12-2008

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REAR IMPACT CRASHWORTHINESS OF A MANUAL WC19 WHEELCHAIR OCCUPIED BY A 50TH PERCENTILE ATD

By

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B.S., University of Louisville, 2005

A Thesis
Submitted to the Faculty of the
University of Louisville
J.B. Speed School of Engineering
in Partial Fulfillment of the Requirements
for the Professional Degree

MASTER OF ENGINEERING

Department of Mechanical Engineering

December 2008

REAR IMPACT CRASHWORTHINESS OF A MANUAL WC19 WHEELCHAIR OCCUPIED BY A 50^{TH} PERCENTILE ATD

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ACKNOWLEDGEMENTS

First and foremost, I would like to thank my parents Ranko and Nermina Salipur who have made it possible for me to pursue a career in scientific research. I am eternally thankful for their endless sacrifices and bravery as my family sought refuge from war and immigrated to the United States. Throughout this difficult journey, they have insisted on the significance of education and intellect. They also instilled in me the value of hard work, decency, integrity, believing in oneself, and the greater good. My parents made my American Dream possible and ultimately led me to discover my research interest in rehabilitation engineering. This is why I am dedicating this thesis to them.

I would especially like to thank my thesis advisor, Dr. Gina Bertocci, for her mentorship. She helped me grow tremendously on both a professional and personal level by constantly challenging me and her guidance was invaluable throughout my thesis project. Dr. Bertocci helped me discover my passion for research for which I am forever thankful.

I am very thankful to Dr. Glen Prater, Dr. Naira Campbell-Kyureghyan, and Miriam Manary for serving on my thesis committee and providing very valuable support and input.

I also wish to thank Miriam Manary, Nichole Ritchie, and the entire UMTRI staff for their assistance in conducting sled tests, as well as Susan Fuhrman, Angela Knight, and

Raymond D’Souza for their aid during model development, troubleshooting, and validation.

This research was supported by a grant from the Paralyzed Veteran’s of America Spinal Cord Injury Research Foundation, Grant # 2422. The opinions expressed herein are those of the author and do not necessarily represent those of the funding agency.

ABSTRACT

For persons with disabilities, access to transportation is necessary for integration into society. The Americans with Disabilities Act (ADA) has been instrumental in assuring transportation access to individuals with disabilities for purposes of employment, education, and recreation. A substantial number of wheelchair users may not be able to transfer from their wheelchair to a motor vehicle seat during transportation. It is necessary to afford these wheelchair users the same level of safety as occupants seated in motor vehicle seats.

The purpose of this study was to investigate the response of a manual wheelchair used as a motor vehicle seat, while the motor vehicle is subjected to rear impact. The specific aims of the study were to (1) identify the most common wheelchair failure mechanisms in a forward facing manual wheelchair subjected to rear impact, (2) develop and validate a computer simulation model of a wheelchair and seated occupant in rear impact, (3) develop wheelchair manufacturer transportation safety design guidelines under rear impact conditions for adult manual wheelchairs, by defining critical loads, wheelchair response, and common failure mechanisms, and (4) develop Wheelchair Tiedown and Occupant Restraint System (WTORS) manufacturer safety design guidelines under rear impact conditions for securing adult manual wheelchairs, by defining critical loads.

In the first part of the study, several rear impact sled tests were performed with a commercial, WC19, manual wheelchair in its original configuration. The wheelchair occupant was represented by a midsized male anthropomorphic test device (ATD) and

the sled tests were carried out according to the proposed ISO rear impact standard. The first set of sled tests were used to identify common wheelchair failure mechanisms under rear impact conditions: front securement point hardware failure, seatback failure, and failure of the wheelchair frame.

A second set of sled tests were conducted with three reinforced, manual, WC19 wheelchairs which did not exhibit failures. Test results from the reinforced wheelchairs were used in the development and validation of a MADYMO™ computer simulation model of the rear impact scenario. During the validation process, key outcome measures from the sled tests were compared to those in the model. Statistical analysis was performed to quantify how well the model outcome measures matched those obtained from sled tests. The model was ultimately deemed validated and used to conduct the parametric sensitivity analysis.

In the parametric sensitivity analysis key model parameters were varied, while outcome measures associated with wheelchair component and WTORS loading were monitored. Together with the common wheelchair failure modes, the parametric sensitivity analysis yielded rear impact design guidelines for wheelchair and WTORS, which will aid in the design, development, and ultimately introduction of rear impact crashworthy wheelchairs and WTORS.

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I. INTRODUCTION

There are 2.3 million wheelchair users in the U.S. (LaPlante, M., 2003) and a substantial number may not be able to transfer from their wheelchair to a motor vehicle seat during transportation. It is necessary to afford these wheelchair users the same level of safety as occupants seated in motor vehicle seats. Aside from the Americans with Disabilities Act (ADA, 1991a), thus far only voluntary frontal impact standards have been introduced to address the issue of transportation safety for the disabled population: ANSI/RESNA WC19: Wheelchairs Used as Seats in Motor Vehicles (ANSI/RESNA, 2000) and SAE J2249: Wheelchair Tiedowns and Occupant Restraints (SAE, 1999). These standards specify frontal impact design guidelines, testing and labeling requirements for manufacturers, and user instructions for wheelchairs and wheelchair tiedowns and occupant restraints (WTORS). To-date, there are no adopted rear impact standards in the U.S. for wheelchairs or WTORS. Thus far very little wheelchair-related research has been done with respect to rear impacts, even though rear impacts account for 43.5% of all motor vehicle crash related injuries (Japan Traffic Safety Association, 1997) and 5.4% of fatalities (NHTSA, 2005). Because of these high injury and death rates due to rear impacts, it is important to evaluate the effects of rear impact on the wheelchair, wheelchair tiedowns and occupant restraint system (WTORS), and the wheelchair occupant. Therefore this study seeks to:

1. Identify the most common wheelchair failure mechanisms in a forward facing manual wheelchair subjected to rear impact.

Objective

i. Perform three forward facing rear impact sled tests with 50^{th} percentile Hybrid III anthropomorphic testing device (ATD) seated in a manual, X-braced, ANSI/RESNA WC19 wheelchair, secured by a four point strap-type tiedowns, and the ATD restrained with a vehicle anchored occupant restraint system (ORS). The following configurations will be evaluated:

   1. Wheelchair with factory settings and in original "out of the box" configuration.
   2. Once identifying a failure mechanism(s), reinforce the wheelchair to eliminate the already identified failure mechanism and identify others.

2. Develop and validate computer simulation model of a wheelchair and seated occupant in rear impact.

Objectives

i. Perform forward facing rear impact sled tests with 50^{th} percentile Hybrid III ATD seated in a reinforced, manual, manual, X-braced, ANSI/RESNA WC19 wheelchair, four point strap-type tiedowns, and the ATD restrained with a vehicle anchored ORS.

ii. Develop wheelchair-occupant computer model subjected to rear impact as in sled test scenario (2.i.) using MADYMO^{TM} crash simulation software.

iii. Validate wheelchair-occupant computer model using:

1. Comparison of gross wheelchair and ATD kinematics from model to those from sled tests.
2. Visual comparison of key outcome measure signals from model to the min/max corridor established from sled tests.
3. Conduct statistical analysis to quantify variation between model and sled test signals of key outcome measures.

3. Develop wheelchair manufacturer transportation safety design guidelines under rear impact conditions for adult manual wheelchairs, by defining critical loads, wheelchair response, and common failure mechanisms.

Objective

i. Using the validated computer simulation model perform a parametric sensitivity analysis by incrementally varying the model parameters below to determine critical wheelchair loads and their influence on wheelchair response to impact.

1. Parameters to be varied incrementally:
   a. Seatback stiffness
   b. Seatback angle
   c. Seat stiffness
   d. Front tiedown securement point locations
   e. Wheelchair weight
   f. ATD weight

g. Rear impact crash pulse severity

2. Critical wheelchair response and loading to be determined:

   a. Seatback deflection

   b. Seatback loading

   c. Seat loading

   d. Wheelchair rotation

   e. Front and rear wheel loading

   f. Securement point loading

4. Develop WTORS manufacturer safety design guidelines under rear impact conditions for securing adult manual wheelchairs, by defining critical loads.

   Objective

   i. Using the validated computer simulation model perform a parametric sensitivity analysis by incrementally varying model parameters below to determine critical WTORS loads.

      1. Parameters to be varied incrementally:

         a. Seatback stiffness

         b. Seatback angle

         c. Seat stiffness

         d. Front tiedown securement point locations

         e. Wheelchair weight

         f. ATD weight

         g. Rear impact crash pulse severity

II. BACKGROUND

A. Wheelchair User Demographics

According to LaPlante (2003), there are 2.3 million wheelchair users in the U.S., and this number is projected to reach 4.3 million by the year 2010, when the leading edge of the baby boom generation reaches 65 years old. The vast majority (83%) of wheeled mobility users use manual wheelchairs and 55.6% are elderly (65 years of age or older). Twenty three percent (23%) of the working age wheelchair user population live below the poverty line; double that of the general population. The rates of wheelchair use among men ages 18-44 yrs is actually higher than that among women, but after age 44 yrs, the rates are higher for women than for men. Native Americans are most likely to use wheelchairs (0.8%), followed by Whites (0.6%), African Americans (0.6%), Asian Americans (0.4%), and Hispanics (0.4%). The most prevalent conditions cited as causing mobility limitations among wheelchair and scooter users are arthritis (13%), stroke (11%), and multiple sclerosis (MS) (5%). Paralysis and orthopedic impairments are also common. MS and paralysis are most prevalent among nonelderly wheelchair users, whereas arthritis and stroke are most prevalent in elderly wheelchair users. (LaPlante, M., 2003).

About 80% of wheeled mobility device users say that public transportation is difficult to use or access and two-thirds say that it is very difficult. In 2002, only 6.5% of wheeled mobility device users who live in transit served areas have used public transportation, whether buses, rapid transit, subways, or street cars. Approximately 26%

of wheelchair and scooter users drive a vehicle and it can be approximated that a quarter will have used paratransit in the past 6 months. (LaPlante, M., 2003).

B. Disabilities Legislation

For persons with disabilities, access to transportation is key for integration into society. The Americans with Disabilities Act (ADA) has been instrumental in assuring transportation access to individuals with disabilities for purposes of employment, education, and recreation (ADA, 1991b). Along with many accessibility regulations, ADA also addresses transportation safety by specifying design loads for mobility device securement systems. The securement systems are required to withstand forward longitudinal loads up to 4000 lb (17 793 N) on large buses, and 5000 lb (22 241 N) on smaller buses (ADA, 1991a).

In February 2001, President G.W. Bush announced the "New Freedom Initiative, as part of a nationwide effort to remove barriers to community living for people with disabilities." (U.S. Department of Health and Human Services, 2003). The Initiative's goals are to increase access to assistive and universally designed technologies, expand educational opportunities, promote home ownership, integrate Americans with disabilities into the workforce, expand transportation options, and promote full access to community life. Offering accessible and safe transportation is essential to the success of the New Freedom Initiative. Other countries have also taken steps to make transportation more accessible. In East Asia and the Pacific, the governments of Australia, China, Fiji, Indonesia, Japan, Malaysia, New Zealand, the Philippines, Republic of Korea, Singapore, Thailand, and Vietnam adopted national policies on accessibility, including accessible public transport (Takamine, Y., 2004). Japan adopted the "Law for Promoting Easily Accessible Public Transportation Infrastructure for the Aged and the Disabled (2000)," and UK implemented the Disability Discrimination Act (1995) to assure wheelchair users are accommodated more safely in transit. With such legislation passed on both a national and international scale, it is projected that more wheelchair users will be accessing transportation to pursue employment, education, and recreation.

C. Wheelchair Transportation Standards

The use of original equipment manufacturer motor vehicle seats and occupant restraints during transportation is always recommended, when possible. However, some wheelchair users are not able to transfer from their wheelchair to a motor vehicle seat and therefore must travel seated in their wheelchair. Generally, the wheelchair can be secured to the vehicle by either a docking-type securement system or in many cases a tiedown system. The docking system allows for more independence for the wheelchair user, but adds weight to the wheelchair through additional hardware required for the interface between wheelchair and docking system. A docking system requires universal docking interface on wheelchairs. The interface hardware may alter the wheelchairs length, turning radius and ground clearance (Hobson, D. A. and van Roosmalen, L., 2007). In absence of a universal wheelchair-docking interface, four point strap-type tiedowns offer an alternative approach to securement. A tiedown-type wheelchair securement system usually involves four separate tiedown straps, one in each corner of the wheelchair (two in the front; two in the rear), which secure the wheelchair to floor of the vehicle. During transport, the wheelchair user also needs to be restrained with the use of a lap and shoulder belt ORS. The shoulder belt is typically vehicle-anchored, while the lap belt may be anchored to either the vehicle or the wheelchair.

Some voluntary wheelchair transportation safety industry standards have been adopted nationally and internationally to address transit related safety concerns:

The American National Standards Institute (ANSI) and Rehabilitation Engineering & Assistive Technology Society of North America (RESNA) have adopted the ANSI/RESNA WC19 “Wheelchairs Used as Seats in Motor Vehicles” standard (ANSI/RESNA, 2000). The WC19 standard focuses on wheelchairs as motor vehicle seats, proposing design requirements for manufacturers, providing instructions to users, and also specifying test procedures. A major requirement of WC 19 is the four-securement points on the wheelchair, whose location, geometry, and labeling are specified. Additional WC19 requirements include: a test for securement-point accessibility and tiedown clear paths, a test for wheelchair lateral stability, and a dynamic frontal impact sled test (48 km/h, 20 g). In the dynamic sled test, the wheelchair-seated occupant is represented by an appropriately sized ATD and restrained using a surrogate lap and shoulder belt, while the wheelchair is secured using surrogate wheelchair tiedowns. The Rehabilitation Engineering Research Center on Wheelchair Transportation Safety (RERC-WTS) reports that as of January 15, 2008 there are 123 wheelchairs that manufacturers reported comply with ANSI/RESNA WC19 (RERC-WTS, 2008). The WC 19 standard test criteria assess wheelchair integrity, as well as occupant and wheelchair kinematics, but only in frontal impact.

The International Standard Organization (ISO) has developed a frontal impact wheelchair standard known as ISO 7176-19 "Wheeled mobility devices for use in motor vehicles" (ISO, 2000). For the most part, ISO 7176-19 and ANSI/RESNA WC19 have been harmonized. However, ISO 7176-19 requires the use of a mid-sized male ATD and allows for wheelchair securement using commercial tiedowns.

ISO is currently working on a proposed forward facing rear impact wheelchair standard, ISO/TC173 "Forward facing wheeled mobility aids in rear impact" (ISO, 2006). This standard is similar to ISO 7176-19 and specifies wheelchair design and performance requirements and associated test methods, as well as labeling and user and maintenance instructions. Part of the ISO/TC173 standard is a dynamic rear impact sled test (25 km/h, 14 g). The design requirements include back support height specifications and head restraint height specifications, if the wheelchair is equipped with a head restraint. In the rear impact dynamic sled test, the wheelchair user is represented by an appropriately sized ATD and restrained by a surrogate vehicle-anchored ORS, while the wheelchair is secured using surrogate four point strap-type tiedowns. ATD and wheelchair kinematics, as well as wheelchair integrity are assessed in the rear impact dynamic test to determine whether a wheelchair is crashworthy in rear impact. Performance requirements for the dynamic rear impact sled test include ATD and wheelchair horizontal excursion limits, head-to-torso angle requirements for the ATD, and that the peak seatback angle should not exceed 65° to the vertical. Additionally, after the dynamic rear impact sled test the following criteria must be met to determine that the tested wheelchair is crashworthy in rear impact:

a) The wheelchair and ATD should be upright.
b) The wheelchair securement point should not exhibit any visible signs of failure.
c) No component larger than 100 g should have separated from the wheelchair.
d) No sharp components should contact the ATD.
e) Primary load carrying wheelchair components should stay intact.
f) Locking mechanisms for tilt seat adjusters should not fail.
g) Tilt seating should not change position.
h) Removal of wheelchair and ATD from sled should not require use of tools.

However, the ISO/TC173 rear impact standard is currently in development and has not been fully adopted.

There is also an Australian standard that addresses forward-facing wheelchairs under rear impact conditions: AS 2942-1987 “Wheelchair Occupant Restraint Assemblies for Motor Vehicles” (Standards Association of Australia, 1987). This standard establishes wheelchair performance criteria under rear impact dynamic loading (16 km/h, 8-15g). The performance criteria during dynamic loading include maintaining wheelchair integrity without fragmentation, keeping the ATD upright (within 20° of the initial position), limiting ATD hip and shoulder fore/aft horizontal excursions to 200 mm, and being able to remove the ATD and wheelchair from the sled without using tools. If the wheelchair is equipped with a headrest, the ATD peak resultant head acceleration should not exceed 75 g for more than 2 ms during the test once the ATD makes contact with the headrest.

D. Wheelchair Tiedown and Occupant Restraint System (WTORS) Standards

There are also domestic and international standards that address WTORS design specifications, labeling, and performance requirements:

The domestic WTORS standard is SAE J2249 "Wheelchair Tiedowns and Occupant Restraints" (SAE, 1999). The SAE J2249 standard specifies design requirements, requirements for instructions, documentation, and labeling, as well as performance requirements for WTORS. The performance requirements include a test for partial engagement of WTORS components, a tiedown webbing slippage test, and a dynamic frontal impact test (48 km/h, 20 g). The dynamic frontal impact test is performed with a mid-sized male ATD seated in a surrogate wheelchair. The performance criteria for the dynamic frontal impact test include maintaining the wheelchair and ATD in an upright position, maintaining the WTORS integrity and preventing tiedown separation from the wheelchair, limiting wheelchair and ATD excursions, as well as allowing removal of the ATD and the test wheelchair subsequent to the test without the use of tools. However, SAE J2249 does not require a dynamic rear impact sled test to determine WTORS crashworthiness in rear impact, which may be different than in frontal impact.

The international WTORS standard is ISO 10542 “Technical systems and aids for disabled or handicapped persons - Wheelchair tiedown and occupant-restraint systems” (ISO, 2001). ISO 10542 has mostly been harmonized with SAE J2249 and also has design requirements, identification, labeling, instruction and warning requirements, as well as performance requirements, including a dynamic frontal impact sled test (48 km/h, 20 g). The requirements in ISO 10542 are very similar to those in SAE J2249, but also do not include a dynamic rear impact sled test to determine WTORS crashworthiness in rear impact.

