U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

Memorandum

Vehicle Research and Test Center P.O. Box B37
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Subject: FINAL REPORT: VRTC-DCD8135 "2005 Ford F-150 Loss of Brake Assist"

Date:

From: W. Riley Garrott *W. Riley Garrott*
Acting Director, Vehicle Research and Test Center

Reply to Attn. Of: NVS-310

To: Kathleen DeMeter
Director, Office of Defects Investigation

NVS-210

Attached are four (4) copies of the subject report. This completes the requirements for this program.

Attachment:
Final Report

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VRTC MEMORANDUM REPORT PE08-001
VRTC-DCD-8135
2005 Ford F-150 Loss of Brake Assist

1.0 Introduction

This program was performed at the Vehicle Research and Test Center (VRTC) at the request of the Office of Defects Investigation (ODI) of the National Highway Traffic Safety Administration. ODI opened a Preliminary Evaluation (PE08-001) on 2005 Ford F-150 vehicles equipped with the 5.4L engine based on consumer complaints that the hose that supplies vacuum to the brake booster can rupture without warning.

Figure 1
2005 Ford F-150

2.0 Background

The subject vehicles are equipped with a gasoline engine and vacuum assisted power brakes. The connection between the vacuum source at the intake manifold and the brake booster is a three-piece hose assembly that uses flexible hoses at each end (manifold and booster) and a solid tube in the center. Consumer reports allege that the flexible hose nearest the manifold can fracture or separate with little or no warning to the operator. When the vacuum source to the booster is interrupted, a check valve in the booster will retain some level of vacuum within the booster until the brakes are applied. Each time the brakes are applied, the level of vacuum that is available for brake assist diminishes somewhat. The purpose of this program was to determine 1) how vehicle loading affected the required brake pedal force and brake pedal travel, 2) how many brake applications would be available to the driver with full brake assist after the vacuum source was interrupted, and 3) how much brake effort would be required to achieve given levels of vehicle deceleration as the vacuum within the booster became depleted through repeated application of the brakes.

3.0 Test Vehicle Preparation

A subject vehicle was leased from a local dealership for testing purposes. Instrumentation was installed on the test vehicle to record the following:

- Brake Pedal Application Force
- Brake Pedal Travel
- Vehicle Deceleration
- Vehicle Speed
- Left Front Brake Line Pressure (used for static tests only)

4.0 Inspection and Testing

4.1 Phase I - Dynamic Testing

Two series of tests were performed on this vehicle. In the first series, dynamic testing was performed with a fully functioning vacuum brake booster to determine the relationship between vehicle deceleration and both brake pedal force and brake pedal travel. Tests were performed with the vehicle loaded to the Gross Vehicle Weight Rating (GVWR) of the vehicle, and to a Lightly Loaded Vehicle Weight (LLVW) which was curb weight plus driver and instrumentation. The test procedure involved accelerating the test vehicle to the desired test speed and then applying a ramping brake force up to the desired levels of deceleration of approximately 0.5 and 0.9G. In each test, brake pedal force was gradually increased so that the maximum deceleration occurred just prior to the vehicle coming to rest. The data from these tests determined the brake pedal force and brake pedal travel that were required to achieve the desired deceleration levels. This information was then used to determine the parameters of the second series of tests. Additionally, the data showed that when the vehicle loading was increased from LLVW to GVWR, the brake pedal force that was required to achieve levels of deceleration up to 0.5G increased by approximately 4 lb. Deceleration levels in excess of 0.5G begin to require brake pedal forces that are non-linear and that are dependent on the rate of application so such a direct comparison could not be made above a deceleration rate of 0.5G. Figure 2 shows the relationship between vehicle deceleration and brake pedal force at both loading conditions between 0.1 and 0.5 G.

