Crystal Group's Autonomous Vehicle Compute System Powers Through Challenging VSI Labs ADAS Testing Cases

The testing of ADAS and automated driving components requires technical competencies that range from vehicle systems architecture to software expertise. System architectures include physical systems as well as all electrical systems. On the hardware side, this includes the vehicle itself, its electrical systems, and the CAN bus architecture.

It all starts with the base vehicle. In VSI's case, this is a Ford Fusion hybrid electric vehicle outfitted with a by-wire interface to tap into the CAN systems including actuation of steering, throttle, and brake. Critical to this is an interface into the vehicle's CAN bus, as there is a lot of information from the vehicle that must be collected in the testing and tuning of ADAS and AD applications. Lastly, a power distribution system is necessary to support powered components including the main computer, sensors, modems, and switches.

At the heart of all ADAS and AD development systems is the domain controller, also known as the central computer. The central computer in a development vehicle like VSI's is no ordinary computer. For one thing, the computer must have a great deal of compute headroom to support network accelerators, GPUs, and storage. The compute load is very high on a development vehicle because the codebases are much heavier compared to a production application. Another requirement is the onboard storage and expansion interfaces as data recording and performance logging must be captured for post-run examinations.

In addition, the onboard computer's ability to operate in extreme conditions involving heat, shock, and vibration is also vital. VSI operates its vehicles in conditions from subzero to triple-digit temperatures, not to mention extreme dust, humidity, heavy rain, snow, and even high altitudes.

The durability of the onboard computer is pushed further by extreme duty cycles associated with ADAS testing. This involves frequent runs, and, depending on the test case, may involve hard braking and/or harsh vehicle maneuvers.

Over the past year, VSI has been using computers from Crystal Group to handle the extreme environmental conditions associated with ADAS/AD test and development.

Over this time, and some 25,000 miles later, VSI Labs has not experienced a single failure in its computer systems.

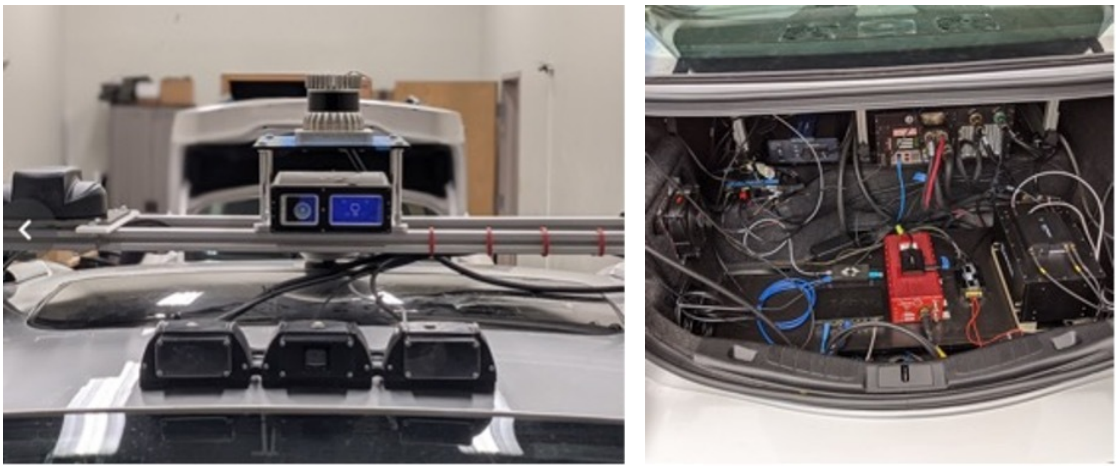
Caution: Challenges Ahead

In 2020, VSI found itself running ADAS applications on a consumer-grade PC in our research vehicle. The PC's compute power and storage solutions our engineers assembled were equipped with an Intel i7 CPU and NVIDIA 1060s/1080s GPUs. This was powerful enough to run ADAS applications, like object detection/tracking and perception software, LKA (Lane Keep Assist), AEB (Automatic Emergency Braking) and ACC (Adaptive Cruise Control), but the quality of the consumer-grade PC degraded over time and experienced many failures.

The root cause of these failures was typically the device being impacted by shock and vibrations from the vehicle during cross-country road trips in different environments and ADAS testing on test tracks.

The most vulnerable cause of failure was heat buildup in the trunk of the vehicle where the computer resides. Even when passive thermal management (i.e. fans and vents) was used, it was impossible to manage the heat buildup in the computer, which ultimately led to failure.

As we added more computing devices, peripheral devices, and cables to our main research vehicle, the small trunk of the sedan became crowded and exposed to many issues that compromised performance. In addition to overheating, it became difficult to manage power sources, stabilize their physical placements, and protect them from shock and vibration. This was a critical limitation for our compute platform, which constantly performs sensor fusion, data collection, and data processing in real time.



