Advanced Technology Group (ATG) in December 2020 and went public through a SPAC merger with Reinvent Technology Partners in November 2021. The Aurora Driver, a self-driving system that consists of sensors, software and hardware, can be integrated into the trucks of fleet owners.

Aurora offers driver-as-a-service including mission control as well as fleet management tools and physical services to carriers via a subscription model. The corresponding truck is provided to

the fleet owners by Auroras partners Paccar and Volvo Group, representing approximately 45% of the U.S. Class 8 truck market.

Together with partners like FedEx and Uber Freight, Aurora creates and implements the tools, processes, and operations to support a 24/7 logistics service, available 365 days per year. Only recently they partnered with Werner Enterprises, a premier logistics provider, with whom Aurora is hauling commercial freight loads on the 600-mile route between Fort Worth and El Paso, Texas.

# EMBARK – PROVIDING THE UNIVERSAL INTERFACE FOR A PLATFORM-AGNOSTIC APPROACH

**Embark Trucks** is a San Francisco based self-driving truck firm that was founded by Canadian computer scientists in 2015 and went public through a SPAC merger with Northern Genesis II in November 2021, just one week after Aurora. They provide platform-agnostic software-as-a-service for an expected fee of \$0.38 per mile directly to the carrier who owns the trucks.

Since carriers in the U.S. usually employ trucks from more than one OEM brand,

Embark tries to differentiate from competition through the Embark universal interface, which links a standardized package including sensors and the compute system to any OEM platform. This way, carriers will be able to adopt Embark technology across their fleets without modifying their acquisition strategy to unlock self-driving capabilities. Embark partners with DHL, Knight Transportation and Swift Transportation, claiming to have industry leading 14,200 reservations already today.

# PLUS – COLLECTING REAL-WORLD DATA BY SUPERVISED L4 AUTONOMY IN COMMERCIAL USE

**Plus** was founded in 2016 and has R&D offices and operations both in the U.S. and in China. The planned SPAC merger with Hennessy Capital Investment Corp. was ultimately called off in November 2021. There are rumours that an intervention of the Committee on Foreign Investment in the United States (CFIUS) was the reason behind this. The geopolitical rivalry between the U.S. and China increasingly limits the transfer of intellectual property between the two countries.

Plus has developed the autonomous driving solution PlusDrive in the versions SL4 (supervised level 4 autonomy) and L4 (level 4 driver-out autonomy). The SL4 driver-in solution is already being delivered to fleets and truck manufacturers and allows Plus to achieve

fuel efficiency gains before the driverless version is being commercialized. It powers the flagship product of FAW Jiefang, China's biggest truck manufacturer. This way, Plus can already collect real-world data in commercial operation to train and validate their L4 technology.

Unlike other autonomous trucking providers, Plus charges the customer upfront and asks for an annual payment rather than a fee per mile. Their SL4 business model also differs from the driver-as-a-service approach, as they are selling PlusDrive-enabled trucks in China and PlusDrive Systems in the United States. It remains to be seen if this go-to-market approach will be successful.



# TUSIMPLE – UNIQUE DUAL BUSINESS MODEL, FIRST TO ACHIEVE DRIVER-OUT OPERATION

**TuSimple was** founded in 2015 and is the only of the Top 5 autonomous trucking providers that carried out a successful IPO in April 2021. Their software and hardware solution was the first to enable level 4 driver-out operation in December 2021.

TuSimple offers capacity-as-a-service with two complementary products: TuSimple capacity or carrier-owned capacity. Their Autonomous Freight Network (AFN) is a unique approach, using shared capacity including terminals to cover transport demand at a \$/mile freight rate. They currently run a fleet of 100 self-driving trucks of which 75 are operated in the U.S. and 25 in China, fully owned by TuSimple.

Traton and their American subsidiary Navistar are partners and shareholders of TuSimple. Commercial production of Navistar trucks with TuSimple's self-driving technology will be launched in 2024. For Europe, the roadmap is still a bit fuzzy. Pilot runs with Scania trucks on Swedish roads are already ongoing. But a launch date has not been communicated so far.

Although their strategic partnership is clearly set, detailed interface definitions are still work in progress. Medium term, TuSimple is expected to pursue a brand-agnostic approach.

# WAYMO – FOCUSING ON TECHNOLOGY TO COMMERCIALIZE AUTONOMOUS FREIGHT MOVEMENT

**Waymo was** founded by Google as far back as 2009, but focused 100% on passenger cars until 2017. In March 2018, they started testing self-driving trucks in Atlanta under the program Waymo Via.