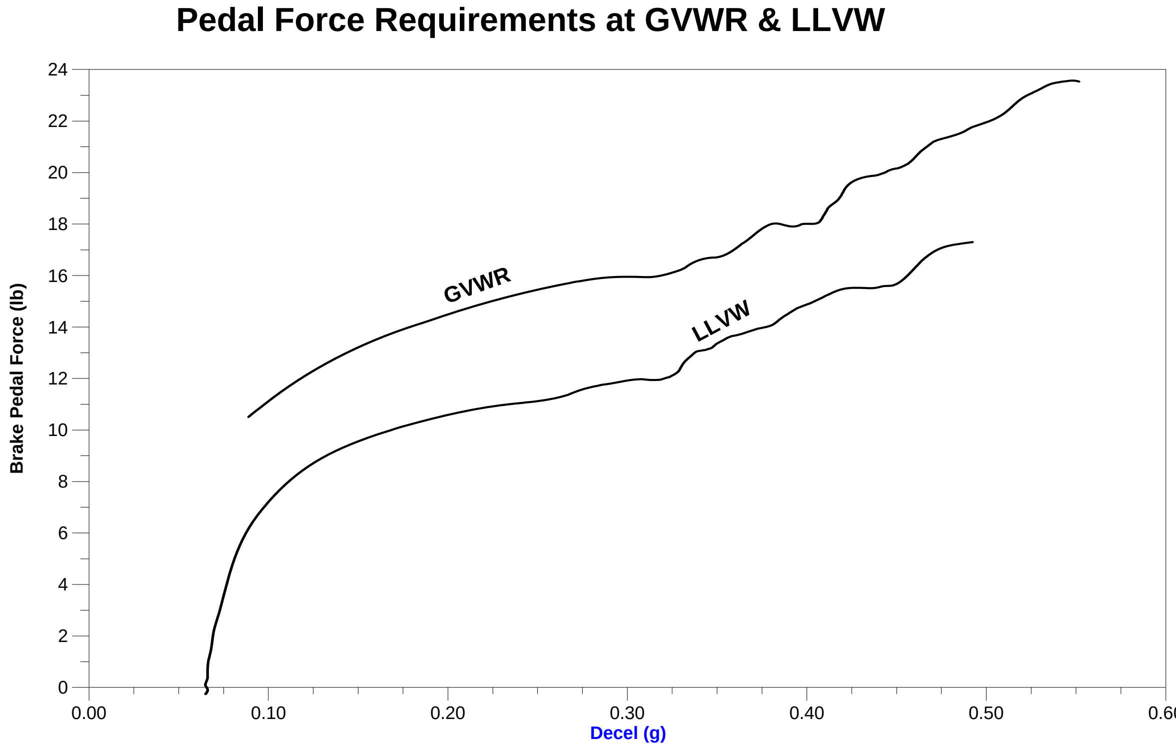

Figure 2
Pedal Force vs. Vehicle Deceleration Up To 0.5G Deceleration

4.2 Phase II - Static Testing

In the second series of tests, static testing was performed to determine the relationship between brake pedal force and brake line hydraulic pressure, and to determine the reserve capacity of the booster. Initial static tests were performed with the engine at idle and the vacuum brake booster functioning normally. Using the brake pedal travel data from the dynamic tests, the brake pedal was depressed to the same pedal travel that had produced the desired level of deceleration at

LLVW. By statically duplicating the dynamic tests, a direct comparison was able to be generated between vehicle deceleration at LLVW and hydraulic brake line pressure.

Next, the engine was turned off. Without replenishing the vacuum in the booster, the brake pedal was then repeatedly applied until the booster no longer provided any assist. For this series of brake applications, the brake was applied to the amount of pedal travel that was determined during the dynamic testing. At low vacuum levels, the desired brake pedal travel could not be achieved without exceeding the 250 lb limit of the pedal force transducer, so at that point, pedal force became the limiting factor.

The rate at which vacuum is depleted is dependent on how far the brake pedal is depressed. Consequently, brake pedal travel, rather than line pressure or pedal force, was used as the determining parameter in the static tests. If the tests had been performed using a brake application that achieved the same brake line pressure each time, additional pedal travel would have been required which would have used up the available reserve vacuum more rapidly. Each of the series of tests described above was performed to simulate decelerations of 0.2, 0.5 and 0.8 G.

By plotting the data from these tests, a comparison could be made of brake pedal force vs. brake line hydraulic pressure, both when the booster was operating normally, and as the booster became depleted. Additionally, by combining the pedal force vs. deceleration data from the dynamic testing with the pedal force vs. brake line hydraulic pressure from the static tests, a prediction could be made as to what sort of pedal force might be required to achieve varying deceleration levels with partially and fully depleted levels of vacuum in the booster.

4.3 Results of Static Testing

Three levels of simulated deceleration were tested.