VSI Labs main research vehicle sensors; Vehicle trunk hosting a variety of devices

As an interim solution for thermal management, VSI engineers screwed holes in the back of the backseats and installed fans to flow the cool cabin air into the trunk while another fan circulated the warmer air from the trunk to outside the vehicle.

VSI had limited success with this passive thermal management; however, the other more significant challenges stemmed from the fact that the in-vehicle compute device couldn't handle the extreme operating demands and environmental variables.

Passive thermal management solution in the trunk

Transitioning from Consumer PCs to the Crystal Group AVC0161

As a leader in rugged, high-performance compute solutions, Crystal Group specializes in the design and manufacture of custom and commercial rugged servers, embedded computing, networking devices, and data storage for high reliability in harsh environments.

Upon partnering with Crystal Group, VSI engineers installed their AVC0161 system on one of our main test vehicles. The system includes a liquid reservoir, liquid cooling pump, and radiator that are all installed in the trunk of the car.

The Crystal Group AVC0161 solution (Source: Crystal Group)

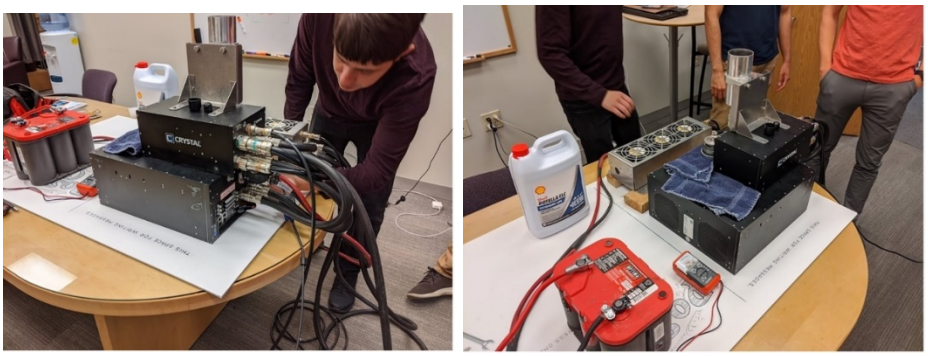
Compelling attributes of the system include liquid cooling options, low noise, reduced footprint and weight, increased processing, and 9V DC to 32V DC power. In addition, this rugged solution is designed, built and tested to withstand harsh environmental conditions, including potholes, collisions, and extreme temperatures that often cause traditional compute systems to fail.

Key features of the AVC0161 include:

- Rugged chassis: Constructed from strain-hardened, 6000-series aircraft aluminum, the chassis helps limit weight, improve thermal conductivity and vibration performance, enhance electrical conductivity for EMI, and is designed to meet military standards like MIL-STD-810, MIL-STD-461, MIL-S-901E, and MIL-STD-167-1.
- Advanced thermal management: To handle the thermal load, our computer from Crystal Group is water-cooled and supported with a coolant reservoir (swirl pot) that serves a closed-loop cooling system. A radiator pulls heat from the fluid while the pump keeps the water circulating.
- Power: Crystal Group introduced the world's only 12V DC, ATX-compliant server power supply that delivers 1,500 watts of power. This allows the system to run off the car battery, eliminating the need for a separate power converter.
- Shock & vibe: The system is designed to withstand extreme levels of shock and vibration, offering solutions that meet or exceed military specifications MIL-S-901E and MIL-STD-810.
- Noise reduction: The chassis reduces acoustical noise by balancing the fans to limit the amplitude of emissions and reduce structure-borne noise. This limits vibrations transferred from the fans and the power supply. These characteristics are critical in various military applications, including subsurface Navy operations.
- Processors & memory: The system has one Intel® Xeon® Scalable processor and two NVIDIA 2090Ti GPUs.

Set Up and Installation

Setting up the system was very easy. After attaching all the cables and hoses, we added the coolant, and then installed Linux and the VSI middleware stack.



Setting up the Crystal Group AVC0161

Installing the system into the car required some creativity as space is limited in the trunk of the vehicle. The main computer was mounted onto the rack while the pump was mounted to the main trunk deck. Finding a suitable place for the radiator was tricky, but we choose a location under the trunk deck. Lastly, the reservoir was mounted high in the rear passenger area on the deck lid.

