SoVa Motion

Southern Virginia Vehicle Motion Labs

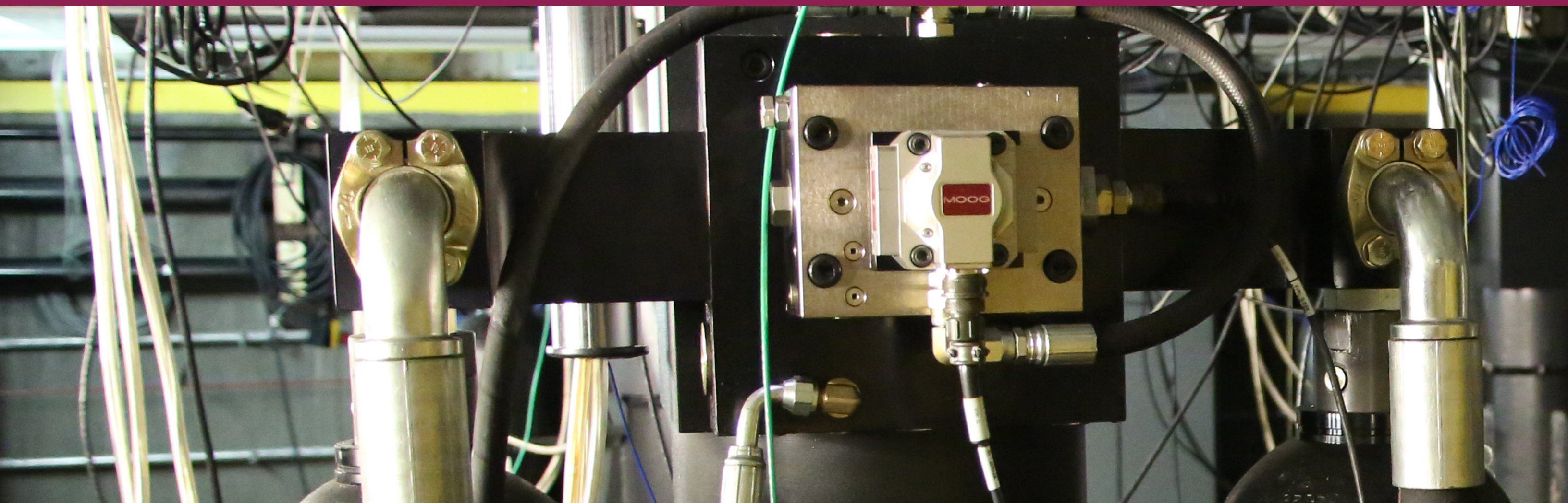
Virginia Tech Transportation Institute

GCAPS

DYNAMIC VEHICLE TESTING

Since 2010, the Southern Virginia Vehicle Motion Labs (SoVa Motion) have revolutionized vehicle testing for the automotive industry. Through SoVa Motion, customers have access to the Multi-post Vertical Dynamics Test Rig, an advanced machine that represents the next generation in dynamic suspension testing equipment. Used to improve the ride and handling dynamics of a vehicle, multi-post rigs have been employed primarily in racing to simulate track environments. This allows various vehicle suspension setups to be tested prior to race events.

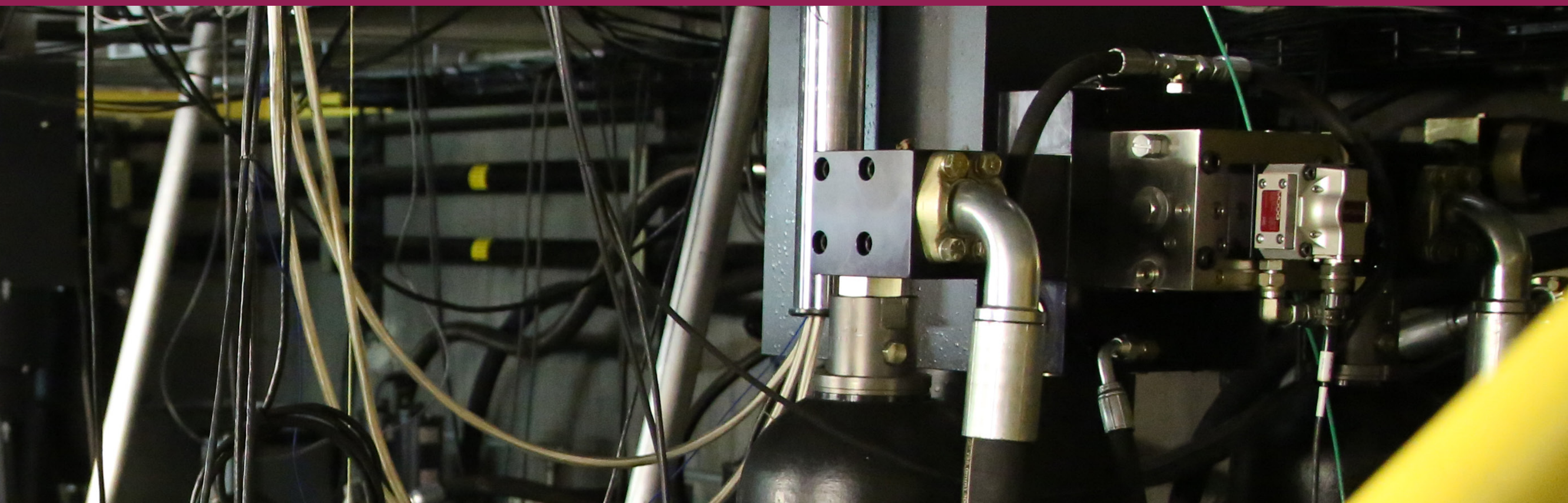
Customers collaborating with SoVa Motion benefit from the knowledge, experience, and capabilities necessary to obtain an ideal testing experience, from drive-file testing to hardware-in-the-loop vehicle simulation. In addition to placing track-measured loads to the vehicle through a drive-file iteration process, SoVa Motion has integrated



an active aerodynamic downforce application scheme. Through simulation, an aero map can be used to calculate the aerodynamic loads acting on the vehicle, and the resulting downforce loads can be changed dynamically to provide the most realistic lab-to-track tests. The system controller will also allow for other hardware-in-the-loop implementations, such as jacking and dive compensation.