E. Automotive Industry Regulations and Standards

Wheelchair transportation standards have generally been modeled after the automotive industry standards. Federal Motor Vehicle Safety Standards and Regulations (FMVSS) applying to the automotive industry address transportation safety. The FMVSS are designed to protect the public against unreasonable risk of crashes occurring as a result of the design, construction, or performance of motor vehicles. FMVSS also protect the public against unreasonable risk of death or injury in the event crashes do occur.

The FMVSS 208 – Occupant Crash Protection (National Highway Transportation Safety Administration, 2004) specifies performance requirements for passive and active occupant restraint systems for the protection of vehicle occupants in crashes. This standard applies to passenger cars, certain multipurpose passenger vehicles, trucks, and buses. Originally, it specified occupant restraint types, but has been amended since to determine ORS crashworthiness in frontal impact (48 km/h, 20 g).

FMVSS 202 – Head Restraints (National Highway Transportation Safety Administration, 1998a) was introduced to reduce head and neck injury in rear impact by establishing head restraint standards for passenger cars and light trucks. The standard allows for the head restraint integrity to be evaluated with either a dynamic test, where a large ATD's head excursion may not exceed 45 deg, or with a static strength test, whereas certain head restraint geometric requirements must be satisfied.

FMVSS 207 – Seating Systems (National Highway Transportation Safety Administration, 1998b) specifies strength of seatbacks and seat attachment hardware. This standard includes a quasi-static test, in which the seatback is loaded longitudinally in both forward and rearward directions to assure that the seat will not slide during a possible crash. In another quasi-static test, the seat-to-seatback interface is tested to avoid seatback failure. There is also a dynamic test, where the unoccupied seat is subjected to 20g acceleration. Sideways facing seats are exempt.

FMVSS 210 – Seatbelt Assembly Anchorages (National Highway Transportation Safety Administration, 1998c) establishes requirements for seat belt assembly anchorages, specifying their appropriate location for effective occupant restraint, while reducing the likelihood of failure. The standard applies to all seatbelt components that transfer loading to the vehicle, other than the webbing or straps.

FMVSS 301 – Fuel System Integrity (National Highway Transportation Safety Administration, 2003) addresses a possible risk from fuel leaking in a rear impact, by subjecting the target vehicle to an impact by a flat, rigid barrier with a velocity of 48.3 km/h. The crash severity will differ between vehicles, since it is a function of vehicle mass and rear end stiffness. Since seatbacks are not addressed in FMVSS 301, it is possible to pass this standard, while exhibiting seatback failure. However, it may be assumed that bad publicity associated with FMVSS 301 outcomes has given manufacturers an incentive to design stronger seatbacks in their motor vehicles.

SAE J211 – Instrumentation for Impact Tests (Society of Automotive Engineers, 1988) is a standard which specifies data collection and filtering during crash or sled impact testing. SAE J211 specifies electronic instrumentation, electronic data collection frequency and post-test filtering. SAE J2249 also specifies photographic instrumentation recommendations and guidelines for head contact duration analysis.

The United Nations Economic Commission for Europe (UNECE) also has regulations that address motor vehicle occupant safety:

ECE Regulation 32 – Uniform Provisions Concerning the Approval of Vehicles with Regard to the Behaviour of the Structure of the Impacted Vehicle in a Rear-End Collision (United Nations Economic Commission for Europe, 1993) was introduced to test rear impact integrity when the vehicle is impacted by a rigid barrier at 35-38 km/h. This standard addresses door and door latch performance issues, as well as whether the vehicle occupant space remains intact during rear impact.

ECE Regulation 17 – Uniform Provisions Concerning the Approval of Vehicle With Regard to the Seat, their Anchorages and Any Head Restraints (United Nations Economic Commission for Europe, 2002a) addresses forward facing seats, seatbacks, and headrests in smaller passenger vehicles. The standard specifies energy dissipation of headrests, headrest position and dimensions, locking systems for moving seat parts, seat anchor and attachment reliability before and after rear impact. Compliance may be confirmed with a dynamic 48-53 km/h rear impact test, or with component testing.

ECE Regulation 44 – Uniform Provisions Concerning the Approval of Restraining Devices For Child Occupants Of Power-Driven Vehicles (United Nations Economic Commission for Europe, 2002b) attends to many aspects of child restraint systems. The standard specifies a dynamic rear impact test (29 km/h, 14-21g) and quantifies child restraint performance with ATD head excursion, head contacts, chest accelerations, as well as ATD abdominal loading. Abdominal loading is determined by visual inspection of modeling clay added to the ATD lumbar vertebrae.

F. Anthropomorphic Testing Devices (ATD)

The anthropomorphic test device (ATD), anthropomorphic test dummy, or crash test dummy is a mechanical surrogate representation of the human body. Developed by the aviation industry to test parachutes and ejection seats, ATDs were later adopted by the automotive industry for safety evaluation in motor vehicles. ATDs are generally required to fulfill multiple requirements. They ought to be sensitive to parameters relating to injury mechanisms. ATDs must be as biofidelic as possible by mimicking relevant human physical traits such as stiffness, energy absorption and energy dissipation, as well as kinematic response. Another important trait is the anthropometry addressed by appropriate size, shapes, and inertial properties. Repeatability and durability are also essential ATD characteristics.

General Motors developed the Hybrid III family of ATDs (ranging from the CRABI 6 month old to the 95^{th}-percentile/large male) in the 1970s and they are currently used in U.S. and worldwide regulations. Instrumentation onboard the Hybrid III ATD can measure linear and angular head acceleration, upper and lower neck loads (shear and axial) and moments, chest accelerations and deflections, pelvic acceleration, as well as lower extremity loading data (Nahum, A. M. and Melvin, J. W., 1993). The Hybrid III ATD has been designed for use in frontal impact. To address rear impact concerns, the biofidelic rear impact dummy (BioRID) and the RID2 – rear impact dummy have been developed in Europe. However, the BioRID and RID2 are intended for lower severity rear end crashes, where “whiplash” injuries occur (Schmitt, K. U., Niederer, P. F. et al., 2004).

G. Overview of MADYMO™ computer modeling software

MADYMO™ (MAthematical DYnamic Modeling) is an advanced software engineering tool developed by TNO (Delft, Netherlands). Although it was originally developed for studying occupant behavior during car crashes, MADYMO™ can be used to analyze collisions involving other means of transport such as motorcycles, bicycles, airplanes, and trains. MADYMO™ was also previously used to study occupant safety in wheelchair transportation, like the frontal impact model of a pediatric wheelchair and seated occupant (Ha, D. R., Bertocci, G. E. et al., 2007). MADYMO™ has combined capability of finite element and rigid multi-body modeling. Multi-body modeling can be used for the simulation of gross motion of systems of bodies connected by different kinematic joints, while finite element techniques can be applied to simulate structural behavior. A model can consist of rigid bodies, finite element bodies, or a combination of the two (TNO, 2006). TNO also offers a database with a variety of ATD models representing crash ATDs available in the industry, like the 50th percentile Hybrid III ATD. The ATD models can be classified into three groups: multi-body, facet, and the finite element ATD. Each model is calibrated and validated through component testing, as well as dynamic crash testing (TNO, 2007).

H. Previous wheelchair transportation related research

Since nearly all wheelchair transportation safety standards address frontal impact, wheelchair transportation safety research has largely focused on frontal impact. However, some rear impact studies have also been performed.

a. Frontal Impact Studies

Before the introduction of ANSI/RESNA WC19, an early wheelchair transportation study used computer simulation to establish transportable wheelchair design criteria (Bertocci, G. E., Hobson, D. A. et al., 1996). The goal of the study was to evaluate loads imposed upon a wheelchair, when subjected to a frontal crash (48 km/h, 20 g). The model utilized DYNAMAN (GESAC Inc, Kearneysville, WV) crash simulation software and featured a surrogate-powered wheelchair, secured with a four-point strap tiedown system. The occupant, represented by a 50th percentile ATD was restrained with a wheelchair anchored pelvic belt and a vehicle anchored shoulder belt. Securement point, seat, lap belt anchor, and wheel loads were measured for three different securement configurations. The model was previously validated. Results showed that locating the rear securement points near the wheelchair's center of gravity could reduce wheelchair loads, while also limiting wheelchair rotation. With rear securement point location at the wheelchair's center of gravity, the maximum rear securement point loads were 21 033 N, while front securement point loading maxed out at 100 N.

Bertocci, et al. also used computer model and sled testing to develop and validate a powerbase wheelchair and occupant subjected to frontal crash conditions (Bertocci, G. E., Szobota, S. et al., 1999). The model simulated a commercial powerbase wheelchair, four-point strap-type tiedowns, three-point lap and shoulder belt system. The wheelchair occupant was represented by a 50th percentile Hybrid III ATD and the average sled deceleration pulse was 48 km/h – 20 g. Validation utilized data from two sled test runs.

First, the gross motions of the occupant and wheelchair in the model were compared to those from sled testing. Peak values and general time history profiles of the following model parameters were compared to sled test results: WTORS loads, resultant head, chest, and wheelchair accelerations, along with head and front wheel excursions. Only limited statistical methods were employed in the validation process by calculating peak value and range percent difference between the model and sled test results for all the validation parameters. The authors concluded that this study yielded a validated computer model that provides a basis for studying frontal crash response of powerbase wheelchairs occupied by mid-sized males.

A study by Leary and Bertocci set out to establish manual wheelchair design criteria for frontal impacts with the use of computer simulation (Leary, A. and Bertocci, G. E., 2001). The computer model was built using DYNAMAN crash simulation software, while the only sled test used to validate the model was conducted in accordance to ANSI/RESNA WC19, with a crash pulse severity of 48 km/h – 20 g. During the validation process, the gross occupant and wheelchair kinematics were first compared visually. The time histories of various parameters were also compared to those in the sled test: shoulder belt loading, lap belt loading, (rear) tiedown loading, wheelchair acceleration, ATD chest acceleration, and ATD pelvic acceleration. Validation criteria were established as having "relatively similar" peak values and "profile fit" between simulation and sled test. No statistical techniques were utilized for validation. The post-validation parametric sensitivity analysis showed that vertical rear securement point position greatly affects wheel loading and wheelchair stability in frontal impact.

A study focused on pediatric transit wheelchairs resulted in the development and validation of a computer model with a 6-year-old occupant seated in a wheelchair, subjected to frontal impact (Ha, D. R., Bertocci, G. E. et al., 2007). This study conducted frontal impact (48 km/h, 20 g) sled testing using three identical Sunrise Medical Zippie pediatric wheelchairs and a Hybrid III 6-year-old ATD to represent the wheelchair occupant. The sled testing was conducted in accordance with ANSI/RESNA WC19. Ha, Bertocci, et al. then reconstructed the sled test scenario in a computer model using MADYMO™ crash simulation software. In the validation process, a visual comparison of the sled test videos and the model animation output was conducted. The authors also compared the trends and peaks of outcome measure time histories in the model to those acquired during sled testing. The outcome measures used in the comparison were wheelchair acceleration, wheelchair rear tiedown forces, occupant restraint shoulder and lap belt forces, and ATD chest and head accelerations. Additionally, a comparison between the model and sled test peak horizontal excursions was made with respect to the wheelchair, ATD knee, and ATD head in the forward direction. The statistical analysis in the validation process consisted of determining percent of peak difference, Pearson's correlation coefficient (r), and performing a linear regression analysis of model and sled test peak values. The statistical analysis results were compared to initially defined criteria and to those from studies conducted previously. The authors concluded that their model was valid and could be used as a foundation for studying injury risk associated with children traveling seated in wheelchairs and providing pediatric wheelchair design guidelines.

A recent study resulted in the development and validation of a computer simulation model of an occupied adult manual wheelchair subjected to a frontal impact (Dsouza, R. and Bertocci, G. E., 2008). Two sled tests were conducted in compliance with the ANSI/RESNA WC19 standard, using a crash pulse of 48 km/h – 20 g. A computer simulation model was developed using MADYMO^{TM} crash simulation software. In the first step of the model validation process, the model-predicted gross kinematics of wheelchair and ATD were visually compared to those recorded from the high-speed sled test videos. Secondly, the model's predicted time histories of force and acceleration data were super-imposed over respective time history min/max corridors from the sled tests. Various model parameters were tuned until time history plots shared similar trends between the model and sled tests. Finally, this study used statistical analysis to quantify the association between model and sled test outcome measures. The average signal from each parameter in the two sled tests was used in the statistical comparison. The statistical analysis utilized five statistical tests to quantify various relationships between each model and sled test outcome measure signal. The authors concluded that the developed computer model was valid and can provide a means for studying wheelchair and WTORS loading, as well as potential occupant injury risk.

b. Rear Impact Studies

Paskoff (Paskoff, G., 1995) investigated wheelchair user neck injury risk during rear impact. The study involved the use of a computer simulation model using

DYNAMAN software. The goal was to examine the roles of seat back height, seatback stiffness, and effectiveness of a head restraint at different impact speeds to determine effects on occupant head response, and neck loads and kinematics. Neck injury criteria was obtained and compared to injury thresholds. The two relatively low crash pulse severities used by Paskoff in this study were 8 km/h – 4 g and 16 km/h – 8 g.

The model development was based on experimental data from quasi-static testing of wheelchairs and wheelchair head rests. The DYNAMAN model featured a modified powered wheelchair and a 50th percentile Hybrid III ATD with a modified RID neck. Even though the model was able to describe occupant kinematics and forces to some extent, the model was not validated in rear impact using dynamic crash testing.

The results from this study indicate that head restraint is beneficial in reducing non-contact neck injury. Seatback height was not found to be a dominant factor affecting occupant kinematics at the low speed. Back stiffness had a large effect on the forces and moments in the ATD neck.

A study by Fuhrman, et al. was the first examining pediatric wheelchair response and WTORS loading under rear impact conditions (Fuhrman, S. I., Karg, P. et al., 2006). This sled test study subjected two identical, pediatric, WC19-compliant, manual wheelchairs to rear impact conditions (26 km/h, 10g). Surrogate WTORS were used, while the occupant was represented with a Hybrid III 6-year old ATD. The study depicted the nature of rear impact dynamics and found that WTORS loads in rear impact differed substantially when compared to WTORS loads in frontal impact. In this rear impact study, peak frontal tiedown loads were 3473-4000 N with peak rear tiedown loads being 346-1117 N. These results highlight that rear impact dynamics cause higher front tiedown loadings than those in frontal impact reported by (Bertocci, G. E., Hobson, D. A. et al.) (100 N).

A recent sled test study was conducted to evaluate the crashworthiness of wheelchairs under rear impact conditions (Manary, M. A., Bezaire, B. A. et al., 2007). The goal was to evaluate the rear impact crashworthiness of 9 frontal impact crashworthy ANSI/RESNA WC19 wheelchairs. The crash severity (25-32 km/h, 12-14 g) was varied in the study, which aided in refining the proposed ISO rear impact standard (International Organization for Standardization, 2006). This study ultimately provided valuable knowledge on wheelchair failure modes under moderate-to-severe rear impact conditions. Wheelchair seatback bending or collapse was found to be the most frequent mode of wheelchair failure. Secondly, the study found that front wheelchair tiedown securement points must be made stronger to withstand loading associated with rear impact dynamics.

III. METHODS

A. Rear Impact Sled Testing of Wheelchair and Occupant

a. Original and partially reinforced wheelchair (for identifying common failure mechanisms)

Three manual, folding, X-braced wheelchairs of the same make and model that comply with ANSI/RESNA WC19 were available for rear impact sled testing. The first wheelchair was in its original "out of the box" configuration as supplied by the manufacturer. Once the initial sled test was conducted and the first failure mechanism was identified, the second wheelchair was be reinforced in a manner that would prevent or minimize the failure means seen in the initial sled test. The goal of the second rear impact sled test was to aid in identifying additional failure mechanisms. The same procedure was repeated in the third sled test, after supplemental reinforcement to identify additional modes of failure.

The wheelchair-seated occupant was represented by a 50^{th} percentile Hybrid III anthropomorphic testing device (ATD – 78.3 kg), while the pulse (25 km/h, 14 g) was as described in the proposed ISO/TC 173 rear impact standard (ISO, 2006).

b. Completely reinforced wheelchair (for developing/validating computer model)

Three identical, reinforced, manual, folding, X-braced wheelchairs (25.1 kg) that comply with ANSI/RESNA WC19 were subjected to a rear impact crash pulse. The wheelchair-seated occupant was represented by a 50th percentile Hybrid III anthropomorphic testing device (ATD – 78.3 kg), while the pulse (25 km/h, 14 g) shown in FIGURE 1 was as described in the proposed ISO/TC 173 rear impact standard (ISO, 2006).

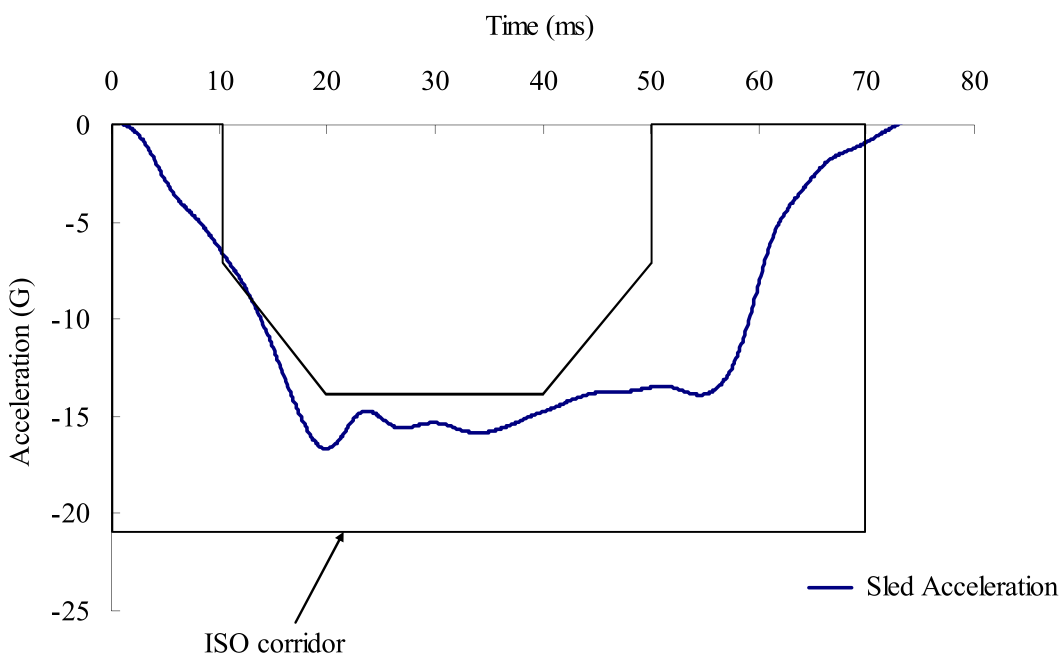

FIGURE 1. Sled Deceleration Pulse vs. Proposed ISO/TC 173 Rear Impact Standard Corridor (Shaded)

Conforming to ANSI/RESNA WC19, a surrogate, vehicle-mounted, 3-point lap and shoulder belt, ORS were used to restrain the ATD during the impact, while the wheelchair was secured with surrogate, four-point strap-type tiedowns. The rear tiedowns and ORS were both instrumented with three-bar belt load cells (Denton Corp.), measuring tension forces in the webbing during the impact sled test. Instrumented rod-ends measured front tiedown loads. Multiple views of the sled tests were captured using Kodak HG 2000 high-speed digital cameras (1000 frames/sec). High contrast markers were placed on the wheelchair and ATD to track kinematic response, while all other signals were acquired and filtered in accordance with SAE J211, Instrumentation for Impact Tests (SAE, 1988).