Crystal Group's AVC0161 solution installed in the trunk of the VSI vehicle

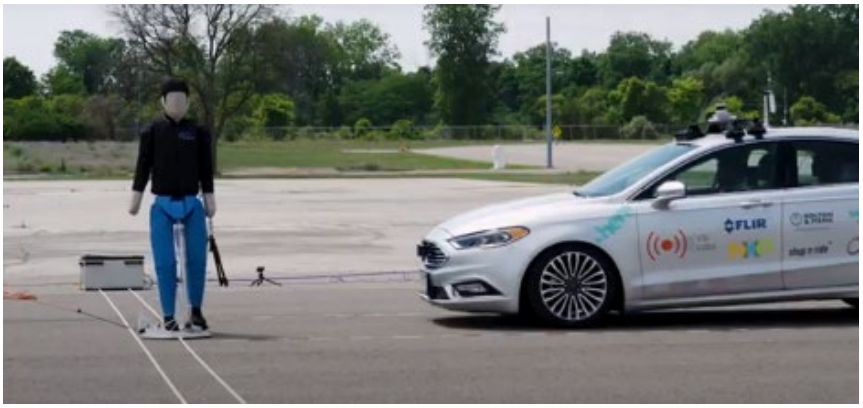
VSI Use Cases

As previously stated, VSI experienced multiple consumer PC failure events during prior cross-country data collection trips. One failure occurred on a 1,500+ mile drive to Las Vegas, Nevada, for the annual Consumer Electronics Show (CES). The consumer-grade PC was unable to withstand the shock and vibrations from the long drive and various environmental conditions, causing a GPU card failure. In addition, excessive heat built up in the trunk while driving through the desert, which forced our engineers to stop several times to cool off the PC.

One of VSI's first ADAS tests with the Crystal Group solution was performed at the American Center for Mobility (ACM) in Ypsilanti, MI. The three test cases that were implemented in our AEB testing were:

1. Car-to-Pedestrian Longitudinal Adult
2. Car-to-Pedestrian Far Side Adult
3. Car-to-Pedestrian Far Side Adult Obstructed

Each test was conducted during both daytime and nighttime conditions for six total test cases. There were five trial runs of each test case, totaling 30 trials.



VSI Labs AEB-P Testing at ACM (Source: Teledyne FLIR)

Testing Details:

- Testing location: American Center for Mobility (ACM) at Willow Run in Ypsilanti, MI
- Test course: Flat, broad expanse of paved road
- Testing velocity: 25 mph (40 kmph)
- Pedestrian target: Euro NCAP Standard Articulating Soft Pedestrian Target (SPT)
- SPT speed: 5 kmph
- SPT meeting point: 50% of the vehicle's width

We also followed the NCAP test protocols for each test case.

- Case 1: Car-to-Pedestrian Longitudinal Adult 50% (CPLA-50)
  A collision situation in which a vehicle travels forward towards an adult pedestrian standing facing the same direction as the vehicle and strikes the pedestrian at 50% of the vehicle's width when no braking action is applied.

- Case 2: Car-to-Pedestrian Far Side Adult 50% (CPFA-50)
  A collision situation in which a vehicle travels forward towards an adult pedestrian crossing its path running from the far side of the vehicle, and the frontal structure of the vehicle strikes the pedestrian at 50% of the vehicle's width when no braking action is applied.

- Case 3: Car-to-Pedestrian Far Side Adult Obstructed 50% (CPFAO-50)
  A collision situation in which a vehicle travels forwards towards an adult pedestrian crossing its path running from the far side of the vehicle from behind an obstruction and the frontal structure of the vehicle strikes the pedestrian at 50% of the vehicle's width when no braking action is applied. SPT comes at 5 KPH behind two parked cars so as to nullify the chances of partial recognition of the SPT's form from behind the obstruction.

Throughout all three NCAP testing cases, the Crystal Group AVC0161 ran AEB-P software without any failure despite numerous abrupt breaking actions.

In addition to the NCAP tests demonstrating the durability of the Crystal Group AVC0161 in extreme conditions, it has performed flawlessly over thousands of road miles driven as part of VSI's Automated Drive Series during 2020 and 2021. After logging approximately 25,000 miles from Arlington, VA, to San Antonio, TX and San Jose, CA, our team has not experienced a single failure in this rugged compute system. These drives have exposed the fleet to a variety of adverse conditions, like heavy snow, torrential rain, 100+ degree sun, curvy mountainous roads, and more.

Conclusion

VSI has seen the AV industry embracing military-grade, rugged computers in research and development vehicles. Using the Crystal Group AVC0161 in our test vehicle, we have clearly seen the benefits Crystal Group provides, both in understanding the technology, environmental, and operational requirements and delivering a solution that meets all of those requirements. Combining power, speed and accuracy with a rugged design built for seamless operation in any conditions continues to accelerate our research and performance—and can do the same for the AV industry.

The AVC0161 rugged compute system is essential for powering vehicle data collection and processing on the road while also running ADAS applications ranging from object detection and tracking, sensor fusion, and LKA to AEB and ACC with the utmost reliability and accuracy in the most extreme testing environments.

About VSI Labs

Established in 2014 by Phil Magney, VSI Labs is one of the industry's top advisors on AV technologies, supporting major automotive companies and suppliers worldwide. VSI's research and lab activities have fostered a comprehensive breakdown of the AV ecosystem through hands-on development of its own automated vehicle platform. VSI also conducts functional validation of critical enablers including sensors, domain

controllers, and AV software development kits. Learn more about VSI Labs at https://vsi-labs.com/.

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