For less aero-sensitive vehicles, SoVa Motion has a suite of laboratory inputs that may be used to characterize the balance, control, and grip of the vehicle. Using data analyses, SoVa Motion can work with novice teams to make suggested changes and optimize vehicle performance.

Along with the National Tire Research Center and the Virtual Design and Integration Laboratory, SoVa Motion composes the foundation of the Global Center for Automotive Performance Simulation (GCAPS). This world-class facility was unveiled during 2014 and provides revolutionary services for both vehicle and tire, including testing, simulation, and modeling. Collectively, these initiatives provide the full range of services essential for creating a more dynamic product through both virtual and physical development.



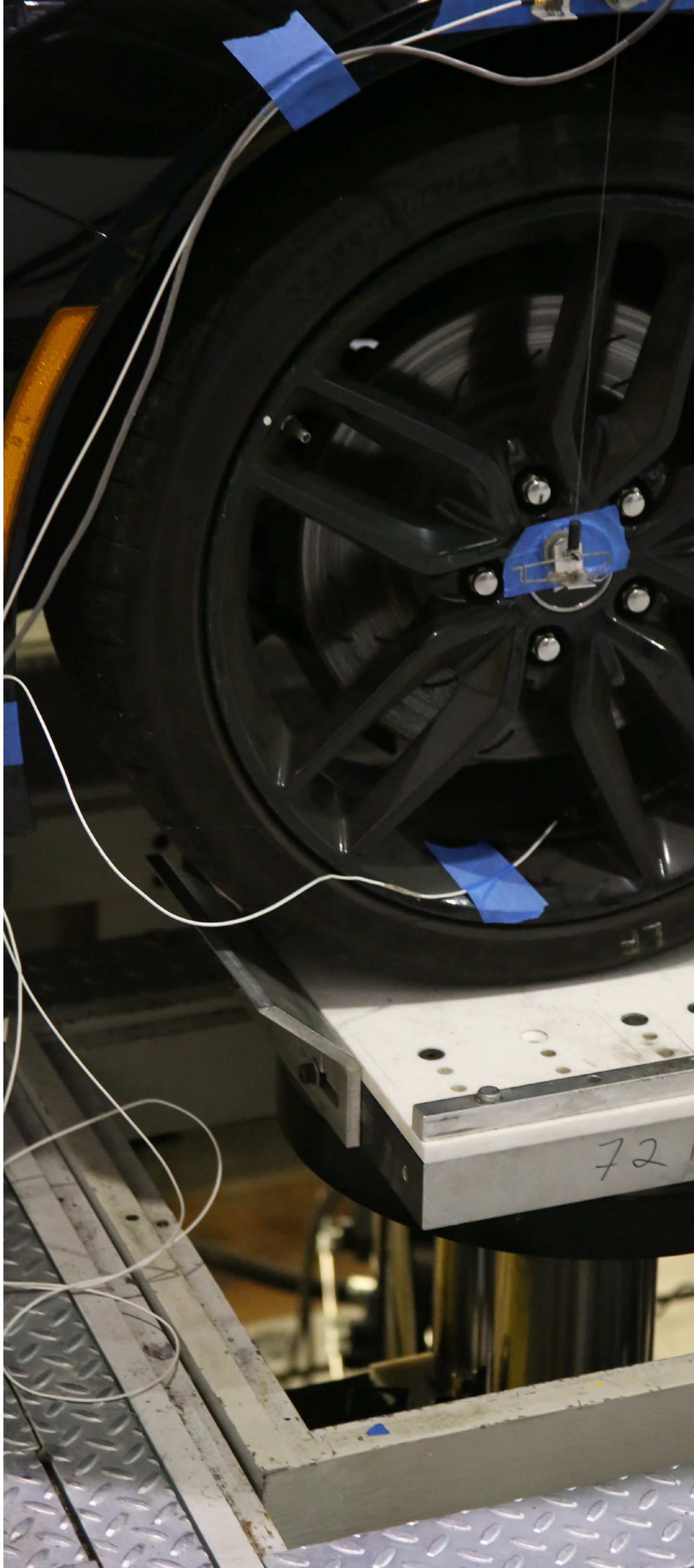
INSIDE

SoVa MOTION SERVICES

The SoVa Motion Multi-post Vertical Dynamics Test Rig includes four hydraulic wheel loaders that simulate ground inputs into the suspension. Three to four hydraulic aero loaders attach to the vehicle body and simulate both the inertial and aerodynamic forces experienced by a vehicle.

The multi-post can be set up in 4-, 7-, or 8-post configurations to:

- Measure the center of gravity
- Calculate suspension parameterization
- Provide suspension tuning/optimization (race and highway)
- Provide damper optimization (race and highway)
- Establish road-to-lab-to-math vehicle tuning



Each of the four wheel platens of the multi-post can produce up to 11,000 pounds (5,000 kg) of dynamic force. Each of the three to four additional downforce actuators can provide up to 4,500 pounds (2,000 kg) of inertial and/or downforce loading. When coupled with 12-inch actuator strokes, the large load capabilities enable a wide variety of road simulations. The wheel platens and downforce actuators are repositionable, allowing for testing of myriad vehicles.

Road inputs can be created from either on-track vehicle data or custom lab inputs created at SoVa Motion. Both of these input types help customers gain a better understanding of the vehicle suspension setup and allow teams to make informed decisions when changes are made at the track.

The overall benefits of using SoVa Motion for vehicle testing include:

- Use of non-running vehicle
- No time on engine
- No wear on tires
- Repeatability and reduction in development time
- Testing that may not be under series sanction
- No track rental

SoVa MOTION SERVICES ctd.

