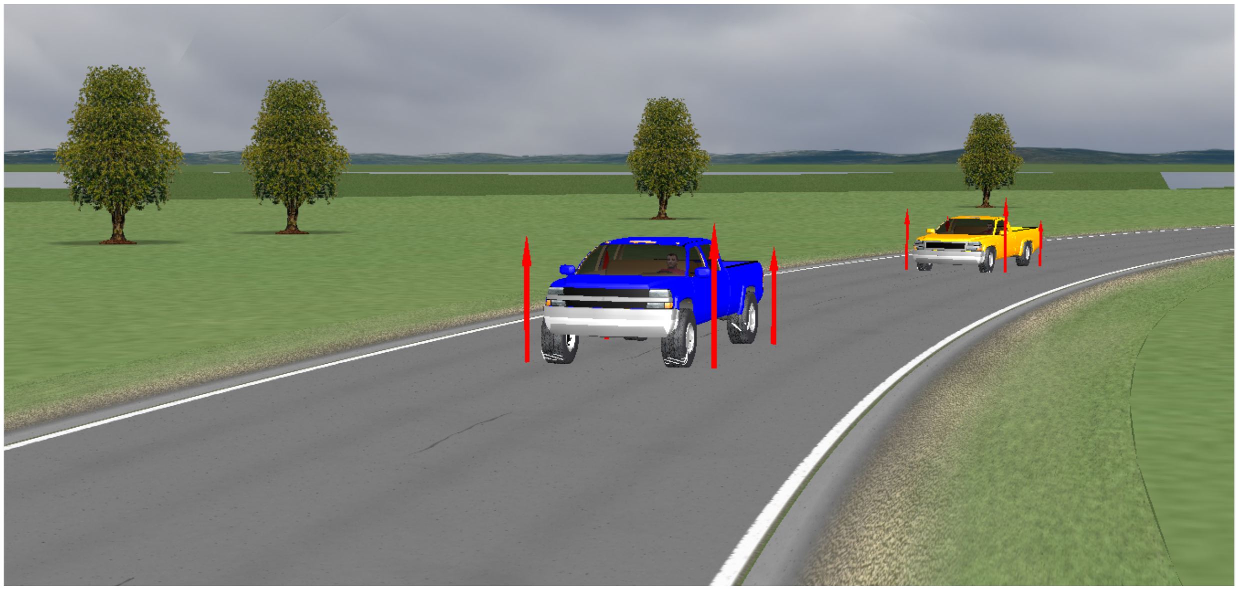
Superlift Ford F150 6" Lift Kit

Vehicle Dynamics Performance Evaluation

- Preview Version -



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Advanced Controls
ACEC, LLC
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TOMORROW'S ENGINEER TODAY

CarSim
Mechanical Simulation

SPECIALTY EQUIPMENT MARKET ASSOCIATION
SEMA

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SUPERLIFT
SUSPENSION SYSTEMS

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Topics in gray are not included in this abridged version of the report.

Executive Summary

This program represents the first complete implementation of an innovative program aimed at providing aftermarket companies the opportunity to employ state-of-the-art engineering technologies in addressing the increasingly complex legal and technical challenges they face. While focusing on FMVSS 126, it also provides insights into how these tools and techniques can be used in both marketing and design activities.

The Superlift 6” Lift Kit Modified Ford F150 that was the subject of this study exhibited exemplary vehicle dynamics characteristics. **Specifically, through Hardware In the Loop (HIL) simulation, it demonstrated**:

- **The reasonable expectation for a physical test of the vehicle to pass the performance requirements of FMVSS 126**. The specified yaw rate ratios (yaw rate at a given time / peak yaw rate) and lateral displacements were well within the required ranges of the regulation. The yaw rate ratios, which need to be < 35% at one given time and < 20% at a second event time, never exceeded being < 5% (yaw rate at event / peak yaw rate). This established an extremely large margin for error. Meanwhile, at the specified larger steer angles, the lateral displacements passed with margins of 40% to 53%. The vehicle greatly exceeded the performance necessary to pass FMVSS 126 [see p 9-16].
- **Compatibility with the control authority Ford Electronic Stability Control (ESC) system**. When the ESC system was activated during FMVSS 126 and “fishhook” testing, the brake pressures required to successfully complete the maneuvers were comfortably within the absolute capabilities of Ford’s ESC system and generally only10%-20% higher than the unmodified production vehicle [see p 17-21].
- **The modified vehicle worked in harmony with the Ford ESC system to mitigate any rollover potential in the extreme conditions of the “fishhook” maneuver**. As expected, the raising of the center of gravity (cg) of the vehicle with the addition of the lift kit resulted in a reduction of the rollover avoidance capabilities of the modified vehicle compared to a lightly loaded base F150 without