B. Computer Model Development

The rear impact sled test scenario described above was reconstructed using MADYMO^{TM} crash simulation software. MADYMO^{TM} was also previously used to develop a frontal impact model of a pediatric wheelchair and seated occupant (Ha, D. R., Bertocci, G. E. et al., 2007).

The wheelchair frame, wheels, seat, and seatback were modeled using multi-rigid body ellipsoids. The masses of these major wheelchair components were measured and their moments of inertia were calculated; both to be incorporated into the model. In the case of the wheelchair frame, frame tubing was lumped together and represented in one body. The moments of inertia of individual frame components were combined using the parallel axis theorem, while their masses were simply summed. The seat was modeled using one ellipsoid surface linked to the seat body, while the seatback was modeled with one body and two ellipsoid surfaces (lower- and upper-back) which allowed for different seatback stiffness at the lower-back vs. the upper-back..

A validated ellipsoid ATD was imported from the TNO database. The 50^{th} percentile ellipsoid ATD has 37 rigid bodies connected by numerous revolute, translational, revolute/translational, and spherical joints. The ATD segment inertial properties, joint and segment stiffness, as well as additional properties have been measured quasi-statically. The ellipsoid ATD has been validated by TNO in a series of tests by TNO, including a frontal impact sled test (48 km/h, 20 g) (TNO, 2007). The four strap-type tiedowns were represented using belt segments, while the occupant restraints (lap and shoulder belt) were modeled using finite element belts.

C. Computer Model Validation

Validation of the model involved matching the model outcome measures to those from the sled tests. The outcome measures evaluated in the model validation are shown in TABLE I below:

TABLE I

LIST OF OUTCOME MEASURES USED IN MODEL VALIDATION

	Outcome measure
1	Front tiedown loading
2	Lap belt loading
3	Wheelchair acceleration (in the direction of travel)
4	ATD resultant head acceleration
5	ATD resultant chest acceleration
6	ATD resultant pelvic acceleration

In an initial visual comparison, video from the sled tests and simulations was used to assess the gross wheelchair and ATD kinematics. Secondly, a min-max corridor was established for all outcome measures using time history data from the three sled tests. The simulation output was then graphically over-laid onto the corridors for visual comparison of general curve shapes. This visual comparison between the time histories was used as a primary means to determine model validity. Finally, four statistical tests were used to quantify and further test agreement between the sled test and simulation outcome measure time histories. Since three sled tests were conducted, the average sled test signal was compared to the signal obtained from the model. The statistical tests were conducted using CurveAnalyzer statistical software (Larsson, A., Pettersson, M. et al., 2003). A summary of the tests and test criteria used in the statistical analysis are shown in TABLE II below:

TABLE II

SUMMARY OF STATISTICAL TESTS AND TEST CRITERIA FOR MODEL VALIDATION ASSESSMENT

Statistical Test	Mean Value Ratio	Correlation Coefficient	Std. Deviation of Residuals	Peak Value
Criteria	L=0.80–1.20	r=0.8	$\sigma_d \leq 0.2P_s$	(+/- 20%, +/- 5ms)

The statistical tests and test criteria were chosen based on a previously conducted study (Pipcorn, B. and Eriksson, M., 2003). Historically, statistical analysis was not conducted to assess validation in occupant crash simulation models. The study by Pipcorn, et al. attempted to quantify the previous subjective approach to model validation. The four statistical tests chosen by the authors and shown in TABLE II address different aspects of signal comparison.

Mean Value Ratio test

The mean value ratio (L) of the signals was computed using

$$L = \frac{\bar{s}_{sledtest}}{\bar{s}_{\mathrm{mod}\,el}} \tag{1}$$

$$\bar{s} = \sum_{i=1}^{n} \frac{f_i}{n} \tag{2}$$

where $\bar{s}$ is the signal mean, f_i is the amplitude of the signal to be compared, i is each point in time, and n is the number of samples. The signal mean value was divided by the signal mean from the model, with a result near unity indicating that the two time histories are likely to be the same or related. The suggested validity range was a result L= 0.80–1.20.

Correlation test

The correlation coefficient (r) will be calculated using

$$r = \frac{\sum_{i=1}^{n}\left(f_i - \bar{f}\right)\left(g_i - \bar{g}\right)}{\sqrt{\sum_{i=1}^{n}\left(f_i - \bar{f}\right)^2 \sum_{i=1}^{n}\left(g_i - \bar{g}\right)^2}} \tag{3}$$

where f_i is the amplitude of the sled test signal, g_i is the amplitude of the model signal, i is each point in time, $\bar{f}$ is the sled test signal mean, $\bar{g}$ is the model signal mean. The suggested validity range was be $r > 0.80$.

Standard Deviation of Residuals test

Since the sled test data and model data was obtained at the same frequency, each signal data point in the sled tests had a corresponding signal data point in the model. The difference between the two data points is the residual. Standard deviation of residuals (σ_d) was be calculated using

$$\sigma_d = \sqrt{\frac{n\sum_{i=1}^{n} {d_i}^2 - \left(\sum_{i=1}^{n} d_i\right)^2}{n(n-1)}} \tag{4}$$

where d_i is the residual, i is each point in time, and n is the number of data points. The suggested boundary value for σ_d was 20% of the peak value from the sled test signal (P_s).

Peak Value test

When comparing signal peaks from the model to those from sled tests, the peak value assessment was not only considering the magnitude of each peak, but also when this peak occurs. The proposed method was to establish a boundary region around the sled test peak (P_s). The lower bound of the region was 80%, while the upper bound was 120% of the sled test peak. The right and left bounds of the time region were +/- 5 ms of when the sled test peak occurs. The model peak needed to fall within the region for the peak value to be considered valid. Only the primary peak in each signal was evaluated, while secondary peaks were ignored.

D. <u>Parametric Sensitivity Analysis</u>

Using the validated computer simulation model, a parametric sensitivity analysis was conducted which investigated the influence of numerous parameters on critical wheelchair and tiedown loading. Each parameter was varied incrementally, one at a time, while others were kept constant. TABLE III shows a summary of the model parametric sensitivity analysis plan.

TABLE III

PARAMETRIC SENSITIVITY ANALYSIS USING VALIDATED COMPUTER SIMULATION MODEL

Model parameters varied	Wheelchair	seatback stiffness seatback angle seat stiffness front tiedown securement point location
	ATD	increased ATD weight
	Other	impact severity
Outcome measures	Wheelchair	seatback deflection normal/shear forces on seatback normal/shear forces on seat pan wheelchair pitch/rotation front/rear wheel forces securement point loading
	WTORS	front tiedown loading rear tiedown loading lap belt loading shoulder belt loading

The parametric sensitivity analysis yielded critical wheelchair and tiedown loading patterns, when a manual wheelchair, occupied by a 50^{th} percentile ATD, was subjected to a moderate severity rear impact scenario (25 km/h, 14 g). Additionally, with the parametric sensitivity analysis, the influence of various parameters on outcome measures could be identified. This critical information may aid wheelchair and tiedown manufacturers in the design of rear impact crashworthy products.

IV. RESULTS

A. <u>Rear Impact Sled Testing of Wheelchair and Occupant</u>

a. Original and partially reinforced wheelchair (for identifying common failure mechanisms)

Three sled tests for identifying common wheelchair failure mechanisms were conducted on two separate occasions at the University of Michigan Transportation Research Institute (UMTRI) sled test facility. FIGURE 2 shows a typical test set-up.

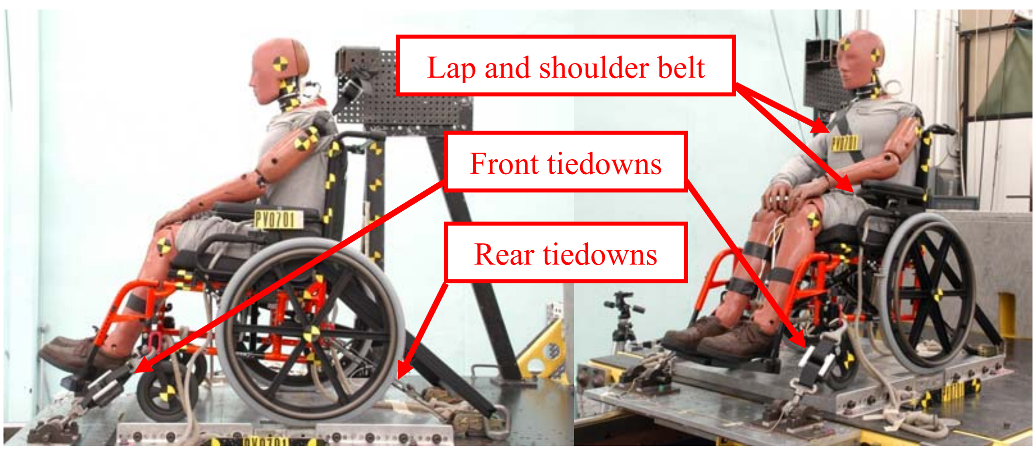

FIGURE 2. Typical Sled Test Set-Up of Wheelchair and ATD.

The 50th percentile Hybrid III ATD was seated in the wheelchair and restrained with a sled anchored, surrogate lap and shoulder belt. The wheelchair was secured to the sled using four-point strap-type, surrogate tiedowns. The impact sled simulated a rear impact crash event of 25 km/h, 14 g.

The most common wheelchair failure mechanisms were front securement point hardware failure, seatback failure, and frame failure. FIGURES 3-5 show these failures that occurred in this series of sled testing.

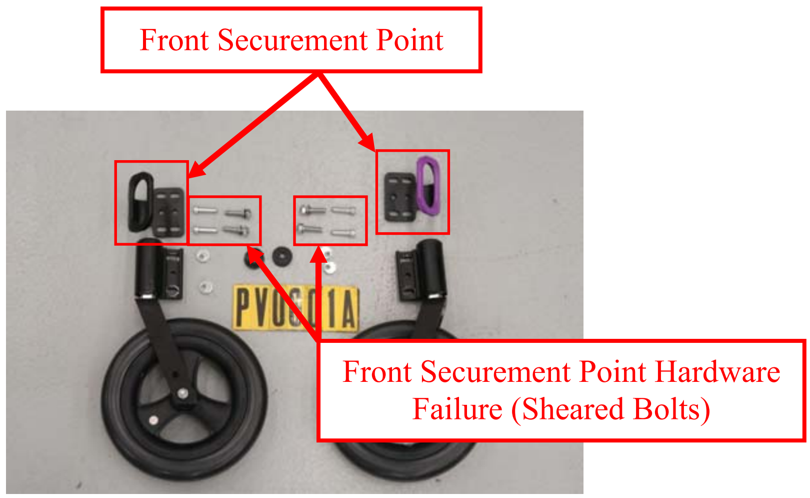

FIGURE 3. Front Securement Point Hardware Failure (Pre-Reinforced) Showing Sheared Bolts.

The front securement point hardware in FIGURE 3 failed (bolt sheared) in rear impact and allowed the securement point and attached front caster to separate from the wheelchair. The wheelchair and occupant both ended up on the floor of the sled. FIGURES 4 and 5 show seatback and frame failure respectively. These failure modes were found once the front securement point hardware was reinforced. The seatback failed in bending (FIGURE 4) allowing the ATD to be ejected from the wheelchair. The frame failures in FIGURE 5 exhibit bending of frame members and cracks at the welds.

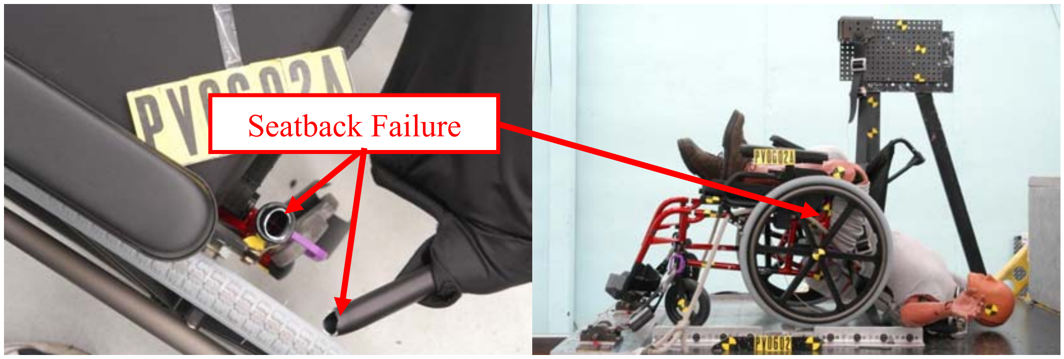

FIGURE 4. Seatback Failure (Pre-Reinforced).

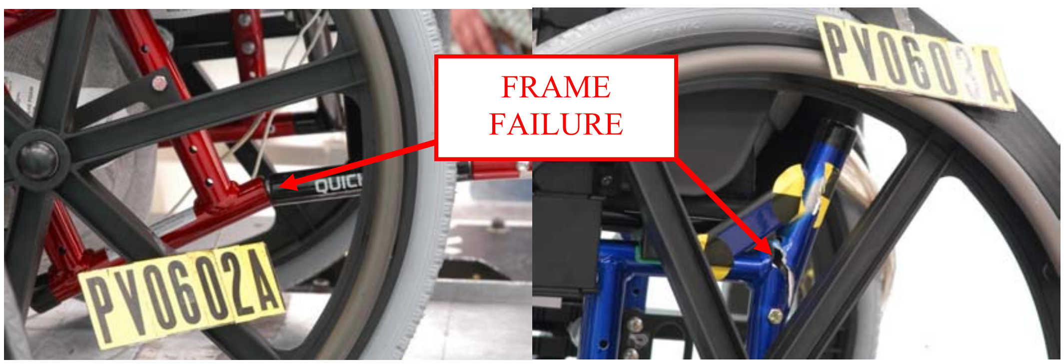

FIGURE 5. Frame Failures (Pre-Reinforced).

b. Completely reinforced wheelchair (for developing/validating computer model)

Three sled tests with three identical, completely reinforced wheelchairs (reinforced front securement point hardware, seatback, and wheelchair frame) for model validation were also conducted on two separate occasions at the UMTRI sled test facility. FIGURE 6 shows a frame sequence during a typical sled test.

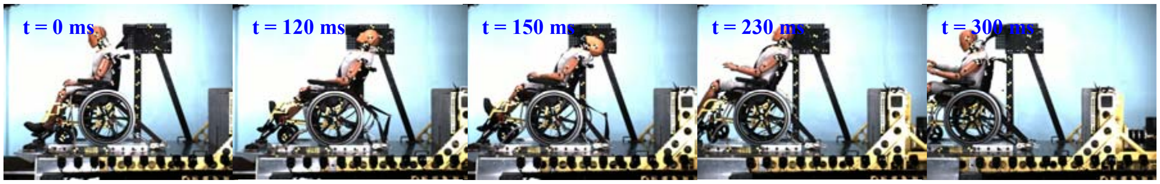

FIGURE 6. Frame Sequence (Left To Right) of Typical Rear Impact Test.

B. <u>Computer Model Development</u>

The model was developed in MADYMO™. FIGURE 7 shows the wheelchair model and the imported 50th percentile ATD. The complete MADYMO™ code for the model is in the Appendix.

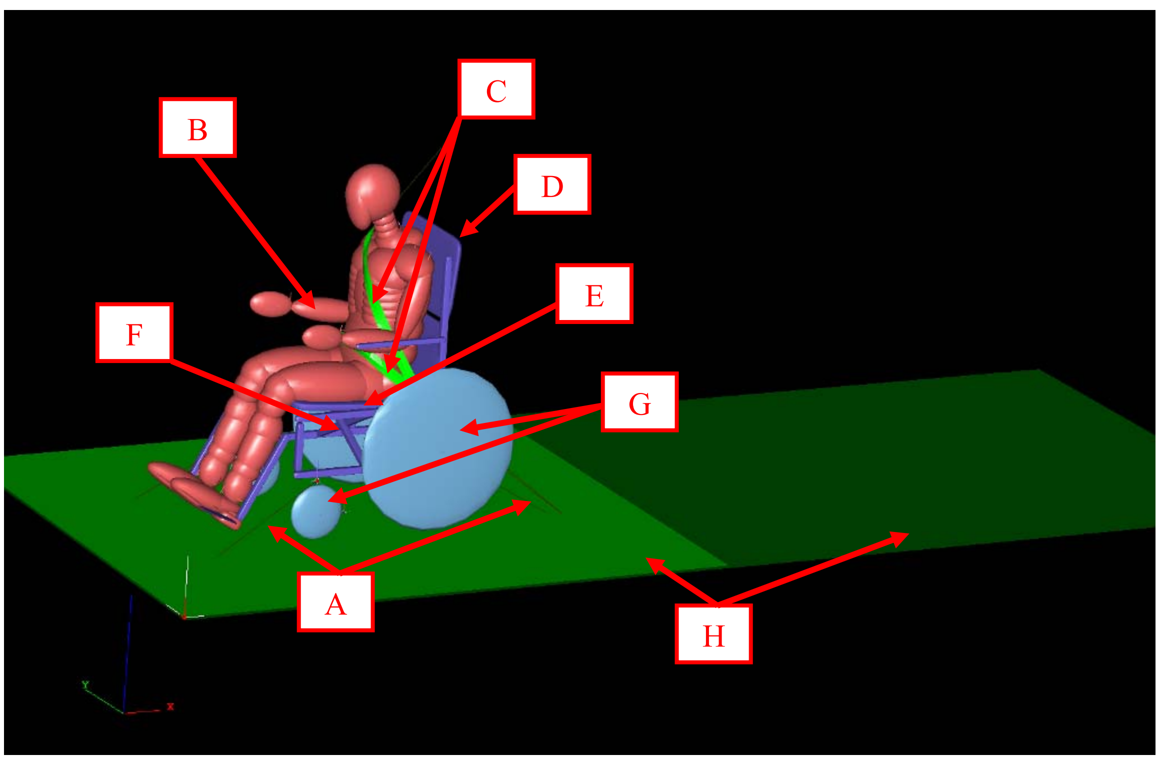

FIGURE 7. Forward-Facing Rear Impact Wheelchair Model With 50th Percentile ATD.