4.3.1 Simulation of 0.2G Deceleration

The data from the dynamic tests that were performed at LLVW showed that a deceleration of 0.2 G required 10.5 lb of brake pedal force and 1.6 inches of pedal travel. The data from the static test with the engine running showed that 1.6 inches of pedal travel produced 219 psi of brake line hydraulic pressure at 10.9 lb of pedal force. In repeated brake applications without replenishing vacuum, the first four applications to 1.6 inches of pedal travel required approximately 11 lb of pedal force and produced approximately 221 psi of brake line pressure. The fifth brake application to 1.6 inches required 23 lb of pedal force and produced 135 psi of brake line pressure. Subsequent applications to 1.6 inches required 55 lb of pedal force and produced approximately 120 psi of brake line pressure. Figure 3 shows brake pedal force vs. vehicle deceleration from the dynamic test and brake pedal force vs. front brake line hydraulic pressure from the multiple static tests at a simulated 0.2G deceleration. Table 1 shows the data from the 0.2G dynamic tests and the simulated 0.2G static tests.

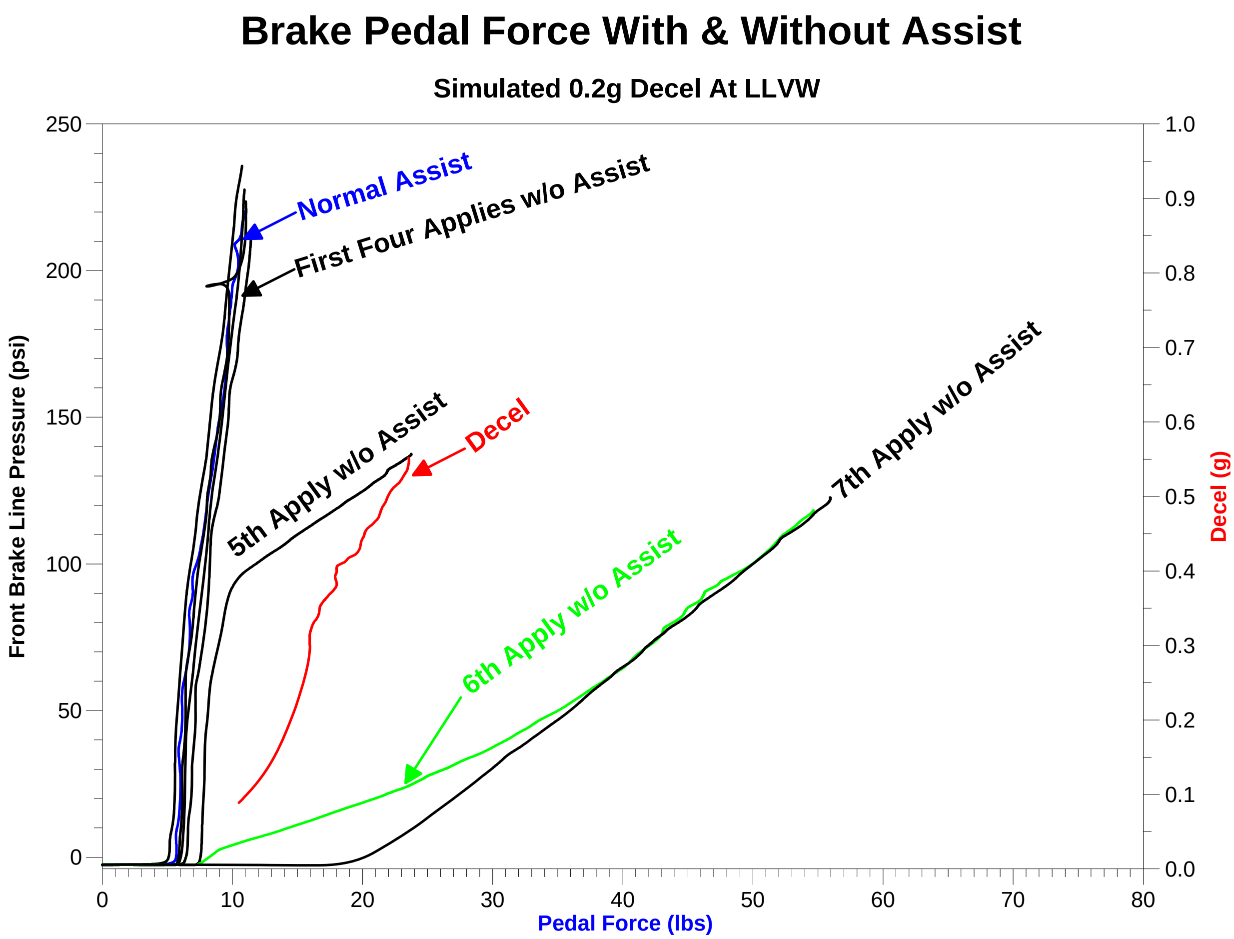

Figure 3
Brake Pedal Force vs. Brake Line Hydraulic Pressure at Simulated 0.2G Decel

	0.2G Decel Data			
	Pedal Travel (inch)	Pedal Force (lb)	Decel (G)	Line Pressure (psi)
Dynamic Test	1.6	10.5	0.2	N/A
Static Test	1.6	10.9	N/A	219
Depl Test 1	1.6	10.3	N/A	225
Depl Test 2	1.6	11.0	N/A	221
Depl Test 3	1.6	10.8	N/A	223
Depl Test 4	1.6	11.4	N/A	216
Depl Test 5	1.6	23.0	N/A	135
Depl Test 6	1.6	54.7	N/A	119