ESC. Yet the activation of ESC enabled the modified vehicle to successfully negotiate the maneuver at a speed similar to the base vehicle [see p 17-21].

- **The absence of "nuisance activations" from the ESC system during low speed high steer angle maneuvers**. This is attributed to the close matching of the understeer characteristics between the base and modified vehicles [see p 22-31]. Physical tests verified this quality in vehicle performance.

In addition to demonstrating the ability to meet the requirements of FMVSS 126, the Superlift 6" Lift Kit Ford F150 repeatedly demonstrated compatibility with the Ford ESC system as well as predictable and controllable handling characteristics in all maneuvers and tests detailed in this report.

Background

The introduction of FMVSS 126 has presented a unique set of challenges to the aftermarket industry. The requirement of a vehicle to be able to meet the performance specifications of FMVSS 126 after modification can be a cost prohibitive proposition. Superlift actively sought to demonstrate the performance attributes of its most recent lift kit design and worked with SEMA companies to establish the appropriate collaborative relationships.

In response to the implications of FMVSS 126, from both regulatory and litigation standpoints, this effort has looked to provide the aftermarket companies involved with knowledge and capabilities that would be difficult to obtain on an individual basis. To that end, a simulation capability has been established through a vehicle dynamics software package (CarSim) and its capabilities to mimic the FMVSS 126 test procedures.

In order to increase the degree of confidence in the simulation of a given vehicle's performance, this project facilitated the development of a flexible Hardware In the Loop (HIL) capability using hardware provided by dSPACE and implemented at their facility in Wixom, MI. This incorporated the actual ESC controller in the simulated performance evaluation and in a representative vehicle present to address all the communication and diagnostic complexities presented by current automotive electronic architectures. The approach follows the techniques established by the OEMs in evaluating their vast array of products. Superlift embraced this strategy and sponsored the first vehicle to be fully tested using this technique.

Procedures

The hardware components required for this proposal are shown below in Figure 1 (courtesy of CU-ICAR):