The wheelchair in the model was secured with front and rear tiedowns modeled with belt segments [A]. The 50th percentile ATD [B] was imported from a TNO database. The lap and shoulder belts [C] were modeled with finite element belts, while the wheelchair seatback [D] was modeled with 2 ellipsoid surfaces and 2 translational-revolute joints. This allowed for differences in stiffness at the top and at the bottom of the seatback. The wheelchair seat [E] was modeled with an ellipsoid surface and translational joint. The wheelchair frame [F] was represented by 1 body and 15 ellipsoid surfaces, while the individual wheels [G] were modeled using single surface ellipsoids. The sled and track [H] were represented using plane surfaces and 1 translational joint.

C. Computer Model Validation

The model was validated with respect to the six outcome measures from TABLE I. The initial validation was done by comparing wheelchair and ATD gross kinematics from the sled tests to those from the model. FIGURE 8 shows both a typical frame sequence during sled testing (top) and the corresponding frames during the model simulation (bottom).

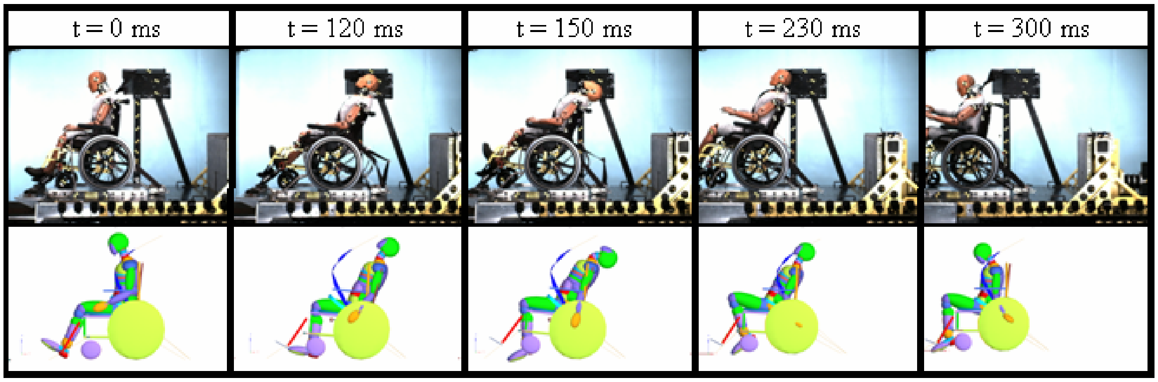

FIGURE 8. Frame Sequence of Typical Rear Impact Test (Top) and Computer Simulation Model (Bottom).

FIGURES 9-20 show the time history comparisons between sled tests and model for the six outcome measures.

FIGURE 9 shows a comparison of the model front tiedown loading to the min-max corridor from sled testing. The model front tiedown loading curve generally falls within the sled test min-max corridor and has a peak value of 7266 N per tiedown. FIGURE 10 compares the front tiedown loading time histories for the model and each individual sled test run.

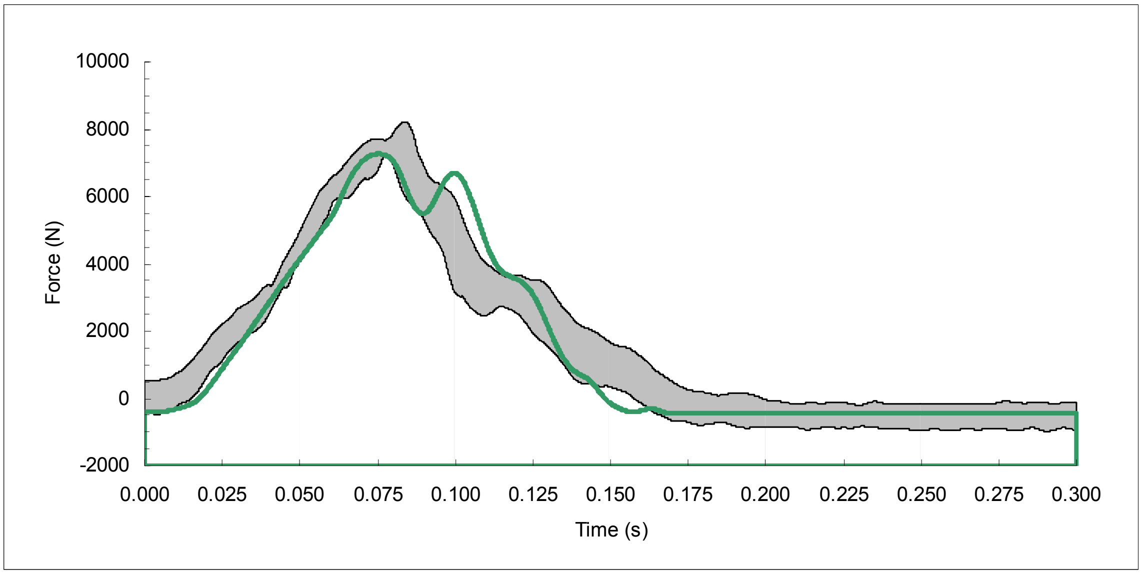

FIGURE 9. Front Tiedown Loading: Model (Green Solid Line) vs. Sled Test Min-Max Corridor (Shaded).

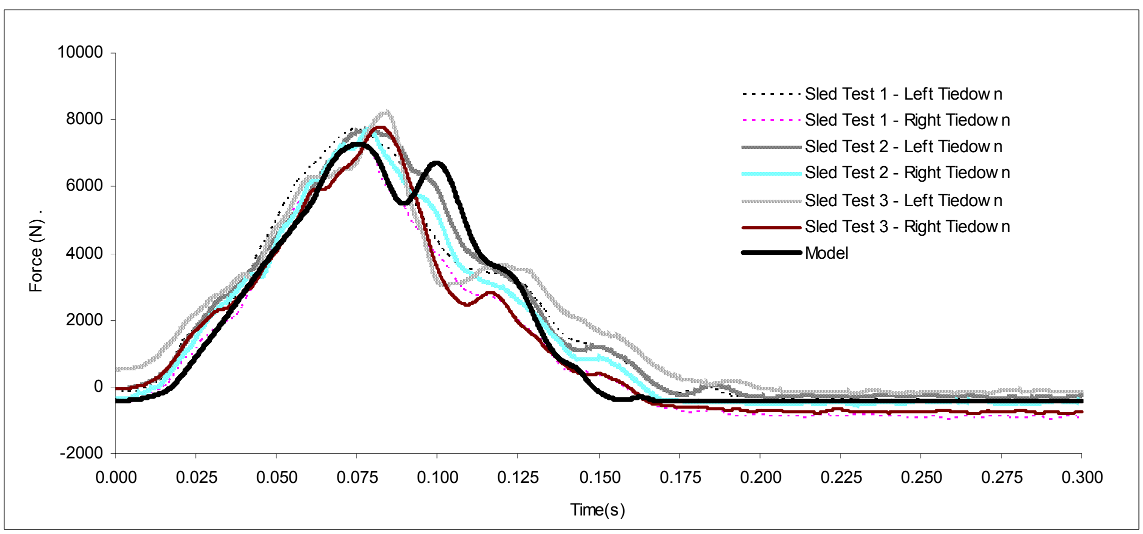

FIGURE 10. Front Tiedown Loading: Model vs. Individual Sled Tests (Left and Right Front Tiedown Loading).

FIGURE 11 shows a comparison of the model lap belt loading to the min-max corridor from sled testing. The model lap belt loading curve generally falls within the sled test min-max corridor and has a peak value of 1023 N. FIGURE 12 shows lap belt loading time histories for the model and each individual sled test run.

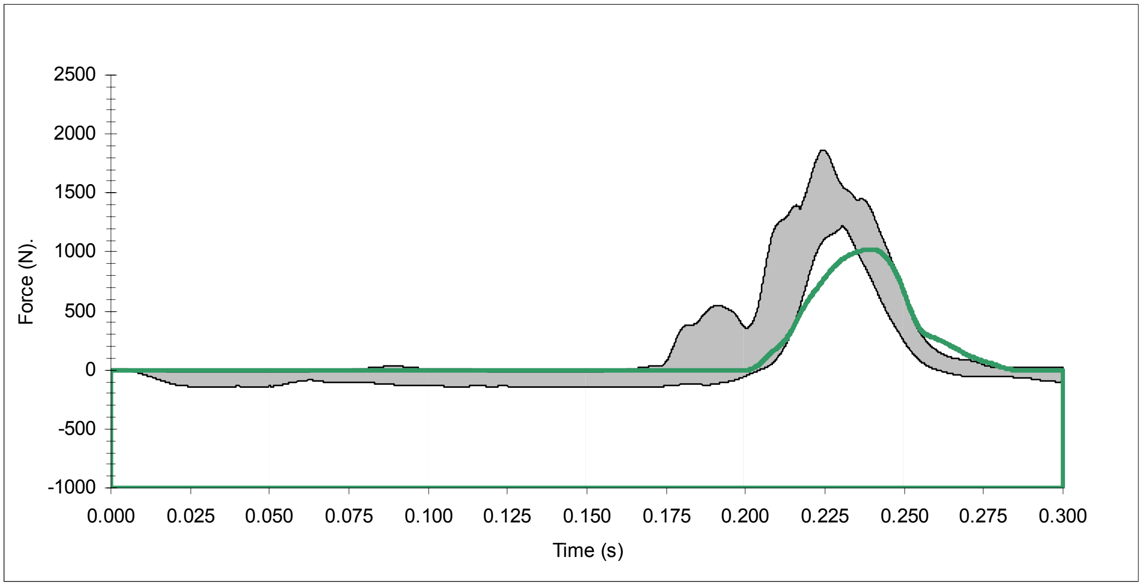

FIGURE 11. Lap Belt Loading: Model (Green Solid Line) vs. Sled Test Min-Max Corridor (Shaded).

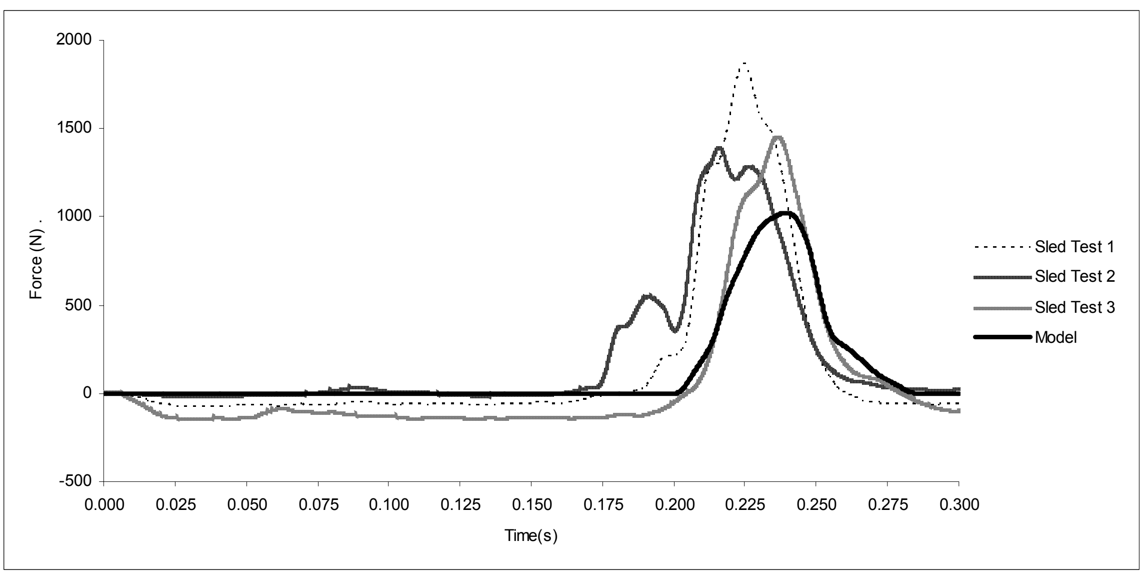

FIGURE 12. Lap Belt Loading: Model vs. Individual Sled Tests.

FIGURE 13 shows a comparison of the model wheelchair acceleration in the direction of travel (x-direction) to the min-max corridor from sled testing. The model wheelchair acceleration peak is 147 m/s^2. FIGURE 14 shows wheelchair acceleration time histories for the model and each individual sled test run.

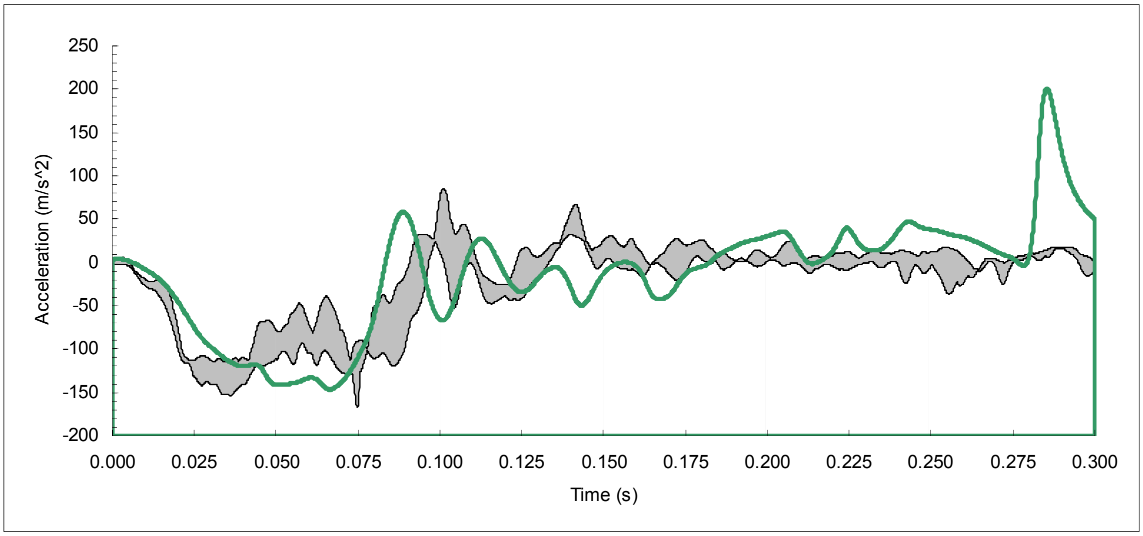

FIGURE 13. Wheelchair Acceleration In Direction Of Travel (x-direction): Model (Green Solid Line) vs. Sled Test Min-Max Corridor (Shaded).

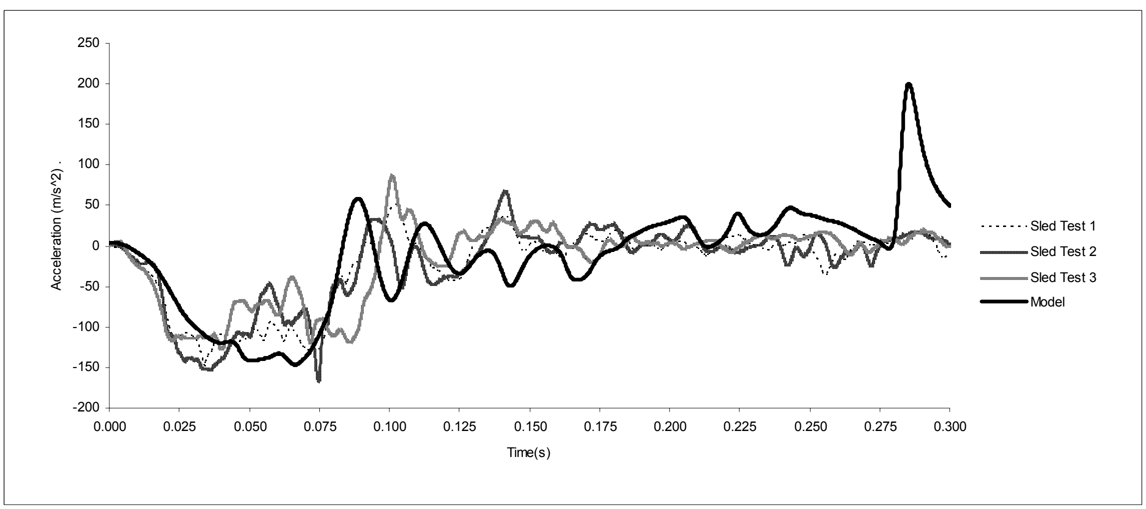

FIGURE 14. Wheelchair Acceleration in Direction Of Travel (x-direction): Model vs. Individual Sled Tests.

FIGURE 15 shows a comparison of the model ATD resultant head acceleration to the min-max corridor from sled testing. The model ATD resultant head acceleration curve generally falls within the sled test min-max corridor and has a peak value of 324 m/s^2. FIGURE 16 shows ATD resultant head acceleration time histories for the model and each individual sled test run.

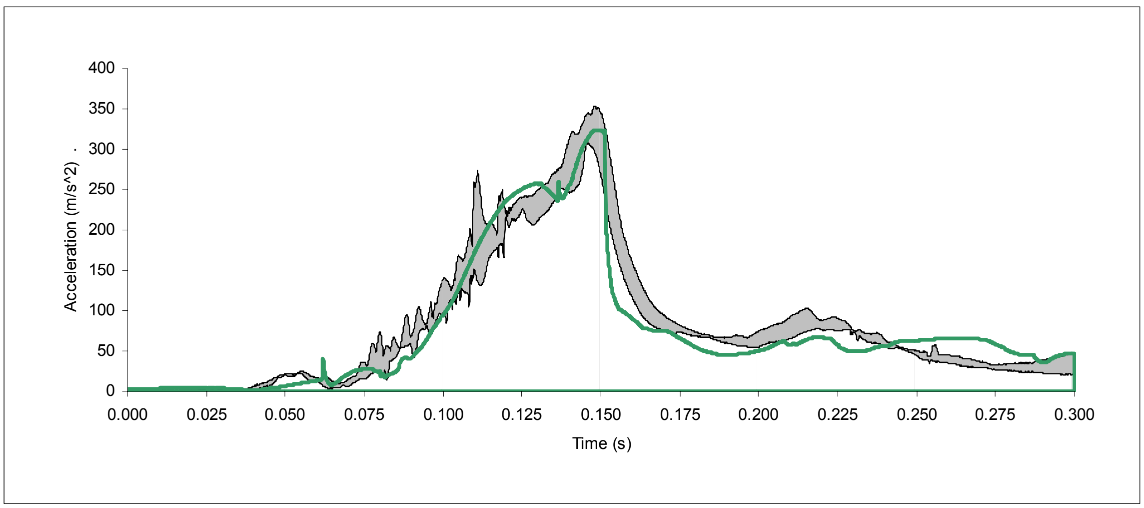

FIGURE 15. ATD Resultant Head Acceleration: Model (Green Solid Line) vs. Sled Test Min-Max Corridor (Shaded).