Depl Test 7	1.6	55.9	N/A	122

Table 1
Simulation of 0.2G Deceleration

4.3.2 Simulation of 0.5G Deceleration

The data from the dynamic tests that were performed at LLVW showed that a deceleration of 0.5 G required 18 lb of brake pedal force and 2.2 inches of pedal travel. The data from the static test with the engine running showed that 2.2 inches of pedal travel produced 545 psi of brake line hydraulic pressure at 18.5 lb of pedal force. In repeated brake applications without replenishing vacuum, the first two applications to 2.2 inches of pedal travel required approximately 19 lb of pedal force and produced approximately 535 psi of brake line pressure. The third brake application to 2.2 inches required 87 lb of pedal force and produced 369 psi of brake line pressure. Subsequent applications to 2.2 inches required approximately 117 lb of pedal force and produced 344 psi of brake line pressure. Table 2 shows the data from the 0.5G dynamic tests and the simulated 0.5G static tests. Figure 4 shows brake pedal force vs. vehicle deceleration from the dynamic test and brake pedal force vs. front brake line hydraulic pressure from the multiple static tests at a simulated 0.5G deceleration.

	0.5G Decel Data			
	Pedal Travel (inch)	Pedal Force (lb)	Decel (G)	Line Pressure (psi)
Dynamic Test	2.2	17.8	0.5	N/A
Static Test	2.2	18.5	N/A	545
Depl Test 1	2.2	18.6	N/A	533
Depl Test 2	2.2	20.2	N/A	538
Depl Test 3	2.1	86.6	N/A	369
Depl Test 4	2.2	116.8	N/A	344

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Table 2
Simulation of 0.5G Deceleration