SoVa 4-POST TESTING

- Ideal for sports cars, GT racing, and initial formula car testing
- Four actuators to simulate track or lab inputs
- Provides highly repeatable environment in which results of vehicle setup changes can be quantified without having to rent track time or place wear on the tires, powertrain, and bearings
- Typical lab inputs consisting of sine sweeps, impulses, and random noise are used to evaluate multiple vehicle base metrics
- Track drive files can be created from damper data sampled above 200 Hz
- Vertical components experienced by a vehicle can be tuned to provide the driver with a balanced vehicle, allowing minor changes once at the track
- Many metrics evaluated are directly related to lateral balance and grip

SoVa 7-/8-POST TESTING

- Developed primarily within the open-wheel formula ranks; these cars typically have monocoque structures with a high torsional stiffness
- Ideal for vehicles that have already been tested on the 4-post and have significant downforce (e.g., GT, formula, and Le Mans prototype cars)
- Uses three to four additional actuators that provide several advantages over the standard 4-post test, including simulation of inertial and aerodynamic forces
- The 8-post mode can transfer loads around the car to better simulate the attitude of the vehicle in braking, acceleration, and cornering
- Data can be analyzed to determine frame height changes, maximum shock travels, tire loads, and splitter height; these metrics are important when evaluating the setup of a vehicle and maintaining a solid aerodynamic platform

SoVa ROEHRIG 4K ELECTROMAGNETIC ACTUATOR (EMA) SHOCK DYNO TESTING

- Ideal if damper curves are not available or limited curves are available and additional information about the dampers is desired
- If information about the vehicle dampers is unknown, this testing will determine the adjustability range, allowing for more educated damper decisions both at the track and on the multi-post rig
- Dampers can be characterized and damper adjustments can be mapped to guide changes, depending on the shock velocities recorded at the track
- Can aid in both 4- and 7-/8-post testing

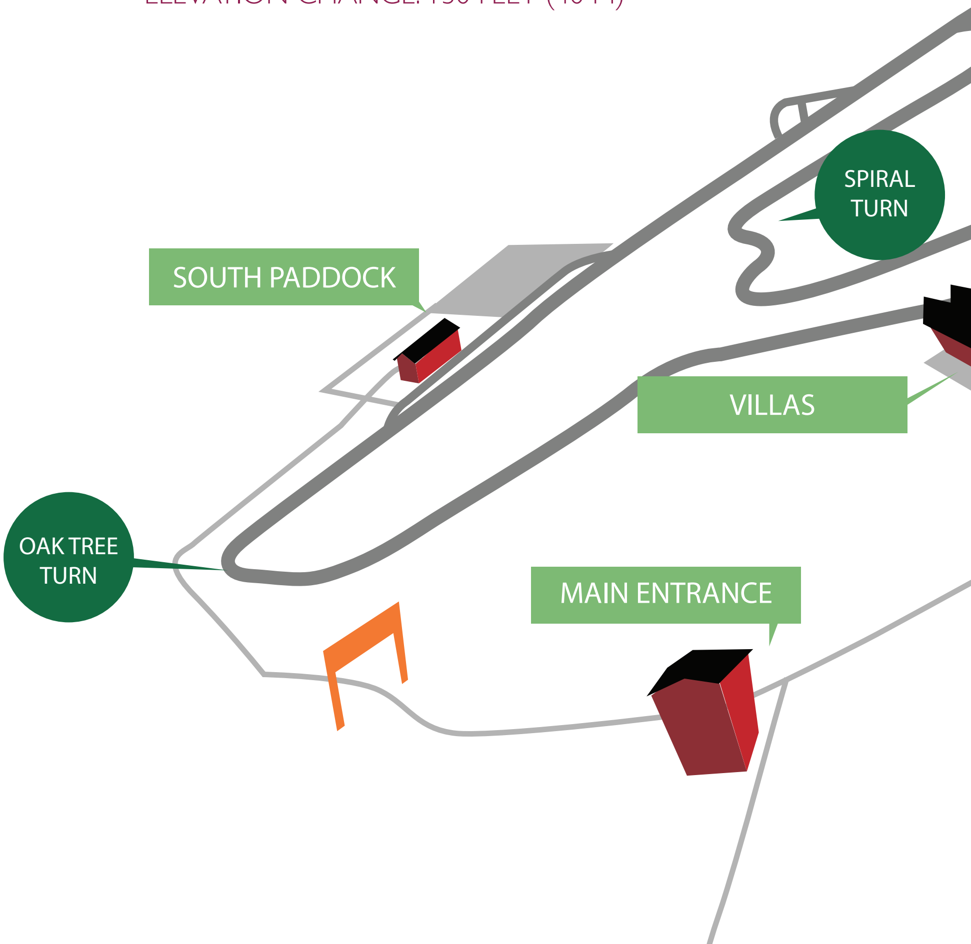
OTHER EQUIPMENT

Through the use of jacks and stands, many part changes can be made while the vehicle is still on the multi-post rig. If a more complicated part change is needed, a hoist is available. SoVa Motion also provides access to a small machine shop and a selection of tools. However, it is still recommended the customer bring all tools required for part changes.