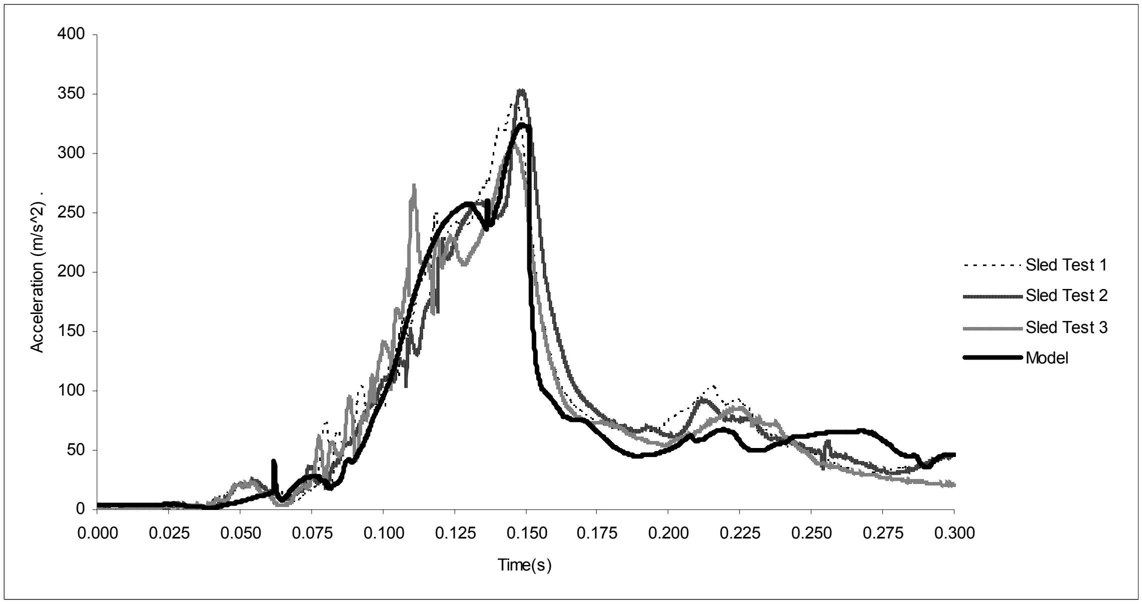

FIGURE 16. ATD Resultant Head Acceleration: Model vs. Individual Sled Tests.

FIGURE 17 shows a comparison of the model ATD resultant chest to the min-max corridor from sled testing. The model ATD resultant chest acceleration curve generally falls within the sled test min-max corridor and has a peak value of 163 m/s^2. FIGURE 18 shows ATD resultant chest acceleration time histories for the model and each individual sled test run.

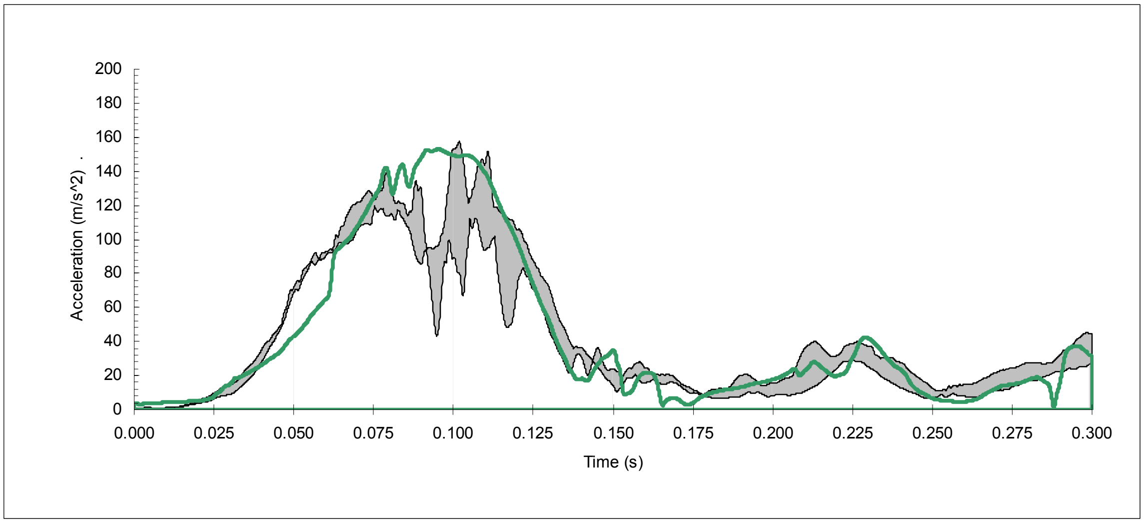

FIGURE 17. ATD Resultant Chest Acceleration: Model (Green Solid Line) vs. Sled Test Min-Max Corridor (Shaded).

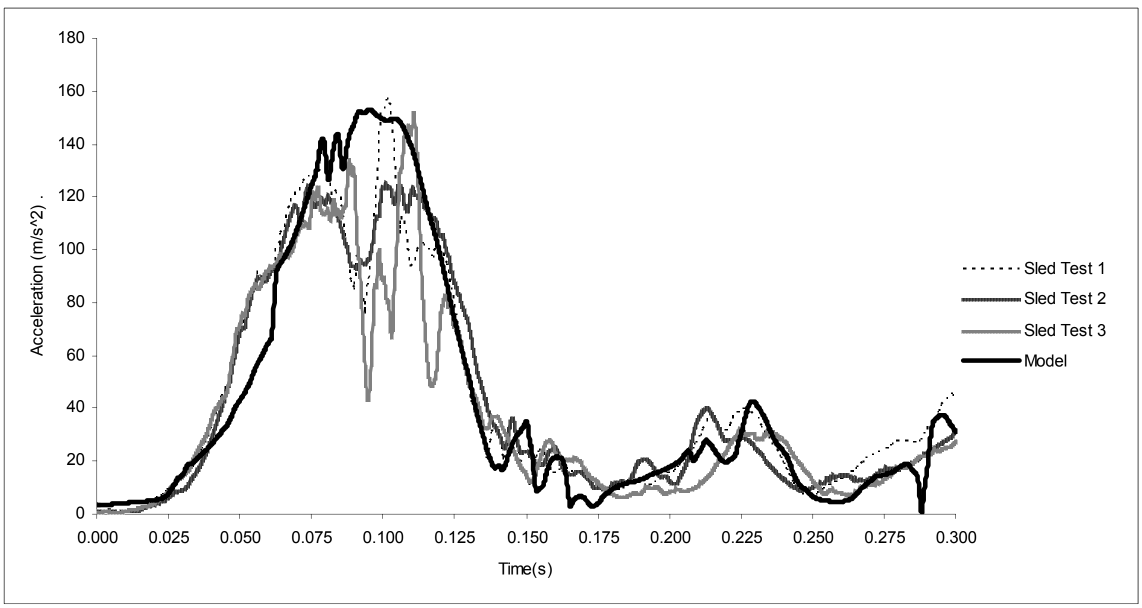

FIGURE 18. ATD Resultant Chest Acceleration: Model vs. Individual Sled Tests.

FIGURE 19 shows a comparison of the model ATD resultant pelvic to the min-max corridor from sled testing. The model ATD resultant pelvic acceleration curve generally falls within the sled test min-max corridor and has a peak value of 172 m/s^2. FIGURE 20 shows ATD resultant pelvic acceleration time histories for the model and each individual sled test run.

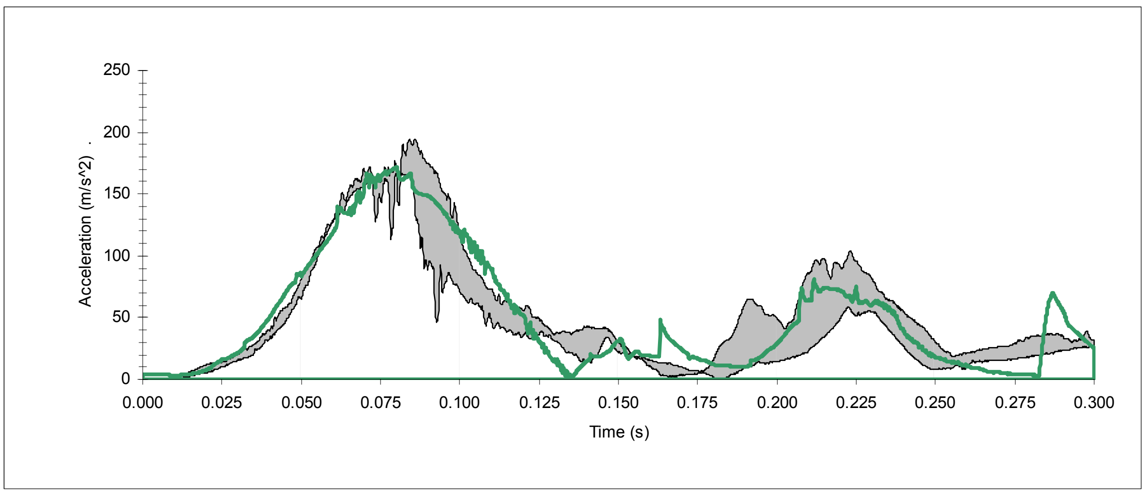

FIGURE 19. ATD Resultant Pelvic Acceleration: Model (Green Solid Line) vs. Sled Test Min-Max Corridor (Shaded).

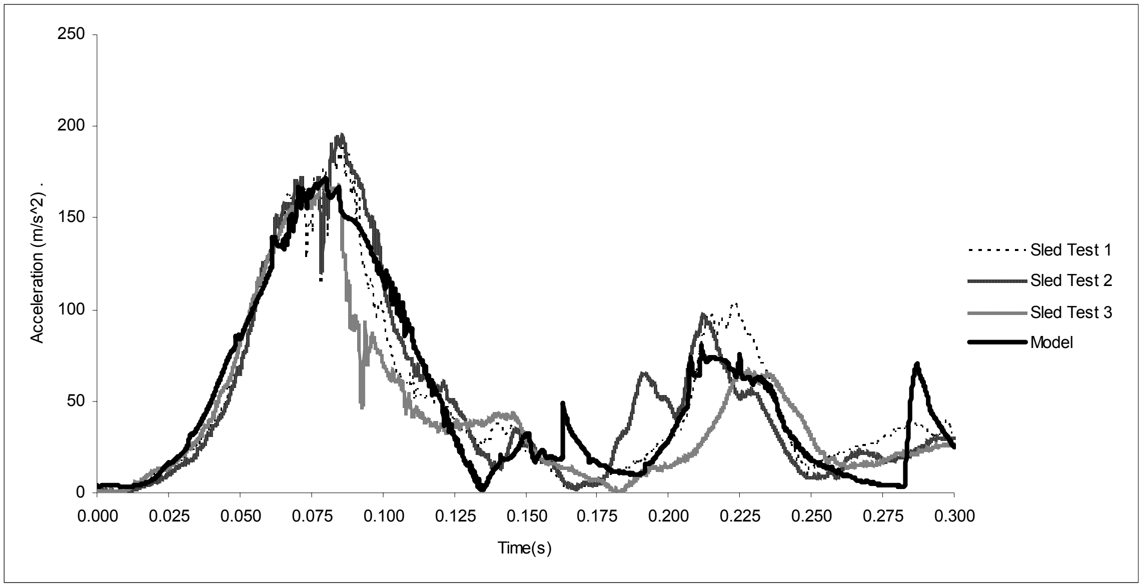

FIGURE 20. ATD Resultant Pelvic Acceleration: Model vs. Individual Sled Tests.

TABLE IV below shows a summary of the statistical test results, comparing the model to the mean of the sled test values for each outcome measure. With the exception of the wheelchair acceleration time history, all outcome measures passed the majority of statistical tests (min 3 out of 4). The wheelchair acceleration statistical analysis was performed 0-280 ms, while all other time histories were compared 0-300 ms.

TABLE IV

SUMMARY OF STATISTICAL TEST RESULTS FOR ALL OUTCOME MEASURES COMPARED TO THE SLED TEST MEAN TIME HISTORIES

	Statistical Test				
	Mean Value Ratio	Correlation Coefficient	Std. Deviation of Residuals	Peak Value	
Criteria	L=0.20	r=0.8	s=0.2	+/- 20% +/- 5ms	# of Tests Meeting Criteria
Front Tiedown Loading	√ x=0.9497	√ r=0.966	√ s=1.2332E-5	√	4
Lap Belt Loading	√ x=0.9203	√ r=0.886	√ s=0.0002	X -27.6%, +14 ms	3
Wheelchair Accel (x-direction)*	√ x=0.9276	X r=0.7405	√ s=0.0016	X -8.0%, +34 ms	2
ATD Resultant Head Accel	√ x=0.9467	√ r=0.9703	√ s=0.0002	√	4
ATD Resultant Chest Accel	√ x=1.0372	√ r=0.9417	√ s=0.0007	X +23.5%, +17 ms	3
ATD Resultant Pelvic Accel	√ x=1.0352	√ r=0.952	√ S=0.0005	√	4

Legend: √ – PASSED (statistical test criteria met)
X – FAILED (statistical test criteria not met)
* – Statistical analysis performed 0-280 ms

TABLE V shows a summary of the statistical analysis for the wheelchair acceleration outcome measure only. In the statistical comparison, the time histories from the model and individual sled tests were compared to the sled test mean time history. The wheelchair acceleration statistical analysis was performed 0-280. The wheelchair acceleration time history from sled test #1 met all of the statistical criteria, while the time histories in sled tests #2 and #3 met only three out of four criteria.

TABLE V

STATISTICAL TEST RESULTS SUMMARY COMPARING THE WHEELCHAIR ACCELERATION (X-DIRECTION) FROM THE MODEL AND EACH SLED TEST TO THE MEAN WHEELCHAIR ACCELERATION TIME HISTORY FROM THE SLED TESTS

	Statistical Test				
Variable	Mean Value Ratio	Correlation Coefficient	Std. Deviation of Residuals	Peak Value	
Criteria	L=0.20	r=0.8	s=0.2	+/- 20% +/- 5ms	# of Tests Meeting Criteria
Model Wheelchair Accel (x-direction)*	√ x=0.9276	X r=0.7405	√ s=0.0016	X -8.0%, +34 ms	2
Sled Test 1 Wheelchair Accel (x-direction)*	√ x=1.0901	√ r=0.9682	√ s=0.0005	√	4
Sled Test 2 Wheelchair Accel (x-direction)*	√ x=1.0546	√ r=0.9574	√ s=0.0005	X +20.5%, +40 ms	3
Sled Test 3 Wheelchair Accel (x-direction)*	√ x=0.8554	√ r=0.9301	√ s=0.001	X -4.6%, +6 ms	3

Legend: √ – PASSED (statistical test criteria met)
X – FAILED (statistical test criteria not met)
* – Statistical analysis performed 0-280 ms

TABLE VI shows a summary of the statistical analysis comparing the wheelchair acceleration from the model to the wheelchair accelerations in the individual sled tests. As shown, the model wheelchair acceleration met as many as three out of four statistical testing criteria (comparison to sled test #2).

TABLE VI

STATISTICAL TEST RESULTS SUMMARY COMPARING THE WHEELCHAIR ACCELERATION (X-DIRECTION) FROM THE MODEL TO THE WHEELCHAIR ACCELERATION FROM THE INDIVIDUAL SLED TESTS

	Statistical Test				
Variable	Mean Value Ratio	Correlation Coefficient	Std. Deviation of Residuals	Peak Value	
Criteria	L=0.20	r=0.8	s=0.2	+/- 20% +/- 5ms	# of Tests Meeting Criteria
Sled Test 1 Wheelchair Accel (x-direction)*	√ x=0.8509	X r=0.7914	√ s=0.0015	X -1.0%, +38 ms	2
Sled Test 2 Wheelchair Accel (x-direction)*	√ x=0.8796	X r=0.731	√ s=0.0017	√	3
Sled Test 3 Wheelchair Accel (x-direction)*	√ x=1.0844	X r=0.5895	√ s=0.002	X +12.9%, +26 ms	2

Legend: √ – PASSED (statistical test criteria met)
X – FAILED (statistical test criteria not met)
* – Statistical analysis performed 0-280 ms

In summary, the model can be considered validated. Firstly, the gross kinematics of the wheelchair and ATD in the model match those from the sled test. The outcome measure time histories match up well with their sled test counterparts, and for the most part follow the established max-min corridor. The statistical analysis revealed that all model outcome measure time histories meet at least three out of four statistical test criteria when compared to the mean sled test time histories, with the exception of wheelchair acceleration. Upon additional statistical analysis, the model wheelchair acceleration meets as many as three out of four statistical criteria when compared to individual sled tests.

D. Parametric Sensitivity Analysis

The parametric sensitivity analysis was conducted to investigate the effects of individual model parameters on key wheelchair and WTORS component loading. This information can ultimately be used to establish design criteria that can be used to produce rear impact crashworthy wheelchairs and WTORS.

TABLE VII below shows a summary of baseline model configuration along with how key parameters were varied in the parametric sensitivity analysis.

TABLE VII

SUMMARY OF ORIGINAL MODEL CONFIGURATION AND VARIATION OF KEY PARAMETERS DURING PARAMETRIC SENSITIVITY ANALYSIS

	Baseline Model Conditions	Variation in Parametric Sensitivity Analysis
Impact Severity	14 g - 25 km/h	21 g - 25 km/h
ATD	50th percentile Hybrid III	95th percentile Hybrid III
Front Securement Point	22 cm from ground	7 cm and 14 cm higher from baseline
Seatback tilt	2 deg posterior from vertical	5, 10, 15, 20, 25, and 30 deg posterior from vertical
Seat stiffness	See FIGURE 21	See FIGURE 21
Seatback surface stiffness	See FIGURE 22	See FIGURE 22
Seat-seatback stiffness	See FIGURE 23	See FIGURE 23

FIGURE 21 shows seat stiffness for the baseline model compared to the range of published seat stiffness data obtained from quasi-static testing of commercial wheelchairs (Bertocci, G., Ha, D. et al., 2001; Ha, D., Bertocci, G. et al., 2002). The published stiffness range was used in increments of 25% to vary the seat stiffness in the parametric sensitivity analysis.