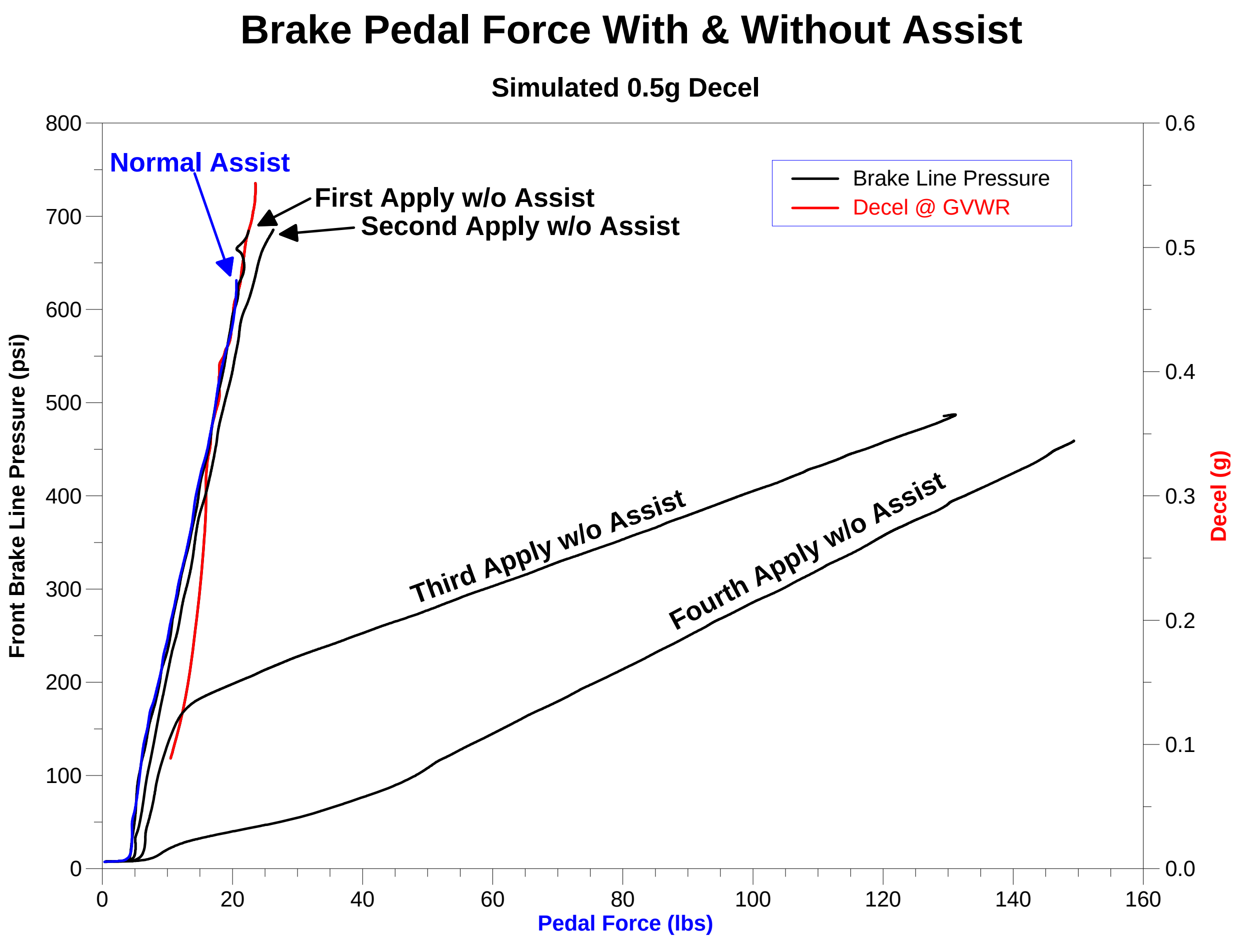

Figure 4
Brake Pedal Force vs. Brake Line Hydraulic
Pressure at Simulated 0.5G Decel

4.3.3 Simulation of 0.8G Deceleration

The data from the dynamic tests that were performed at LLVW showed that a deceleration of 0.8 G required 94 lb of brake pedal force and 3.9 inches of pedal travel. The data from the static test with the engine running showed that 3.9 inches of pedal travel produced 1440 psi of brake line hydraulic pressure at 93 lb of pedal force. In repeated brake applications without replenishing vacuum, the first application to 3.9 inches of pedal travel required 137 lb of pedal force and produced 1417 psi of brake line pressure. Subsequent applications to 3.9 inches required in excess of 250 of pedal force (limit of force transducer) and produced 1172 psi of brake line pressure. Figure 5 shows brake pedal force vs. vehicle deceleration from the dynamic test and brake pedal force vs. front brake line hydraulic pressure from the multiple static tests at a simulated 0.8G deceleration. Table 3 shows the data from the 0.8G dynamic tests and the simulated 0.8G static tests.