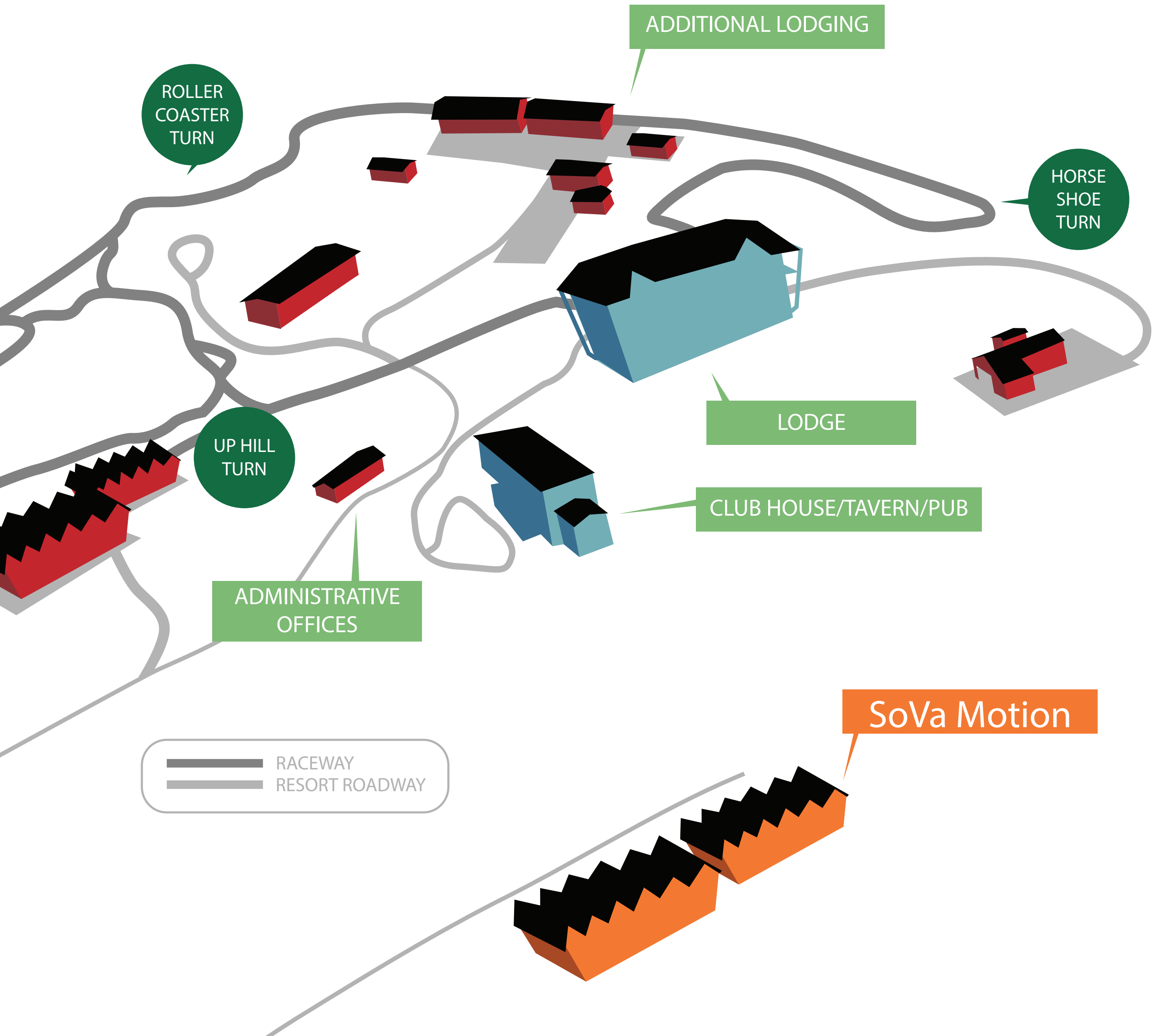
Located adjacent to SoVa Motion is the Virginia International Raceway (VIR), which allows for easy track-to-lab-to-track comparisons and provides customers multiple advantages in terms of reducing cost, travel, and time. VIR is used by global tire, vehicle, and motorsports companies to fine-tune vehicle and/or tire performance. The proximity of the VIR to SoVa Motion enables vehicle configurations to be determined indoors and then confirmed on the track, all without loading the vehicle onto a trailer. Before a practice or race at VIR, vehicles can be tuned at SoVa Motion without running the engine or causing tire wear, allowing customers to travel straight to the track and win in a matter of hours instead of days.

VIRGINIA INTERNATIONAL RACEWAY: TRACK CONFIGURATION

- GRAND COURSE: 4.20 MILES (6.76 KM)
- FULL COURSE: 3.27 MILES (5.26 KM)
- NORTH COURSE: 2.25 MILES (3.62 KM)
- SOUTH COURSE: 1.65 MILES (2.66 KM)
- PATRIOT COURSE: 1.10 MILES (1.77 KM)
- FRONT STRAIGHTAWAY: 3,000 FEET (914.5 M)
- BACK STRAIGHTAWAY: 4,000 FEET (1,219.2 M)
- ELEVATION CHANGE: 130 FEET (40 M)