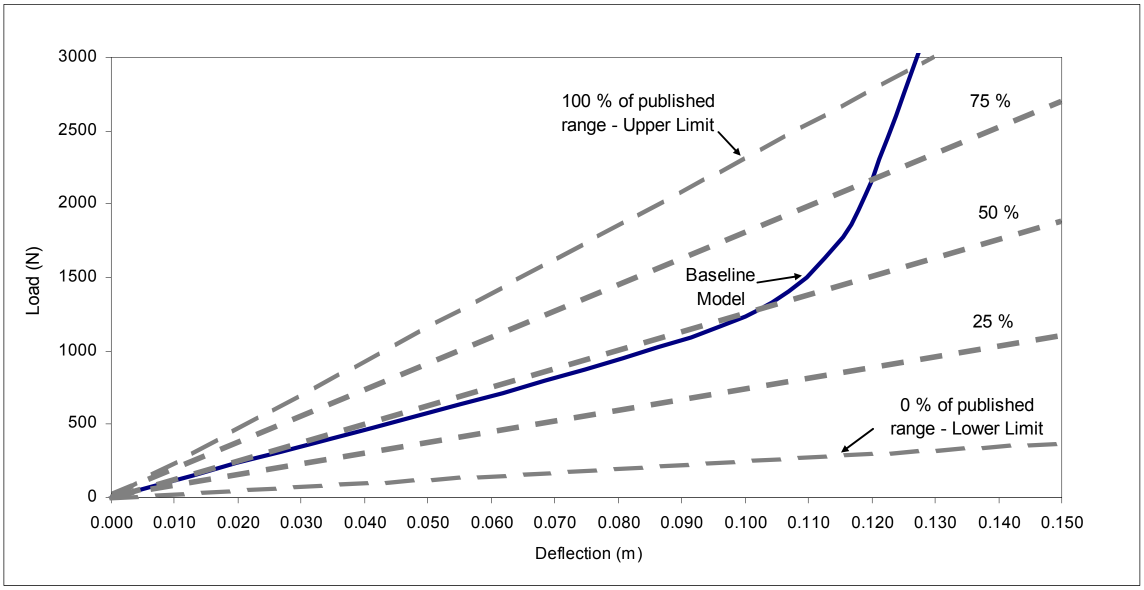

FIGURE 21. Model Seat Stiffness and Range of Published Seat Stiffnesses (Bertocci, G., Ha, D. et al., 2001; Ha, D., Bertocci, G. et al., 2002).

FIGURE 22 depicts seatback surface stiffness in the baseline model as well as a range of published seatback surface stiffness data obtained from quasi-static testing of commercial seatbacks (Ha, D., Bertocci, G. et al., 2000; Ha, D., Bertocci, G. et al., 2002). The lower limit of the seatback surface stiffness is stiffer than the stiffness used to validate the model. The published stiffness range was used in increments of 25% to vary the seatback stiffness in the parametric sensitivity analysis.

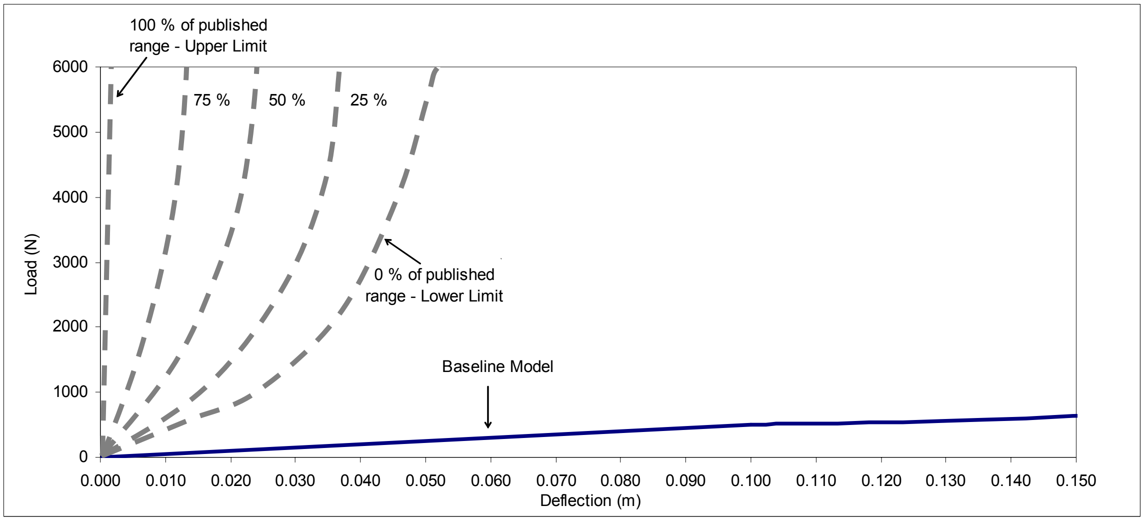

FIGURE 22. Model Seatback Surface Stiffness and Range of Published Seatback Surface Stiffnesses (Ha, D., Bertocci, G. et al., 2000; Ha, D., Bertocci, G. et al., 2002).

FIGURE 23 portrays the seat-seatback joint stiffness in the baseline model as well as a range of published seat-seatback stiffness data obtained from quasi-static testing of seating systems (van Roosmalen, L., Bertocci, G. et al., 2000). The lower limit of the seat-seatback stiffness is stiffer than that used to validate the model. The published stiffness range was used in increments of 25% to vary the seat-seatback stiffness in the parametric sensitivity analysis.

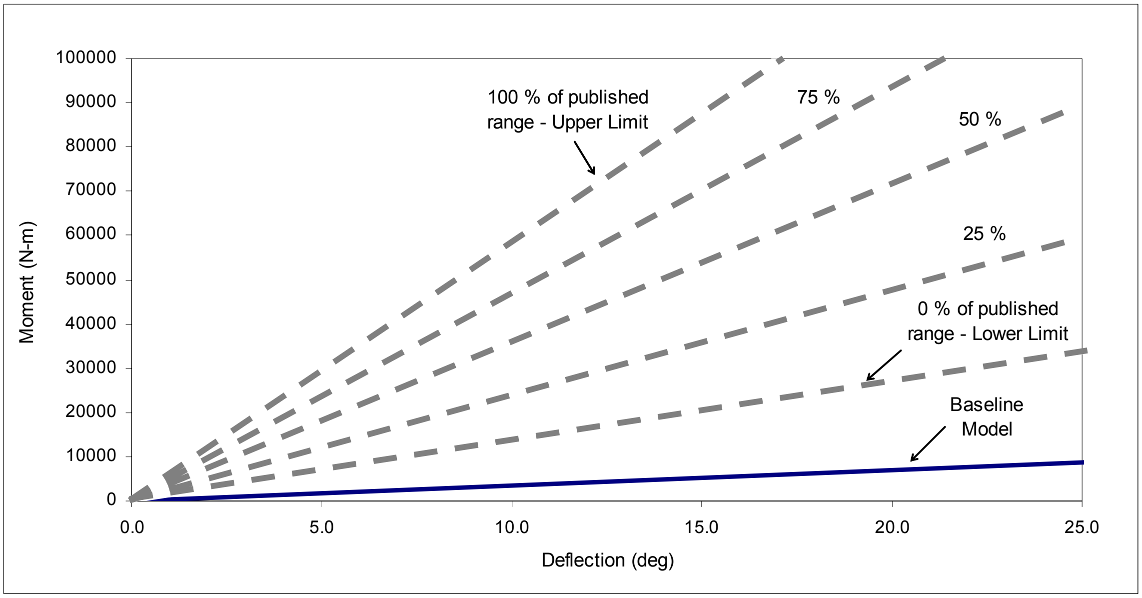

FIGURE 23. Model Seat-Seatback Stiffness and Range of Published Seat-Seatback Stiffnesses (van Roosmalen, L., Bertocci, G. et al., 2000).

FIGURES 24 – 37 show a graphical representation of the results from the parametric sensitivity analysis by illustrating a range of outcome measure values obtained as key model parameters were varied. TABLE A.I. in the ANNEX shows a matrix of all values obtained during the parametric sensitivity analysis.

FIGURE 24 shows seatback deflection as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in setback deflection of 13.18 deg. The highest overall seatback deflection of 27.62 deg was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall seatback deflection of 5.46 deg was due to varying initial seatback tilt angle (30 deg). Varying seat stiffness had a negligible effect on seatback deflection.

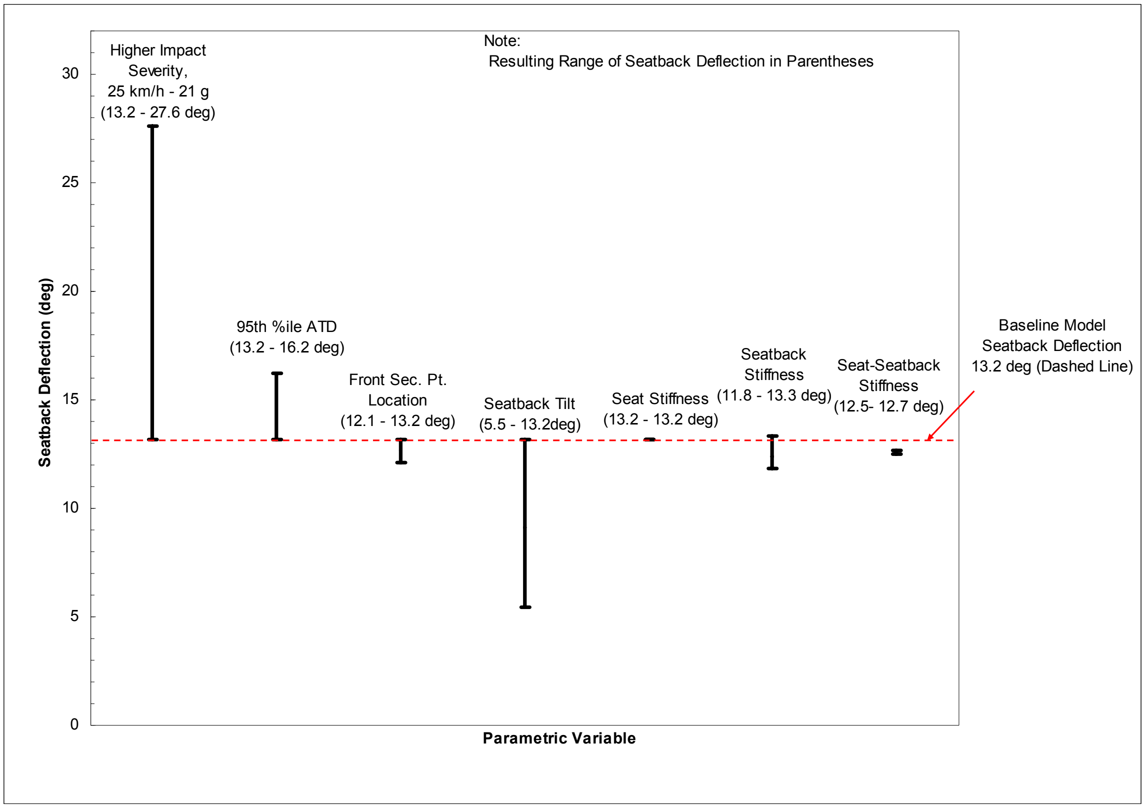

FIGURE 24. Seatback Deflection Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 25 shows seatback normal loading as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in setback normal loading of 3270 N. The highest overall seatback normal loading of 8185 N was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall seatback normal loading of 2916 N was due to varying initial seatback tilt angle (10 deg). Varying seat stiffness and seat-seatback stiffness had a negligible effect on seatback normal loading.

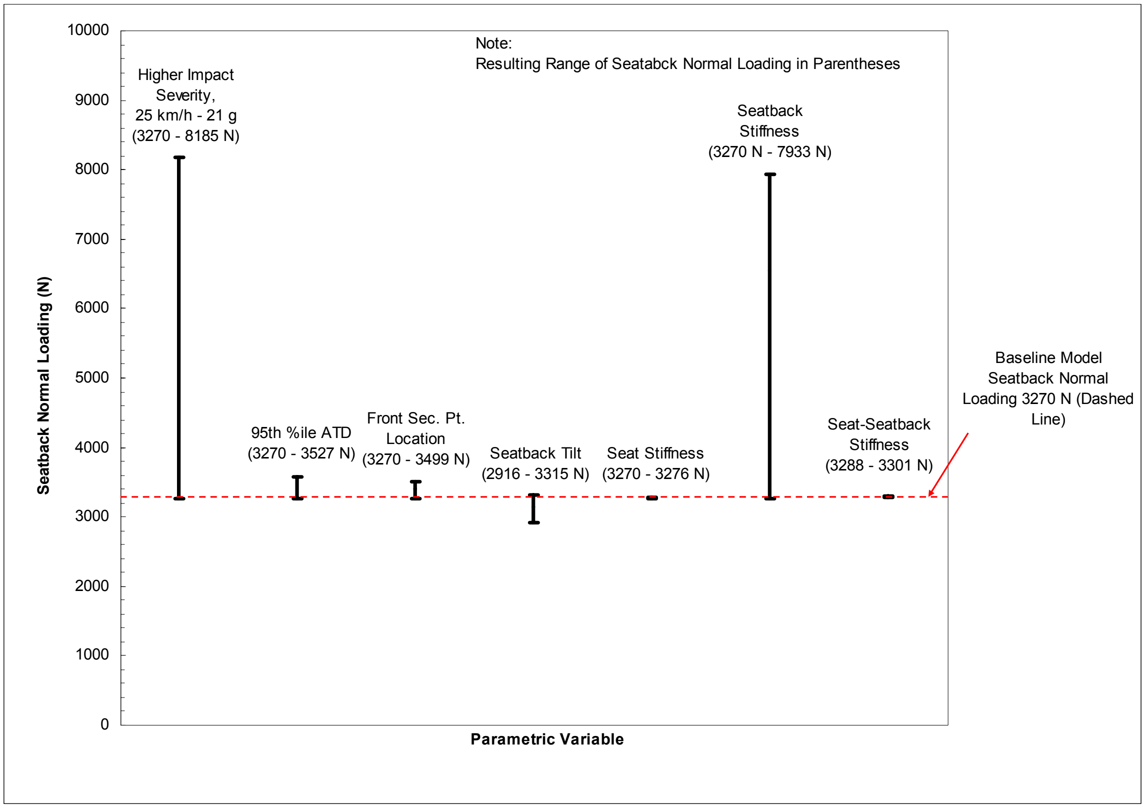

FIGURE 25. Seatback Normal Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 26 shows seatback shear loading as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in seatback shear loading of 2246 N. The highest overall seatback shear loading of 3441 N was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall seatback shear loading of 1544 N was due to varying the front securement point location (up 14 cm from baseline configuration). Varying seat stiffness and seat-seatback stiffness had a negligible effect on seatback shear loading.

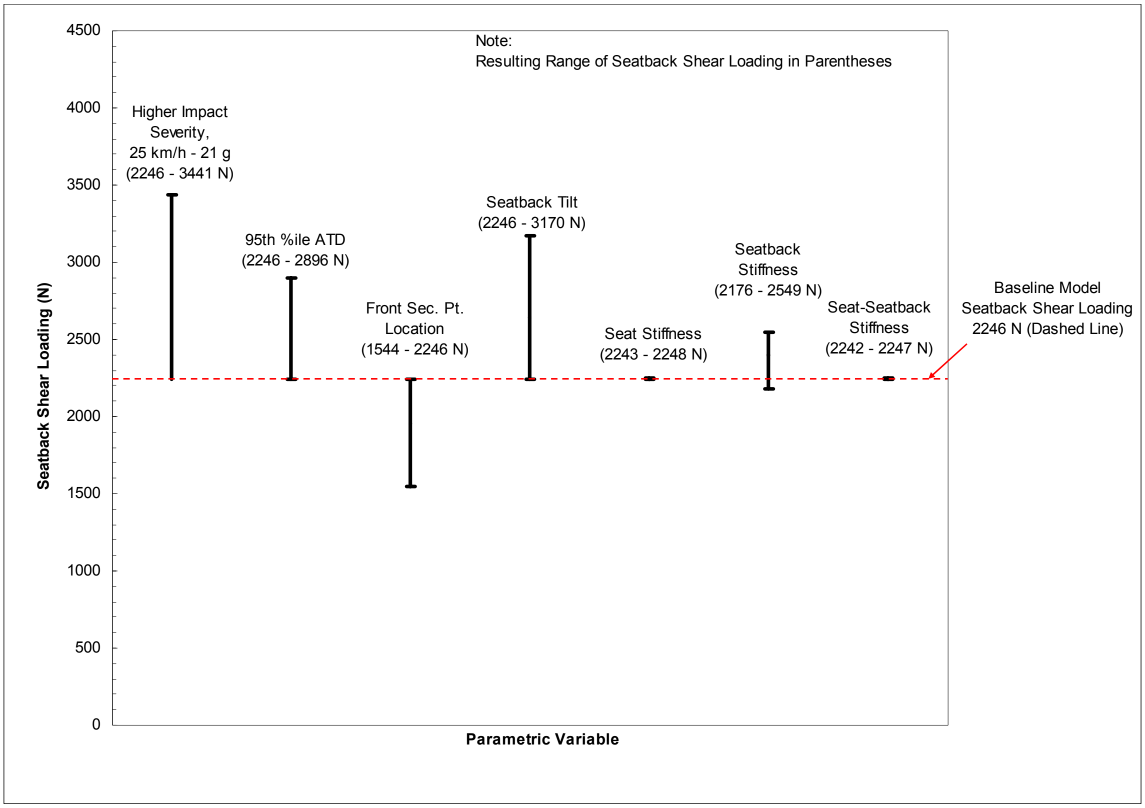

FIGURE 26. Seatback Shear Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 27 shows seat normal loading as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in seat normal loading of 1772 N. The highest overall seat normal loading of 8185 N was achieved by varying the seatback stiffness (25 % of published range). The lowest overall seatback normal loading of 1011 N was due to varying the front securement point location (up 7 cm from baseline configuration). Varying seat stiffness and seat-seatback stiffness had a negligible effect on seatback normal loading.