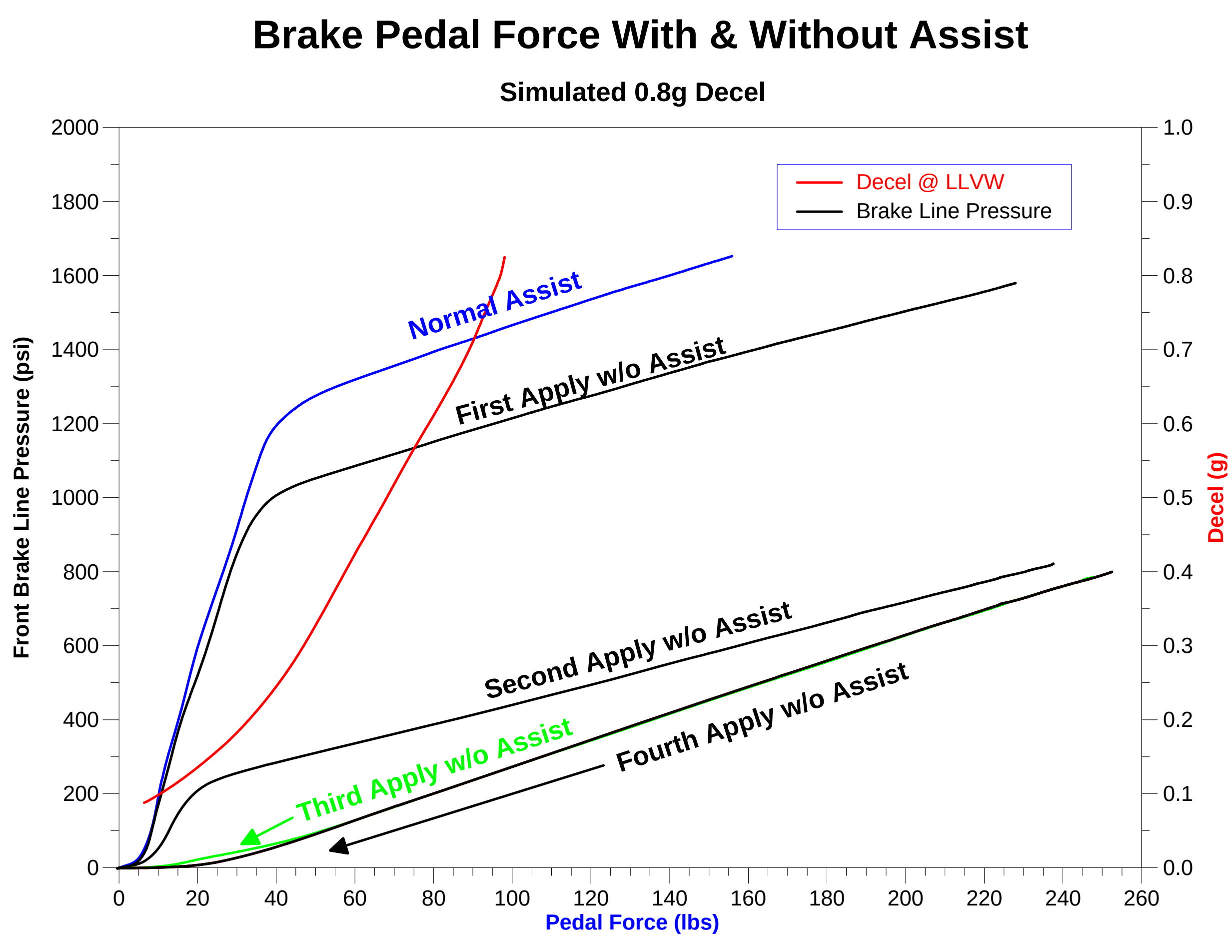

Figure 5
Brake Pedal Force vs. Brake Line Hydraulic Pressure at Simulated 0.8G Decel

	0.8G Decel Data			
	Pedal Travel (inch)	Pedal Force (lb)	Decel (G)	Line Pressure (psi)
Dynamic Test	3.9	94.4	0.9	N/A
Static Test	3.9	92.5	N/A	1440
Depl Test 1	3.9	137.1	N/A	1417
Depl Test 2	3.9	280+	N/A	1172

Table 3
Simulation of 0.8G Deceleration

5.0 Conclusions

- Increased vehicle loading required slightly increased pedal force to achieve a given deceleration rate. Tests for this program showed a constant increase of approximately 4 lb between LLVW and GVWR at deceleration levels up to 0.5G.

- Reserve capacity in the vacuum booster in this vehicle varied with the level of simulated deceleration. In repeated simulated 0.2G decelerations, four brake applications were possible with full brake assist available. When the repeated simulated deceleration was increased to 0.5 G, only two brake applications were possible with full brake assist available. When the repeated simulated deceleration was increased to 0.8 G, full brake assist was not even available in the first application.