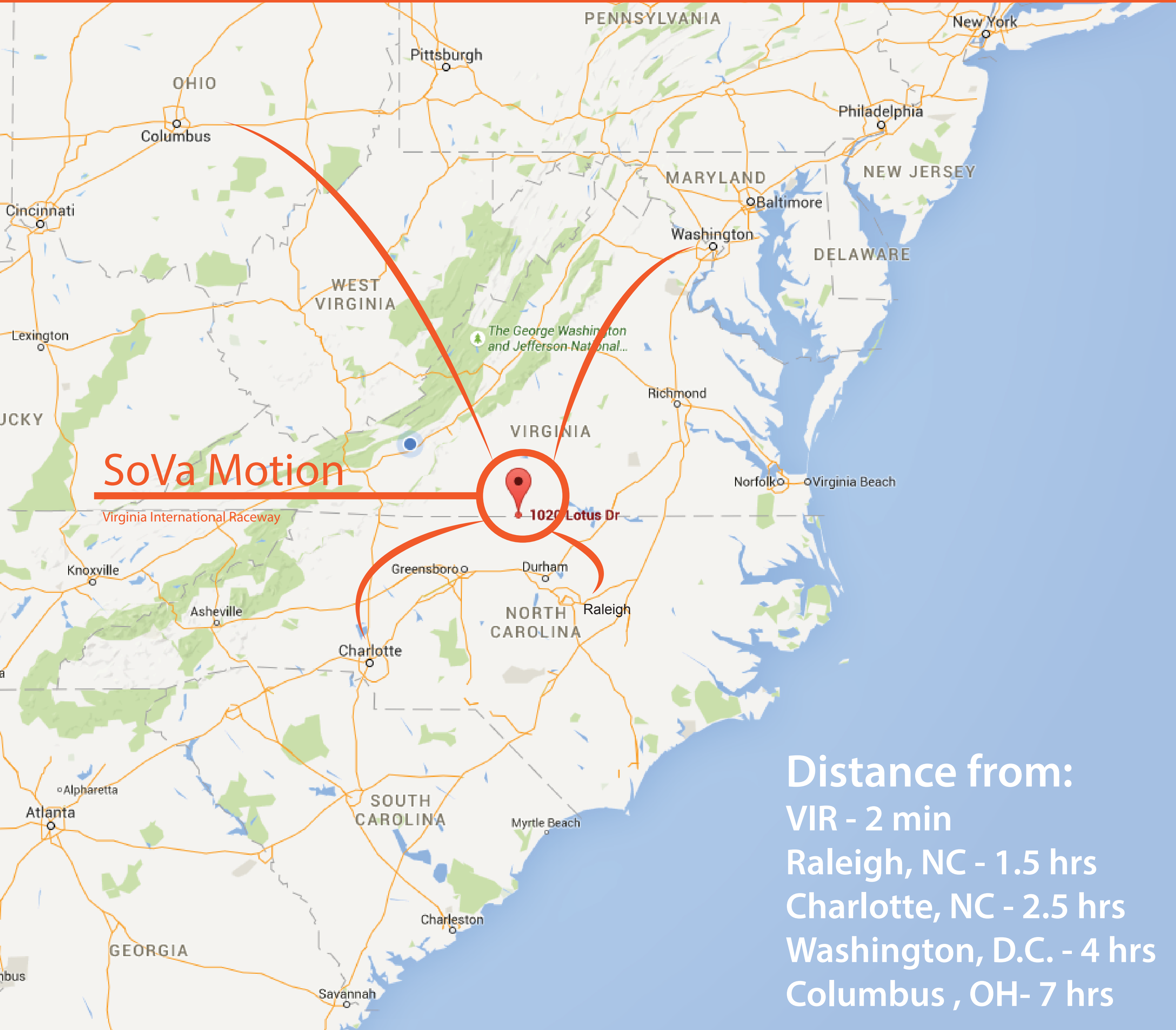


VIRGINIA INTERNATIONAL RACEWAY TESTING



Facility Location

1020 Lotus Drive
Alton, VA 24520



Distance from:

VIR - 2 min
Raleigh, NC - 1.5 hrs
Charlotte, NC - 2.5 hrs
Washington, D.C. - 4 hrs
Columbus , OH- 7 hrs

USER EXPERIENCE

To ensure an efficient development session, SoVa Motion typically asks that customers provide the following information:

- Current spring rates, bar rates, and damper settings
- Track width and wheelbase
- Hot tire pressures
- Driver weight (ballast weight is available)
- Available parts (e.g., springs, bars)
- Types of adjustments that may be made if shocks are adjustable (e.g., low-speed compression, low-speed rebound, high-speed compression, high-speed rebound), as well as ranges of each adjustment and current settings
- Shock curves, if available (these should be provided prior to testing)

If 7-/8-post testing is desired, advanced planning must occur to correctly attach the additional posts.

USER EXPERIENCE ctd.

INSTRUMENTATION

Information about the standard vehicle and rig instrumentation used during SoVa Motion testing is provided below. All channels are logged at 1,024 Hz for 4-post tests and 512 Hz for 7-/8-post tests.

VEHICLE INSTRUMENTATION

- 4 Hub accelerometers
- 4 Body accelerometers
- 1 Seat track or center vehicle accelerometer
- 4 Wheel displacement transducers
- 4 Body displacement transducers

RIG INSTRUMENTATION

- 4 Platen loads
- 4 Platen displacements
- 3/4 Downforce loads (7-/8-post testing)
- 3/4 Downforce displacements (7-/8-post testing)

Approximately 100 additional channels are calculated using these direct measurements, including body attitude in heave, pitch, and roll; frame height from ground; splitter height; and rake deviation. Such measurements are important to the overall track performance of a vehicle.

Customers should note that vehicle instrumentation setup time typically takes 45 minutes if the wheelbase and track widths are provided prior to the testing date.

TESTING PROCEDURE

To determine vehicle parameters and overall vehicle balance, the SoVa Motion testing procedure for lab inputs consists of several frequency sweeps in heave, pitch, and roll. Other inputs include impulses at varying speeds that simulate track curb strikes and a random excitation across a wide frequency range, which can help determine contact patch load variation (i.e., grip). Body and wheel control are also compared to the baseline vehicle setup. Body control is optimized for balance and platform stability, while wheel control is optimized for contact patch load variation. The test list, details, and approximate run times for 4- and 7-/8-post testing are as follows:

- Sine sweep heave (0.5 – 30 Hz): Balance and parameters (6 minutes)
- Sine sweep pitch (0.5 – 6 Hz): Balance and parameters (3 minutes)
- Sine sweep roll (0.5 – 6 Hz): Balance and parameters (3 minutes)
- CG height estimation: Parameters (30 seconds)
- Impulses (several speeds tested): Grip and control for body and wheel (1 minute)
- Random road (0.5 – 30 Hz content): Grip and control for body and wheel (30 seconds)
- Lap drive file (pitch and roll inertial effects are removed in 4-post testing; 7-/8-post testing will include all inertial and aerodynamic effects): Grip and control for body and wheel (dependent upon lap time, approximately 2 minutes)

USER EXPERIENCE ctd.

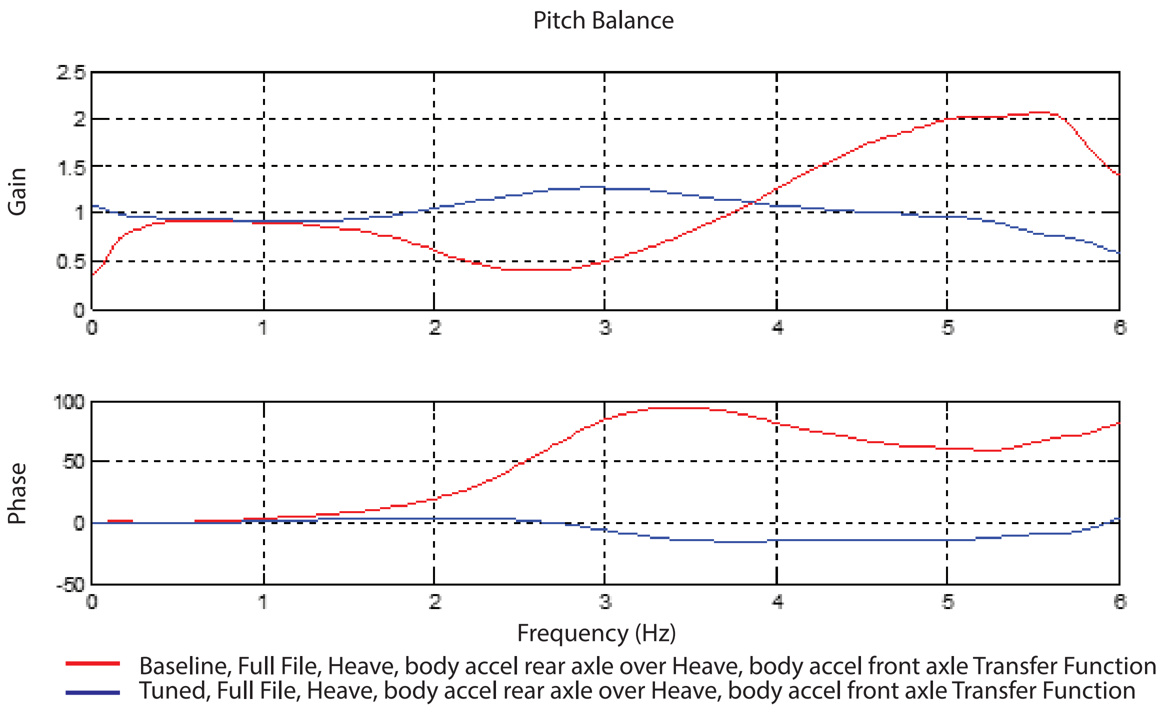
To create a successful drive file, damper displacement data gathered from an accelerometer located near the vehicle's center of gravity and logged at a minimum of 200 Hz will be needed. These data must be provided at least 24 hours prior to the testing date. Once the vehicle is on the multi-post rig, drive-file iteration will take approximately two to four hours.