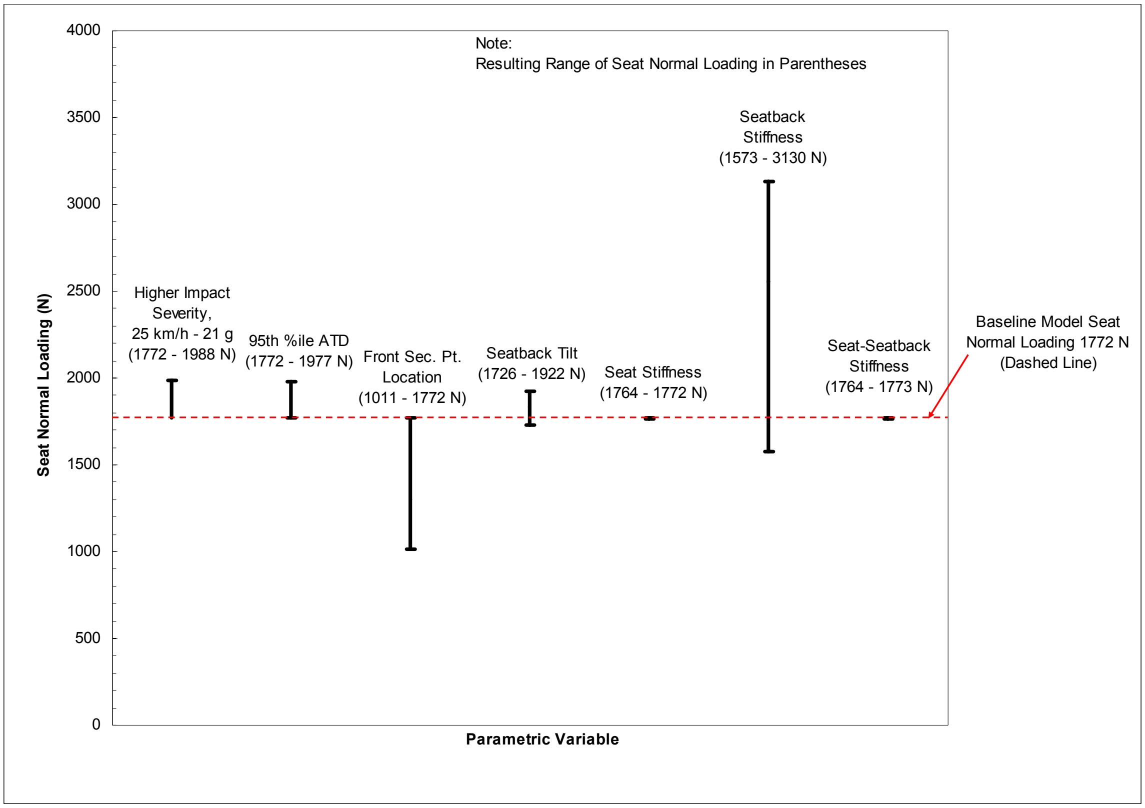

FIGURE 27. Seat Normal Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 28 shows seat shear loading as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in seat shear loading of 7710 N. The highest overall seat shear loading of 16 469 N was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall seat shear loading of 4448 N was due to varying the front securement point location (up 7 cm from baseline configuration). Varying seat stiffness and seat-seat stiffness had a negligible effect on seat shear loading.

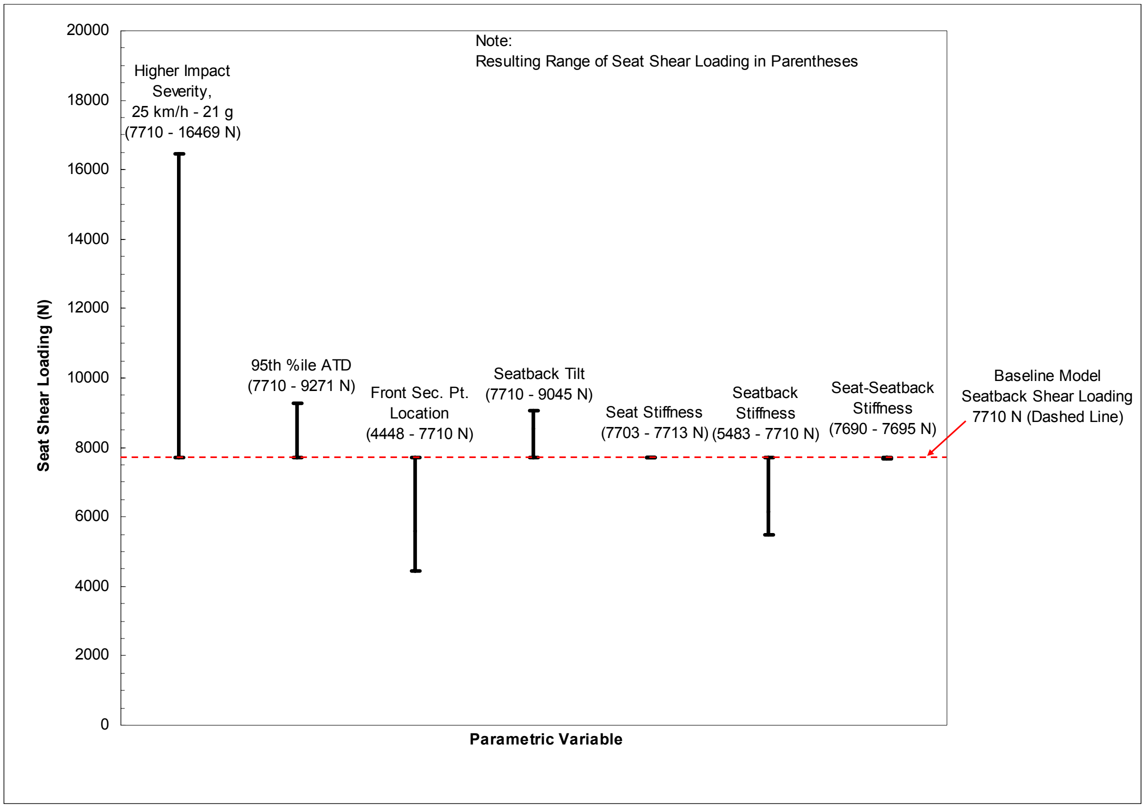

FIGURE 28. Seat Shear Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 29 shows wheelchair pitch measured from the horizontal as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in wheelchair pitch of 13.47 deg. The highest overall wheelchair pitch of 19.04 deg was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall wheelchair pitch of 7.02 was due to varying the seatback stiffness (0% of published range). Varying seat stiffness had a negligible effect on seat shear loading.

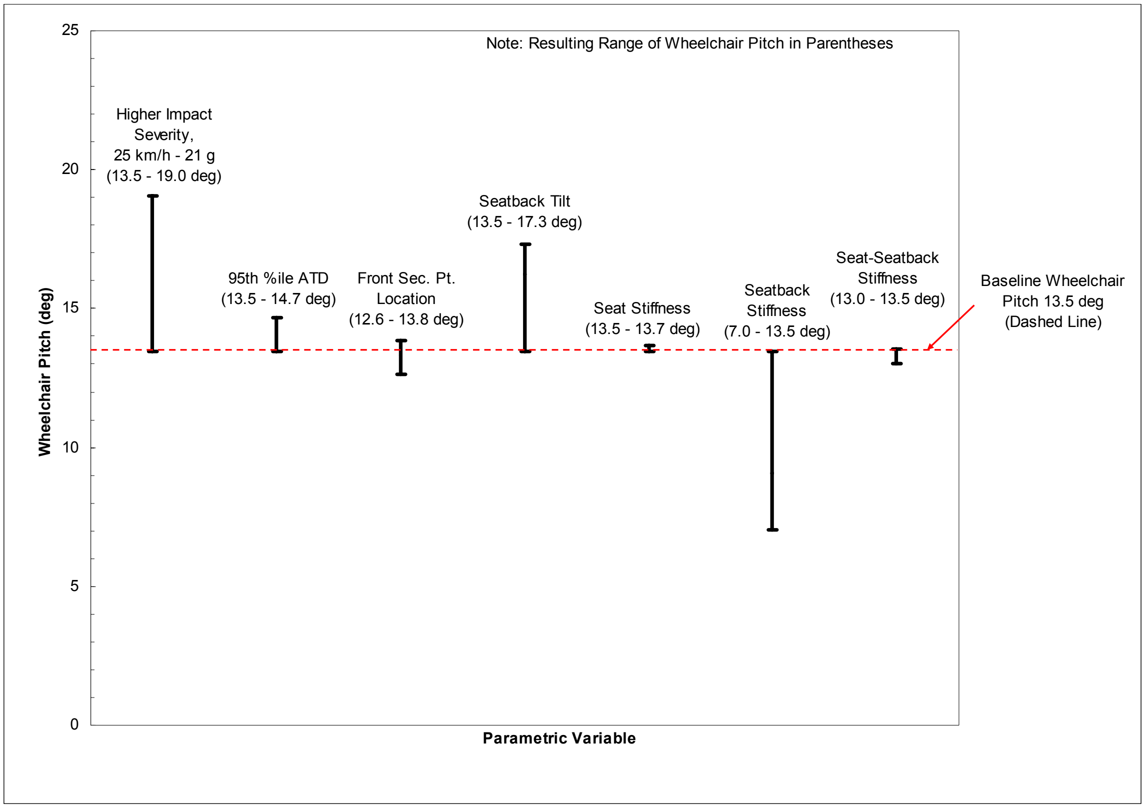

FIGURE 29. Wheelchair Pitch Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 30 shows loading on each front wheel as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in front wheel loading of 814 N. The highest overall front wheel loading of 6918 N was achieved by varying the front securement point location (up 14 cm from baseline configuration). The lowest overall front wheel loading of 805 N was due to varying the seat stiffness (0% of published range). Varying seat stiffness and seat-seat stiffness, seat-seatback stiffness, and increasing the ATD weight and inertia to the 95th percentile Hybrid III had a negligible effect on front wheel loading.

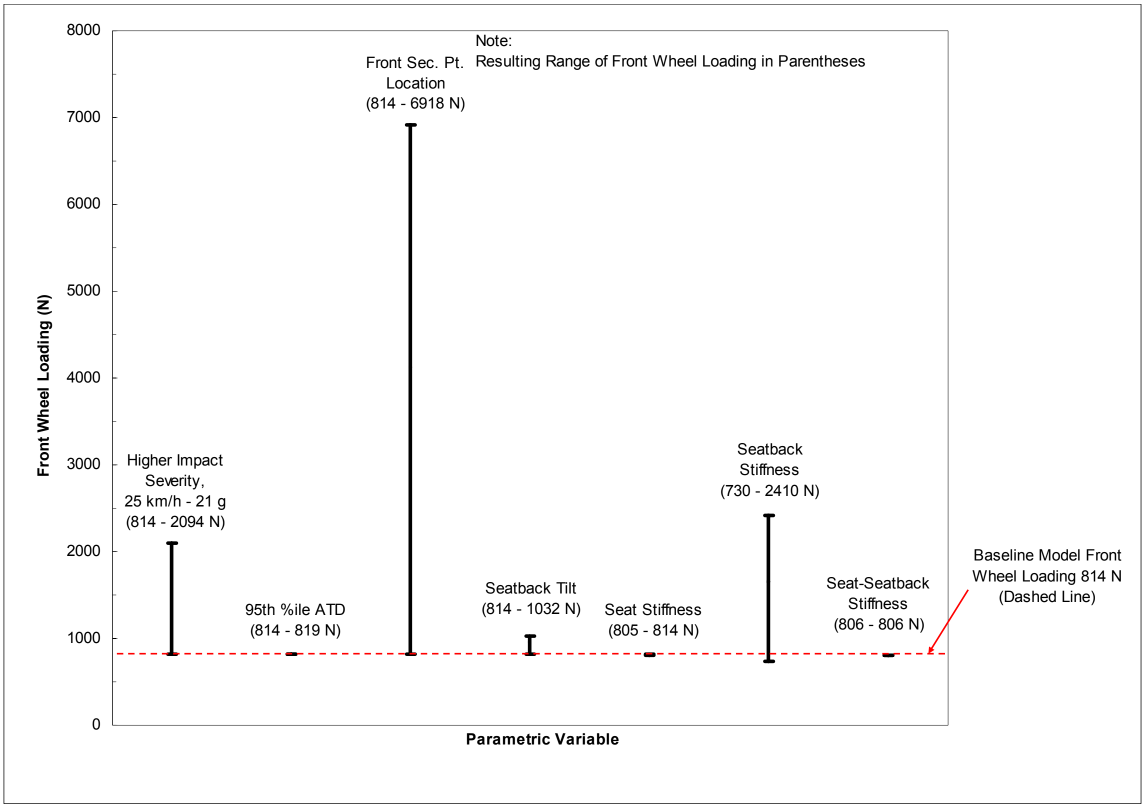

FIGURE 30. Front Wheel Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 31 shows loading on each rear wheel as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in rear wheel loading of 4499 N. The highest overall rear wheel loading of 7940 N was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall rear wheel loading of 2384 N was due to varying the front securement point location (up 14 cm from baseline configuration). Varying seat stiffness and seat-seat stiffness had a negligible effect on rear wheel loading.

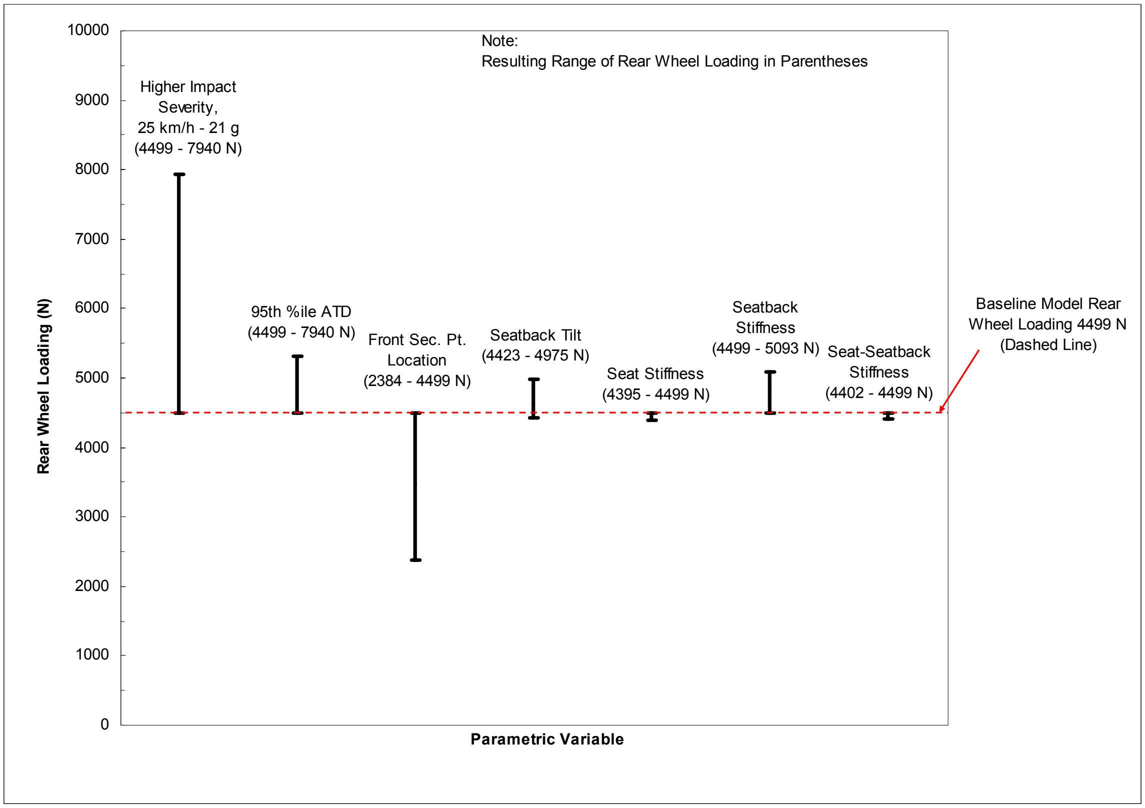

FIGURE 31. Rear Wheel Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 32 shows individual front securement point loading as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in front securement point loading of 7366 N. The highest overall front securement point loading of 15 093 N was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall front securement point loading of 7013 N was due to varying the seatback tilt angle (30 deg). Varying seat stiffness and seat-seat stiffness had a negligible effect on front securement point loading.

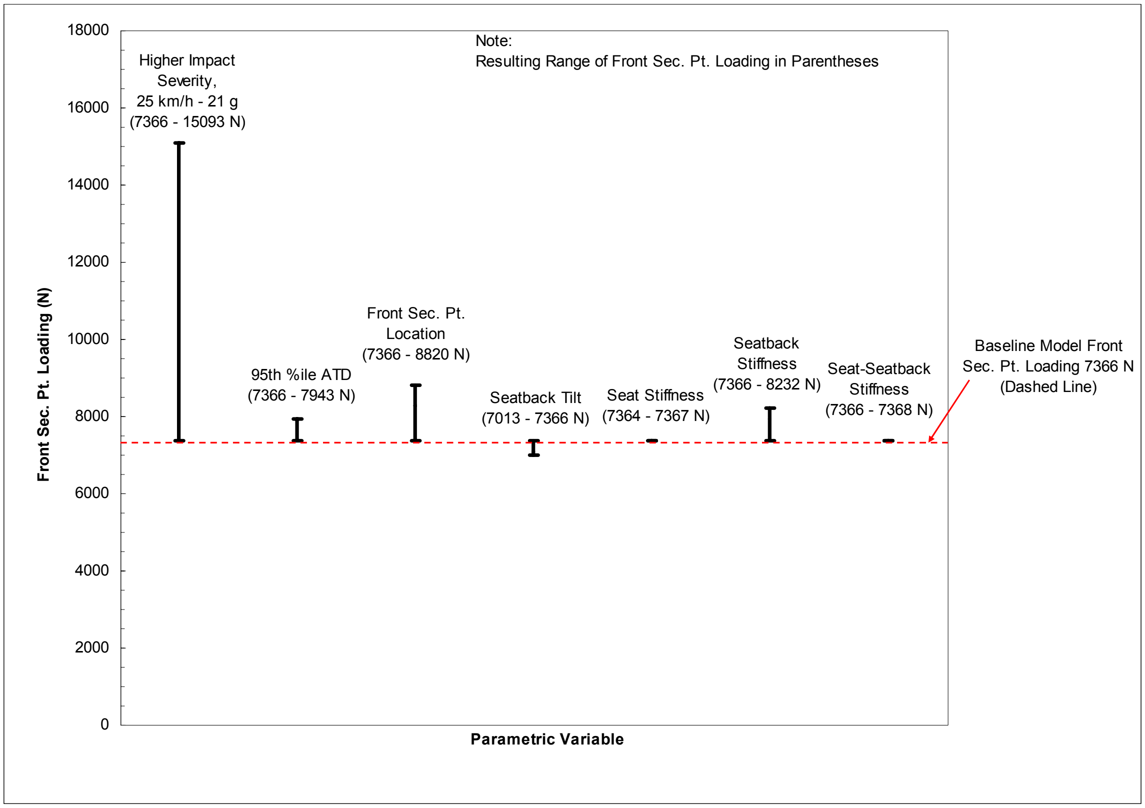

FIGURE 32. Front Securement Point Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 33 shows individual rear securement point loading as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in rear securement point loading of 709 N. The highest overall rear securement point loading of 1782 N was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall rear securement point loading of 688 N was due to varying the seat-seatback stiffness (0% of published range). Varying seat stiffness had a negligible effect on rear securement point loading.