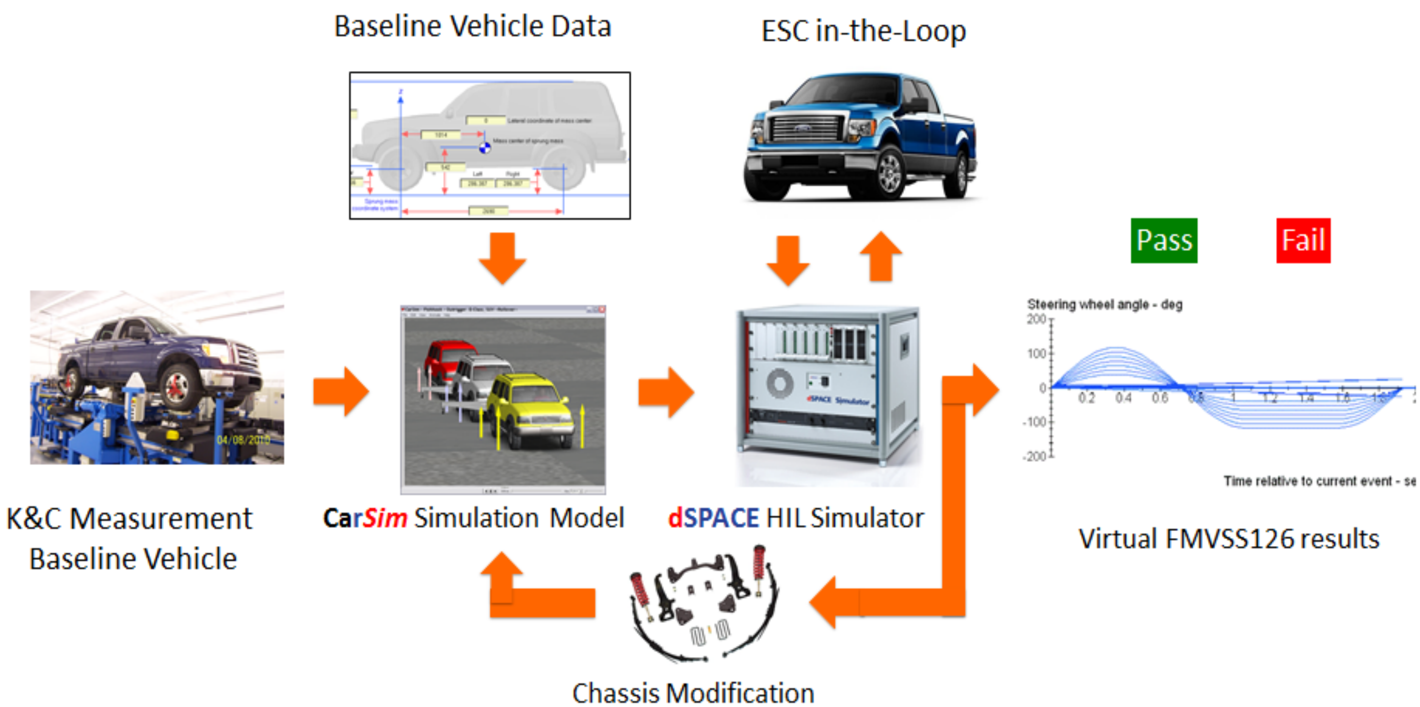

Figure 1. Overview Diagram of HIL Components

The vehicle used in the HIL testing only needs to be representative of the original vehicle before modification. The key elements are the actual ESC controller and the electrical architecture of the OEM vehicle. Vehicle modifications and proposed variants are comprehended by parameters set in CarSim.

The HIL approach addresses the control algorithm and calibrations issues, as well as the need for modeling sensors and actuators, by using the actual systems in the simulation. Using tools provided by Mechanical Simulation and dSPACE, a static vehicle is connected to the CarSim simulation software through the dSPACE HIL simulator hardware to determine how its electronic controllers respond to simulated test maneuvers with the baseline and modified vehicle characteristics.

By using this approach, Superlift did not need to delve into the intellectual property contained within the controllers. The algorithms and calibrations established between the Original Equipment Manufacturer (OEM) and its chosen Tier One Supplier remain confidential, respecting their proprietary nature. Every controller on the vehicle is treated on a “signals in, signals out” basis.

In order to achieve this capability, three sets of data need to be defined:

1. Kinematics and Compliance – This data involves the static parameters of the vehicle and the dynamic aspects of its steering and suspension systems. Measurements of characteristics such as center of gravity, roll, pitch, and yaw inertias, as well as frame torsional flexibility and suspension compliance are all used to describe a specific vehicle. These parameters were determined by Morse Measurements [1] for both the baseline Ford F150 and the Superlift modified version.

2. Tire Data – Since the forces developed at the tire road interfaces are critical to a vehicle’s dynamics, measures of a tire’s longitudinal and lateral force transmittal characteristics are paramount in establishing a meaningful simulation. Effective rolling radius, rolling resistance, and spring rate are some of the other parameters also required. The tire information for the base vehicle was provided by Michelin in an encrypted form, while the aftermarket tires were tested by Smither’s Testing Services [2].

3. Signal Composition – The nature of sensor information is key to being able to simulate accurately. Directly wired sensors are readily mimicked, but serial communication based sensors take time to decipher. Knowing the protocol for information transfer enables the appropriate simulation techniques to be employed. The sharing of select information by Ford Engineering greatly aided the timely progress of this activity.

The establishment of this HIL foundation regarding a chosen base vehicle enables the evaluation of countless vehicle modifications in an innumerable amount of select repeatable vehicle dynamics tests. This, in turn, provides the capabilities to:

- Evaluate a finished design
- Explore parameter variations to establish design guidelines and required performance envelopes for key components
- Integrate simulation into the initial design process to reduce the need for prototype fabrication

Although this project focused on FMVSS 126 and related testing, HIL simulation can be applied to countless design and evaluation activities of the aftermarket.

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