Customers should note that some tests will be run twice to ensure repeatability and to establish a solid baseline.

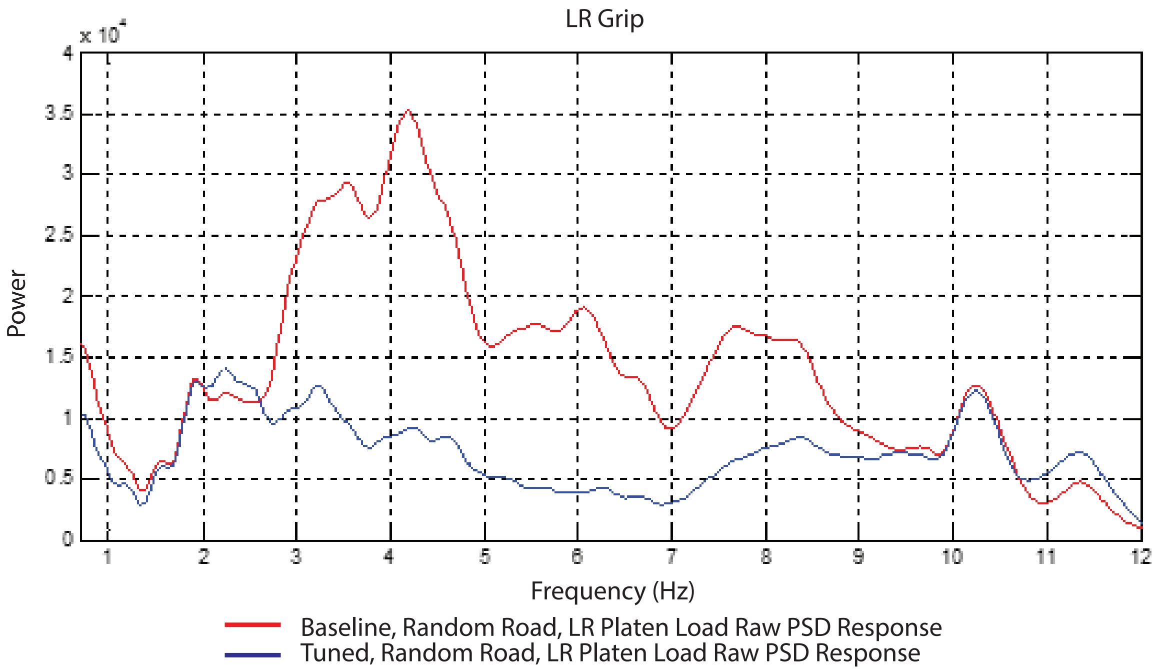
TESTING ANALYSES

After initial tests are performed, results will be analyzed using the following metrics. The vehicle will then be tested again to optimize each metric to its full potential.

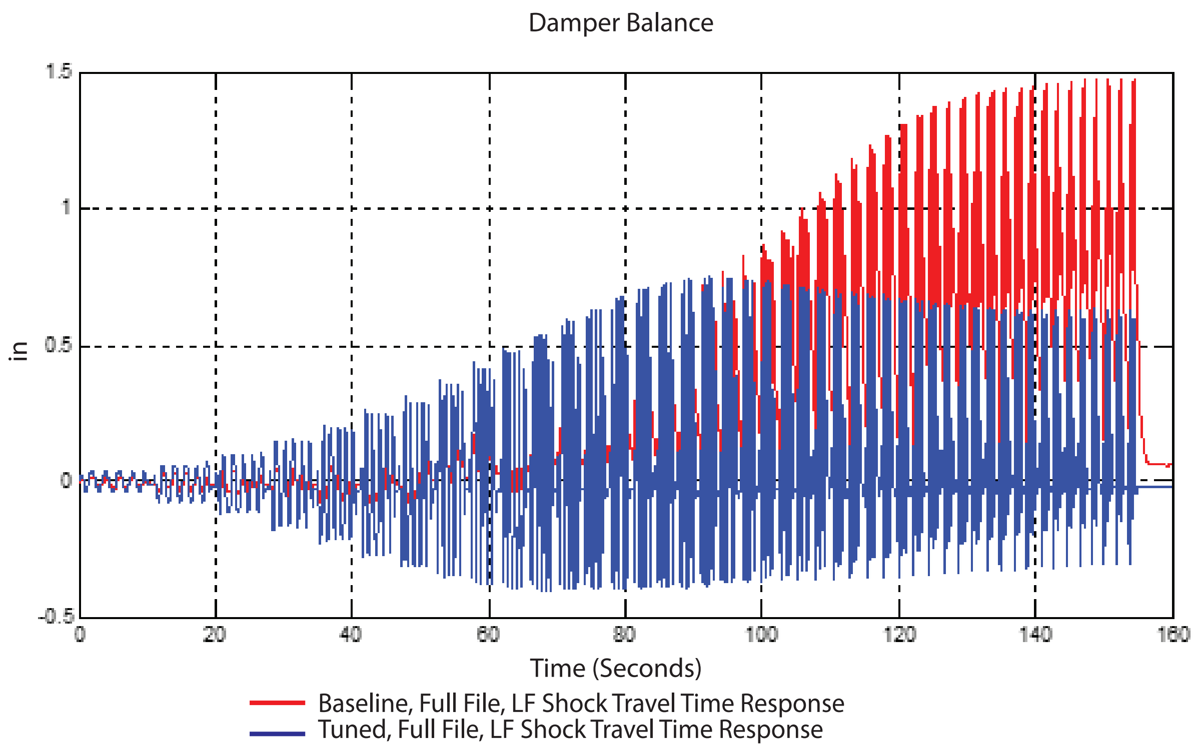
- Pitch Balance: Using the sine sweep in heave, front and rear natural frequencies will be analyzed by comparing both magnitudes and phases. This will determine the balance of the vehicle across the tested frequency range. An unbalanced vehicle will have excessive body motions at either the front or rear of the vehicle over track disturbances, potentially resulting in unpredictable behavior mid-corner or under heavy braking. A balanced vehicle will typically have similar front or rear natural frequencies and magnitudes that can be determined by viewing the transfer function of front-to-rear body accelerations.