In 2020 Waymo entered a partnership with Daimler Truck to develop self-driving software for the Freightliner Cascadia. From the Daimler Truck perspective this is somehow redundant to the activities of their Autonomous Technology Group (ATG) with Torc Robotics in the tech lead.

Waymo follows a hardware & software sale business model, giving truck OEMs the opportunity to deploy driver-as-a-service for carriers and fleets themselves.

To get access to a broad network of carriers and logistics companies, Waymo partnered with major players like C.H. Robinson and Uber Freight. Together they explore how to integrate the Waymo Driver into supply chains and logistics platforms in order to commercialize autonomous freight movement.



# VALUE CREATION DEPENDS ON THE SPEED OF TECH DIFFUSION

**In recent** years the tech players were competing for funding, right now they are competing for autonomous miles driven as well as edge cases discovered and resolved. In two years they will be competing for fleets and trucks in commercial driverless operation and for freight to be hauled. Once the technology is mature, how quickly will its diffusion take place?

In our opinion, two major levers can be identified: first, technology push due to the continuous improvement of the tech stack and the expansion of the operating design domain (ODD). Secondly, the massive pull from truck operators due to the promised reduction of the total cost of ownership (TCO).

According to a Berylls survey, industry experts expect the market penetration of autonomous trucks to be around 10% in 2030. In absolute terms, this equals 20,000 – 25,000 new driverless Class 8 trucks per year, depending on the size of the total market (which is quite volatile). Self-driving trucks will first penetrate hub-to-hub transport. Later on, they will expand step by step into other applications as the operational design domain gets bigger.

Above we raised the question how truck OEMs will participate in the autonomous trucking game. We don't see them in the role of providers of self-driving technology, but as a key path to market for the tech players. To play this role successfully, they need to adapt both products and operating models to safeguard their current market position in long-haul transport.

# IMPERATIVE FOR TRUCK OEMS: THE SOFTWARE-DEFINED TRUCK

**In our view**, the software-defined truck will be the basis for the integration of autonomous driving functions into the vehicles. Truck OEMs must prepare their hardware and software architecture to cope with the strong technology push we expect in this area. Development times and product life cycles must be radically shortened. A decentralized architecture will no longer be sufficient for this.

We see two potential threats for OEMs here: Firstly, manufacturers might lose some of their control over the range of functions and thus their position as a supplier to fleets, as through autonomous driving a central application creating significant value for the customer comes from a third party.

Secondly, truck manufacturers face the risk of falling back technologically if they are too restrictive, trying to defend the sovereignty over the E/E architecture of their products. Yes, truck OEMs have decades of experience in developing motion control functionality. But they also have decades of experience in developing powertrain technology, which does not prevent startups from ripping Diesel engines and gear boxes out of the trucks and repowering them with battery or fuel cell electric technology.

So the incumbents better be humble and open to partnerships. But above all, they must adopt software-driven architectures and development cycles as soon as possible.



# CALL TO ACTION

We outlined in this paper that an enormous value pool will be created by autonomous trucking and how the redistribution of this value pool depends on various factors. The path towards driverless operation does not yet seem fully predictable. However, we believe that autonomous trucking holds huge opportunities for all parties along the transportation and logistics value chain.

In order to benefit from this disruption, we have identified the following need for action:

- Tech players need to **finalize** their **tech stack** and **prepare** it for **commercialization** as quickly as possible, as cash runways are not infinite and revenues will be needed rather sooner than later
- Autonomous trucking providers must finetune their **go-to-market strategy**, taking in-to account **value propositions** for truck **OEMs** and **fleet operators**, multi-channel sales as well as competitive pricing
- **Platform-agnostic** approaches will be effective in the long run, but short term could inhibit the rapid development of an operable service – it must be carefully evaluated whether the long-term benefit offsets the additional burden before go-to-market
- OEMs need to **adapt** their **hardware & software architectures** to prepare for the deep integration of autonomous driving into their vehicles – the software-defined truck is a long-term imperative, so “slice the elephant” and get started
- Truck manufacturers also have to define a clear **target picture** of their future role and **share** of the autonomous trucking **value pool** soon – new business models like driver-as-a-service or even transport-as-a-service need time for development

Autonomous trucking players have made significant progress based on the funding provided by their investors. The final sprint to driverless truck operation is a crucial phase – they must succeed to move from venture capital to customer revenues as source for future growth. Truck OEMs face an even bigger challenge, as autonomous driving is not just another component. It actually redefines the truck and will fundamentally change it step by step.

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