The evolution of automotive technology has consistently been propelled by advancements in racing car development. High-performance racing serves as a testing ground for cutting-edge innovations, which eventually permeate commercial vehicle manufacturing. For instance, disc brakes were first effectively utilized in racing by Jaguar during the 1953 Mille Miglia, leading to their adoption in production cars like the 1955 Citro¨en DS, thereby enhancing safety and reliability. Similarly, turbocharging technology, initially developed for high-performance racing applications, was later incorporated into consumer vehicles, exemplified by models such as the Porsche 911 Turbo introduced in 1975. This trend is evident in the realm of vehicle automation, where autonomous racing initiatives, such as the Indy Autonomous Challenge, are at the forefront of technological progress and influencing broader applications in autonomous vehicle development.

Global Autonomous Racing Research and Development Centers:

Several countries have established dedicated centers for autonomous racing car research, aligning their efforts with broader commercial vehicle development:

• \*\*United States:\*\* Institutions like the Massachusetts Institute of Technology (MIT) have active autonomous racing teams, such as MIT Driverless, which collaborates with industry partners to test autonomous technologies in real-world racing scenarios. These initiatives contribute to advancements in commercial autonomous vehicles.

• \*\*Germany:\*\* The Formula Student Germany competition includes a Driverless category, encouraging universities to develop autonomous race cars. This fosters innovation that aligns with Germany’s strong automotive industry.

• \*\*China:\*\* Chinese universities participate in events like the China University Student Electric and Unmanned Formula Competition, promoting the development of autonomous racing vehicles and supporting the country’s growing autonomous vehicle sector.

Formula Student Competitions as Catalysts for Autonomous Racing Research: Formula Student competitions have been instrumental in advancing autonomous

racing research. The introduction of the Driverless category has enabled university teams to develop and test autonomous race cars, bridging the gap between academic research and practical application. For instance, the MIT Driverless team, in collaboration with Delft University of Technology, secured third place in the Driverless category at the 2019 Formula Student Germany competition.

Taiwan’s Position and Proposal for Autonomous Racing Research:

In Taiwan, several universities have developed Formula Student Driverless (FSD) vehicles, reflecting a growing interest in autonomous racing. However, a dedicated research group focusing on high-speed autonomous racing has yet to be established. This proposal aims to create Taiwan’s first research group dedicated to autonomous racing, leveraging existing FSD initiatives to advance vehicle automation technologies and contribute to the global automotive industry. By establishing this research group, Taiwan can position itself at the forefront of autonomous vehicle innovation, fostering collaboration between academia and industry to drive technological

advancements in both racing and commercial vehicle sectors.

When the speed of autonomous vehicles increases, the challenges and requirements for their systems grow exponentially, distinguishing high-speed autonomous operations from their low-speed counterparts. High-speed scenarios demand advancements in perception, decision-making, and control to ensure safety, reliability, and performance.

Key Differences in High-Speed Autonomous Vehicle Operations

1. \*\*Shortened Reaction Time:\*\* - At higher speeds, vehicles have significantly less time to detect, interpret, and respond to environmental changes. For instance, a vehicle traveling at 100 km/h (62 mph) covers nearly 28 meters per second. This drastically limits the window for decision-making, necessitating ultra-fast processing and robust predictive models.

2. \*\*Extended Stopping Distances:\*\* - The stopping distance of a vehicle increases quadratically with speed due to the combined effects of perception-reaction time and braking dynamics. Autonomous systems must predict and preemptively act to avoid collisions, incorporating real-time data to optimize braking performance.

3. \*\*Enhanced Perception Requirements:\*\* - Sensors must operate at higher ranges and resolutions to detect objects and hazards early enough. However, challenges such as motion blur in cameras, reduced LiDAR efficacy at longer distances, and environmental conditions like rain or fog become more pronounced at higher speeds.

4. \*\*Complex Vehicle Dynamics:\*\* - The dynamics of a vehicle at high speeds are markedly different. Factors like aerodynamic drag, reduced tire traction, and centrifugal forces during cornering demand precise control algorithms to maintain stability and ensure responsive handling.

5. \*\*Uncertainty Amplification:\*\* - Uncertainties in sensor measurements, environmental conditions, and the behavior of surrounding vehicles are amplified at high speeds. Autonomous systems must incorporate probabilistic models to quantify and mitigate these uncertainties effectively.

6. \*\*Collaborative Maneuvers:\*\* - High-speed environments, such as highways or racing tracks, often involve multiple vehicles operating in close proximity. Coordination and collaboration between vehicles (e.g., overtaking or merging) require real-time communication and advanced decision-making algorithms.

7. Driver Behavior Prediction:\*\* - In mixed traffic, autonomous vehicles must predict the intentions of human drivers, whose reactions and decisions are less predictable at high speeds. For example, last-minute lane changes or braking by human drivers introduce additional layers of complexity.

8. \*\*Energy and Thermal Management:\*\* - Higher speeds demand more power, increasing the strain on battery systems in electric autonomous vehicles. Effective energy management and thermal regulation become critical to ensure system reliability.

9. \*\*Safety Margins:\*\* - Safety margins at high speeds are narrower, leaving little room for error. This necessitates robust fail-safe mechanisms, redundancy in critical systems, and continuous performance monitoring.

10. \*\*Regulatory and Testing Frameworks:\*\* - Existing regulations and testing protocols for autonomous vehicles are primarily designed for low to medium speeds. Developing and validating systems for high-speed operations require new benchmarks, specialized test tracks, and simulation environments.

Opportunities in High-Speed Autonomous Development

By addressing these challenges, high-speed autonomous systems have the potential to redefine transportation. From improved highway efficiency to enhanced safety in competitive environments like autonomous racing, these advancements will contribute directly to the evolution of commercial vehicle technologies. Developing robust solutions for high-speed scenarios not only pushes the boundaries of

autonomy but also establishes foundational principles that trickle down to everyday autonomous applications.