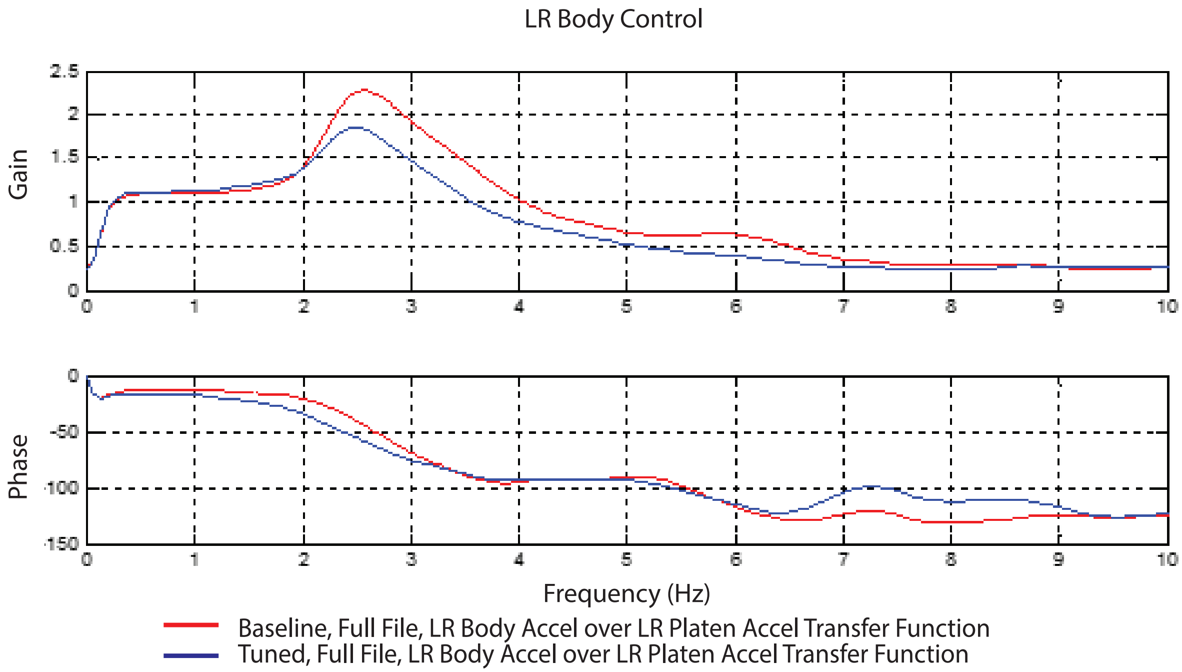
- Contact Patch Load Variation (Grip): Using the random road, impulses, sine sweeps, or track drive files, the contact patch load variation (i.e., grip) can be determined. Random excitations will have frequency content similar to most race tracks, but track drive files will be more tailored to a specific track. To accomplish this, load cells in the platens (road) record a range of load values during the tests. Since tires generate the most lateral force with consistent and higher loads, smaller variations should produce better cornering performance from the vehicle. Similar front and rear grip values are also desired in a well-balanced vehicle.



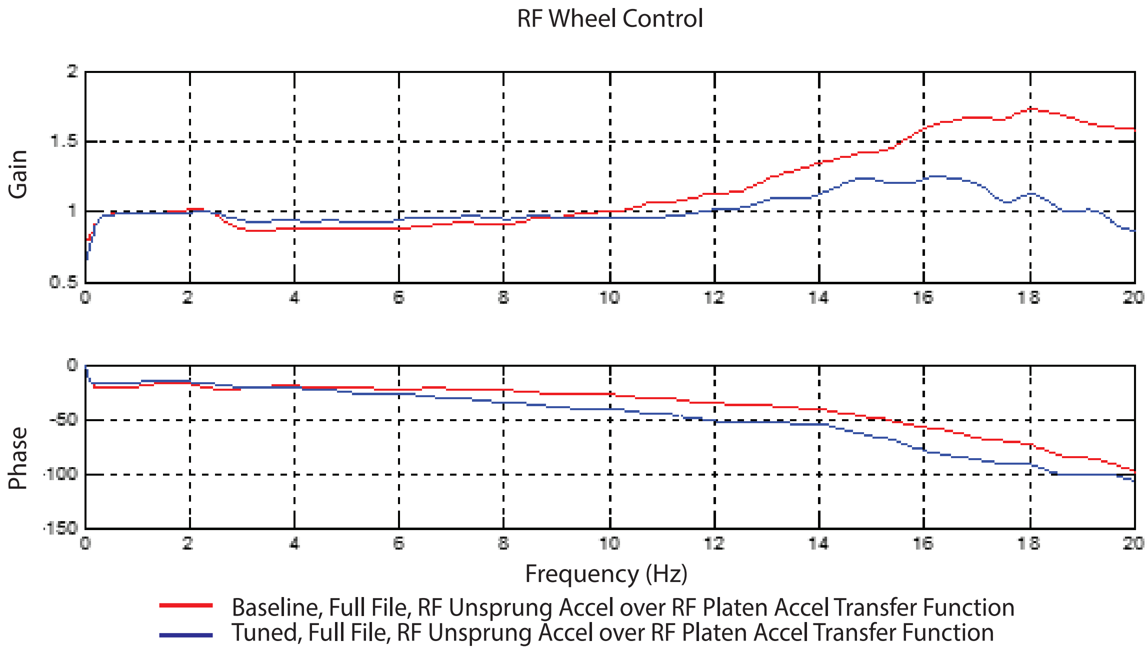
- Damping Balance: Using the sine sweep in heave, the damper balance can be determined. If excessive damping in either rebound or compression is present, the vehicle will be jacked down or up, respectively. This will potentially reduce damper travels or upset the aero platform. Viewing the time history trace of the wheel displacement will show both of these behaviors.



- Body Control: Using the random road, impulses, sine sweeps, or track drive files, the body control can be determined. Body control is calculated by taking the transfer function of the four platen (road) accelerations to the four body accelerations. Ideally, a well-controlled vehicle will have a gain value closer to zero, meaning the body is isolated from the road inputs. A controlled body will provide the driver and the aerodynamic package with a stable platform. A single metric number is calculated for easy comparison across the relevant frequency ranges.



- Wheel Control: Using the random road, impulses, sine sweeps, or track drive files, the wheel control can be determined. Similarly to body control, wheel control is calculated by taking the transfer function of the platen (road) accelerations to the four hub accelerations. Ideally, if the hub is following the platen (road), it will have a magnitude of one. Therefore, any deviation from one is undesirable and will either cause a reduction in grip or overwork the tire, causing premature wear.



OPTIMIZATION PROCESS

Optimization is performed using the initial baseline and multi-post rig inputs. Since the test rig measures vertical force only, it does not simulate the entire environment that a vehicle may encounter on the road or track, such as lateral loads. However, trends and directions of vehicle improvement or loss can be identified and used at the track for race-day tuning.

After the vehicle is analyzed in its baseline state, changes to spring rates may be necessary to bring the vehicle back into balance. Once the vehicle is balanced, the dampers are optimized. It is usually necessary to perform a basic damper setting sweep, the purpose of which is to determine the sensitivity of the vehicle to changes in damping levels and to make any necessary adjustments. Once enough runs are made, metrics are plotted that provide a visual representation of trends.

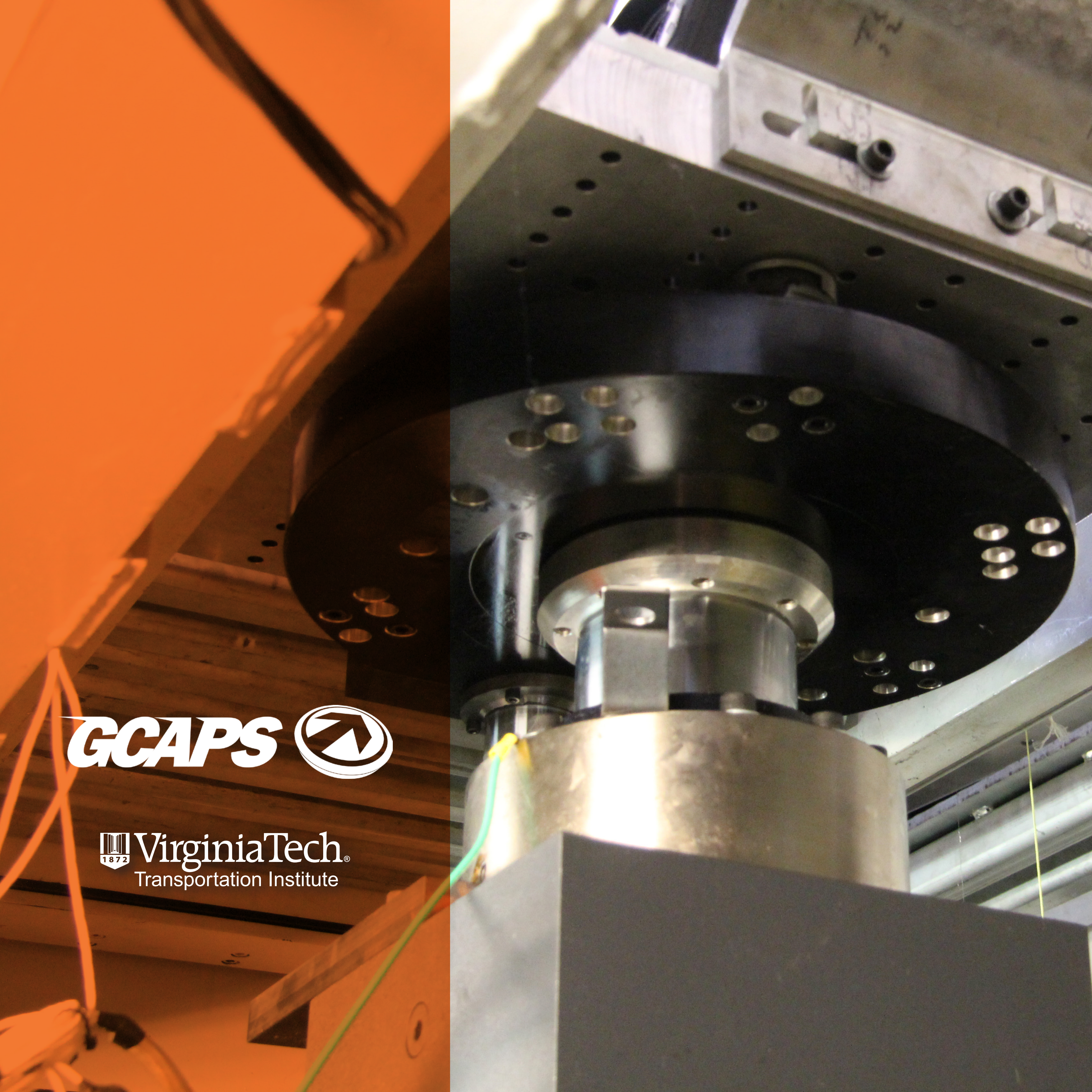
REPORTING PROCESS

After testing is complete, SoVa Motion will prepare a summary of the testing that was performed. Time histories, power spectral densities, and transfer functions are used to illustrate the differences in the vehicle and to show control and grip trending. Metric plots and damper settings will also be provided to guide the customer in making informed decisions at the track, including setup changes.

CONTACT US

To learn more about how GCAPS and SoVa Motion can help your company excel in the industry, visit www.sovamotion.com or call 434.766.6644.

If you are interested in becoming a part of the GCAPS team, contact Human Resources at hr@sovamotion.com.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