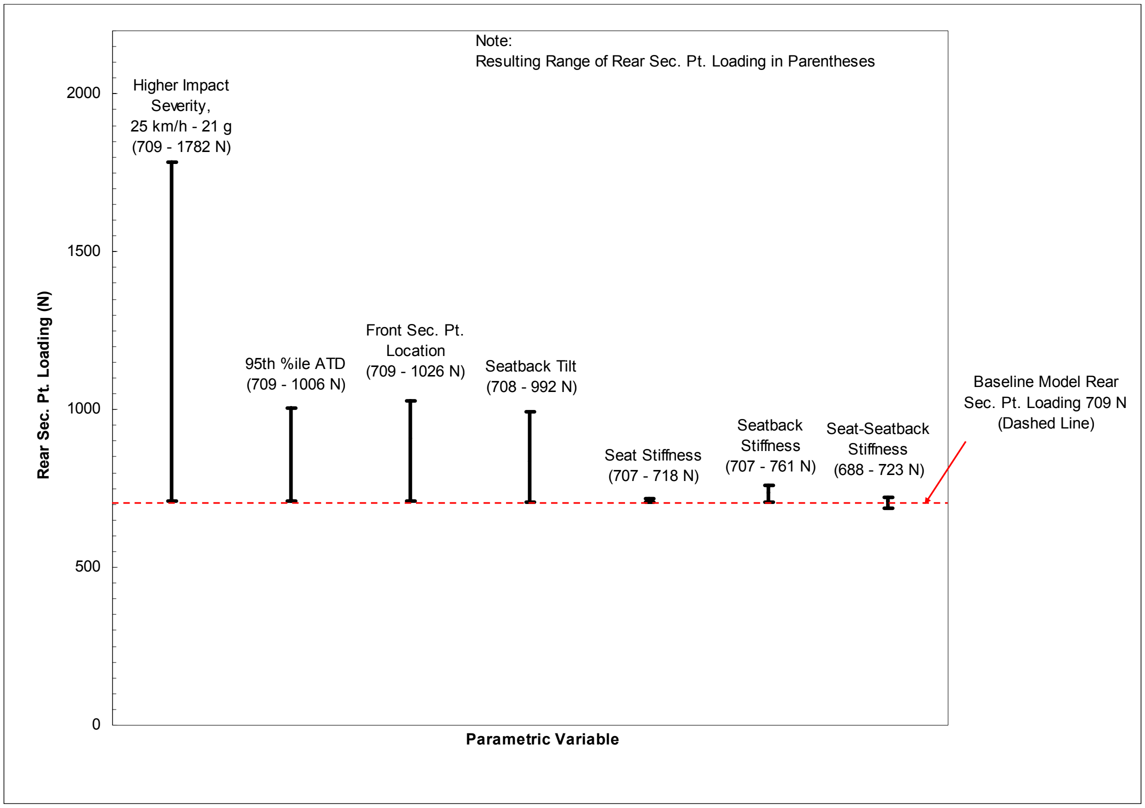

FIGURE 33. Rear Securement Point Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 34 shows front tiedown loading on each tiedown strap as a result of varying key model parameters in the parametric sensitivity analysis. The loading profile is identical to the front securement point loading. Baseline model configuration resulted in front tiedown loading of 7366 N. The highest overall front tiedown loading of 15 093 N was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall front tiedown loading of 7013 N was due to varying the seatback tilt angle (30 deg). Varying seat stiffness and seat-seat stiffness had a negligible effect on front tiedown loading.

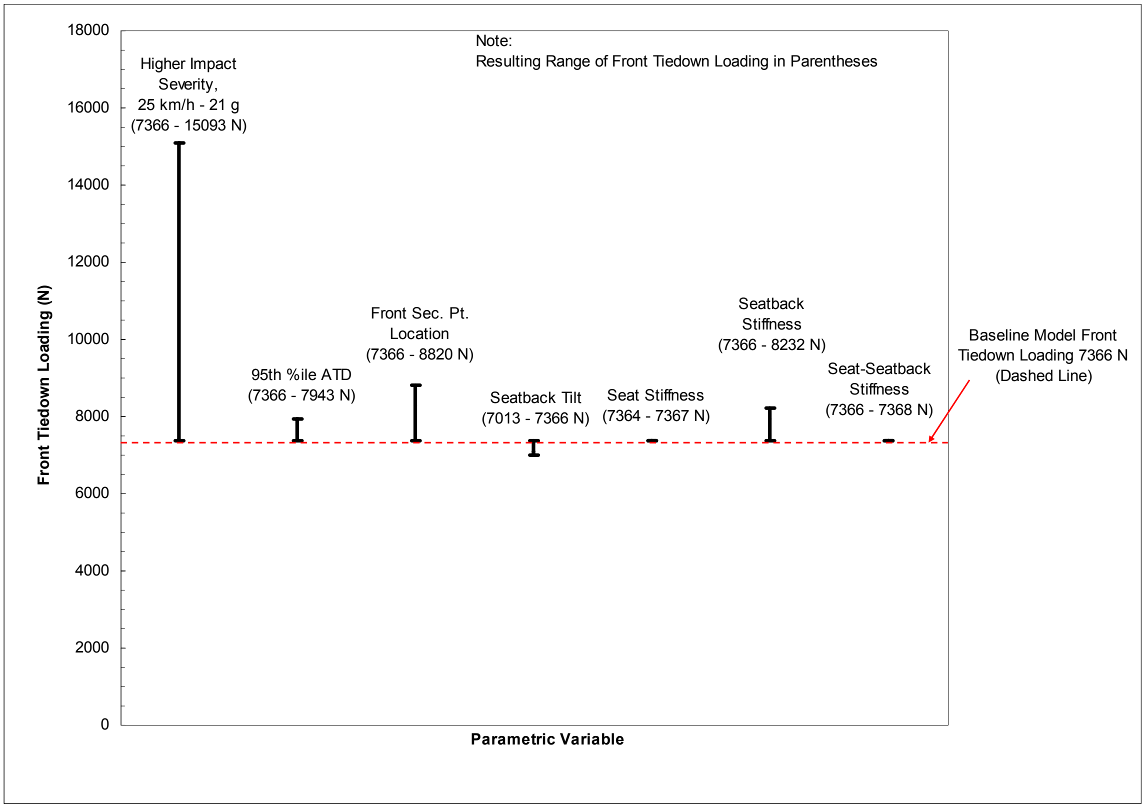

FIGURE 34. Front Tiedown Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 35 shows individual rear tiedown loading as a result of varying key model parameters in the parametric sensitivity analysis. The loading profile is identical to the rear securement point loading. Baseline model configuration resulted in rear tiedown loading of 709 N. The highest overall rear tiedown loading of 1782 N was achieved by increasing impact severity to 25 km/h – 21 g. The lowest overall rear tiedown loading of 688 N was due to varying the seat-seatback stiffness (0% of published range). Varying seat stiffness had a negligible effect on rear tiedown loading.

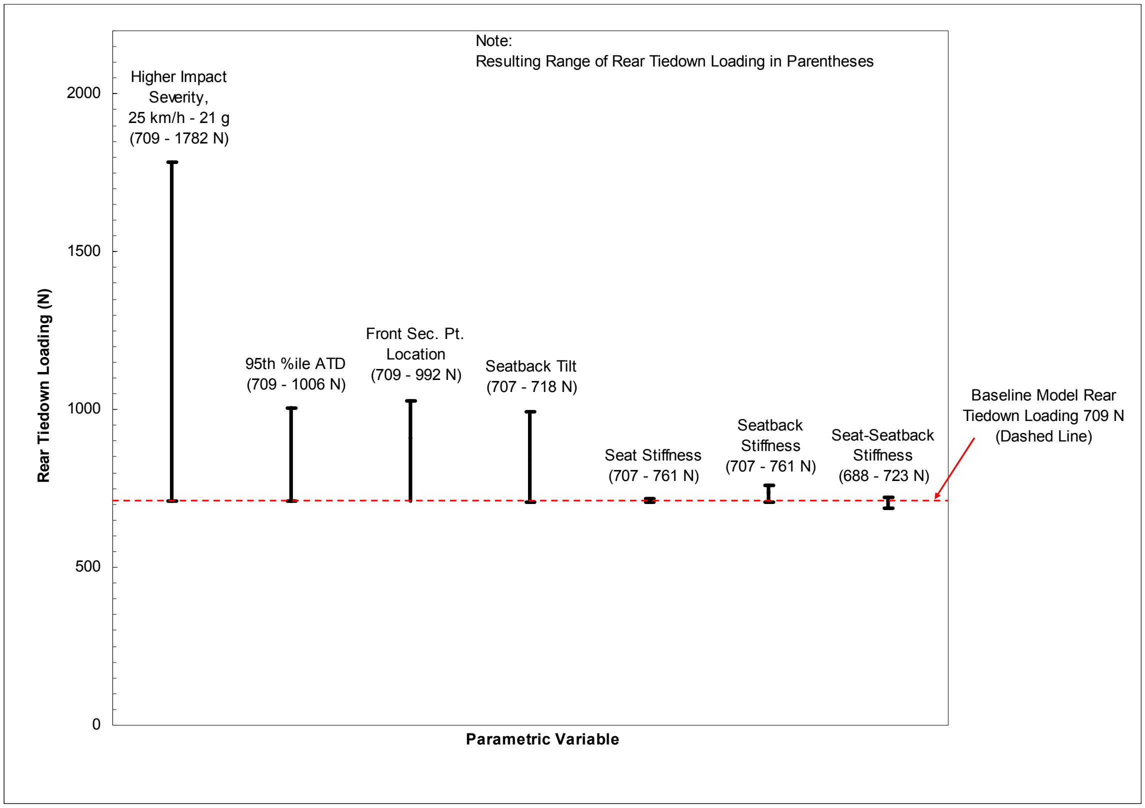

FIGURE 35. Rear Tiedown Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 36 shows lap belt loading as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in lap belt loading of 1023 N. The highest overall lap belt loading of 1464 N was achieved by varying the seatback stiffness (100% of published range). The lowest overall lap belt loading of 18 N was due to varying the seatback tilt angle (30 deg). Varying seat stiffness had a negligible effect on lap belt loading.

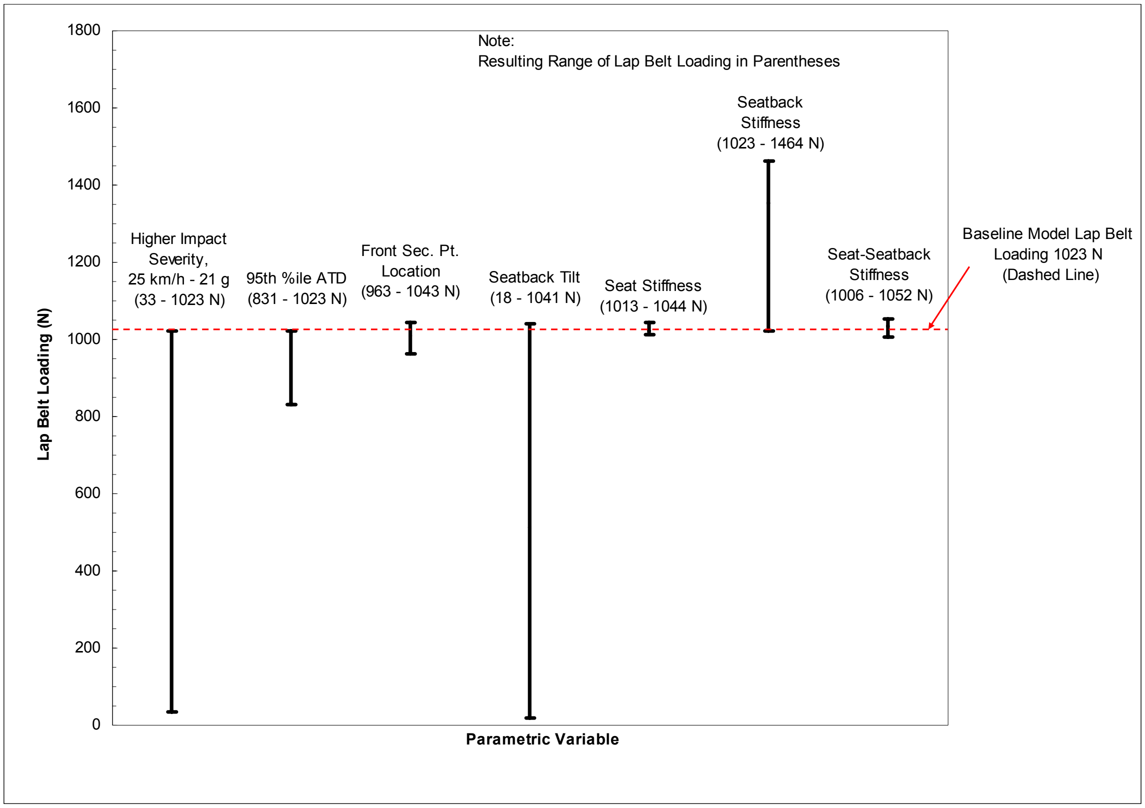

FIGURE 36. Lap Belt Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

FIGURE 37 shows shoulder belt loading as a result of varying key model parameters in the parametric sensitivity analysis. Baseline model configuration resulted in no shoulder belt loading. The highest overall shoulder belt loading of 622 N was achieved by increasing impact severity to 25 km/h – 21 g. All other parameters varied in the parametric sensitivity analysis had no effect on shoulder belt loading resulting, with the shoulder belt load remaining at zero.

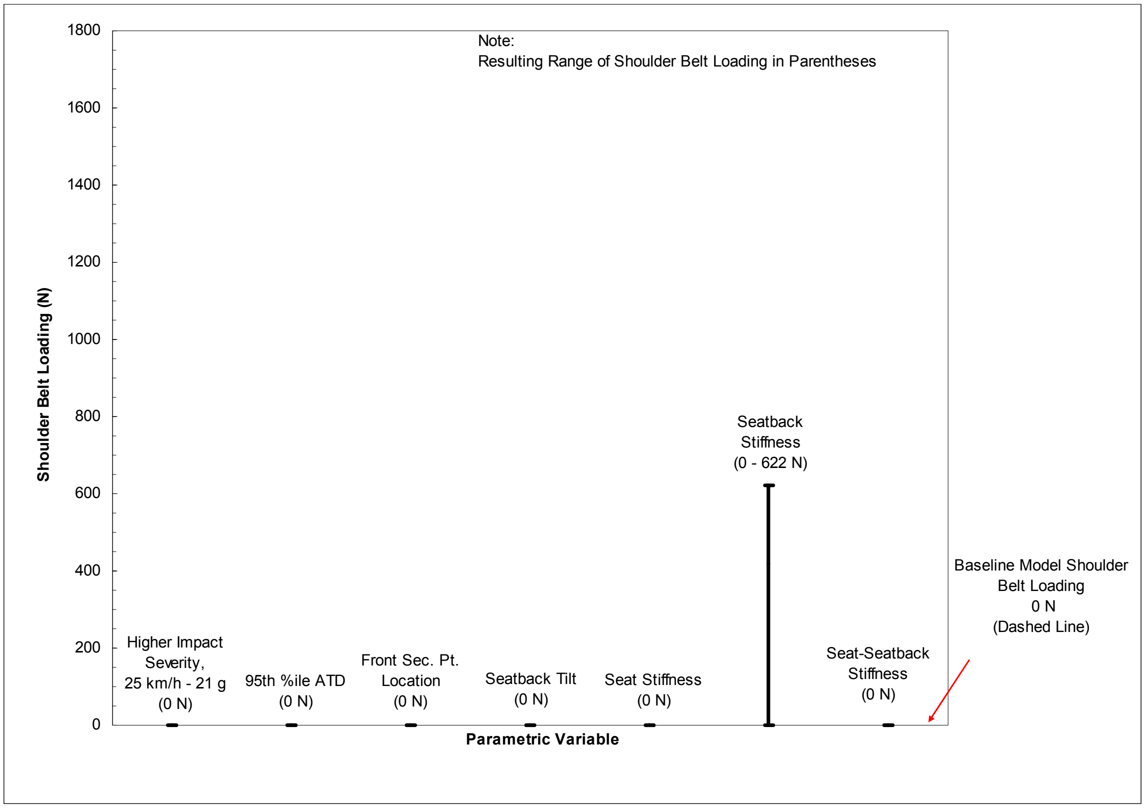

FIGURE 37. Shoulder Belt Loading Results Form the Parametric Sensitivity Analysis (See TABLE VII for Baseline Model Configuration and Variation of Key Parameters).

In summary, the parametric sensitivity analysis reveals that an increase in impact severity from 25 km/h – 14 g to 25 km/h – 21 g has the relatively largest effect on model outcome measures, when compared to other varied parameters. The 95th percentile ATD had relatively moderate effects on key outcome measures. With the exception of a relatively high increase in front wheel loading, the vertical location of the front securement point had a moderate effect on outcome measures. The seatback tilt angle also had low to moderate effect on outcome measures, except lap belt loading. Seat stiffness on the other had had a negligible effect on outcome measures throughout the parametric sensitivity analysis. Seatback stiffness had an overall substantial effect on outcome measures, especially causing relatively high normal seatback loading and lap and shoulder belt loading. Seat-seatback stiffness only had a notable effect on Seatback deflection.

TABLE IIX shows a summary of peak loads obtained in the parametric sensitivity analysis.

TABLE IIX

PEAK WHEELCHAIR AND WTORS LOADING RESULTING FROM PARAMETRIC SENSITIVITY ANALYSIS

Parameter	Maximum Load In Rear Impact
Normal Seatback Loading	8185 N
Shear Seatback Loading	3441 N
Normal Seat Loading	3130 N
Shear Seat Loading	16469 N
Front Wheel Loading	6918 N
Rear Wheel Loading	7940 N
Front Securement Point Loading	15093 N
Rear Securement Point Loading	1782 N
Front Tiedown Loading	15093 N
Rear Tiedown Loading	1782 N
Lap Belt Loading	1464 N
Shoulder Belt Loading	622 N

V. DISCUSSION

A. Rear Impact Sled Testing of Wheelchair and Occupant

a. Original and partially reinforced wheelchair (for identifying common failure mechanisms)

The wheelchair failure mechanism found in the initial sled testing was front securement point hardware failure, as shown in FIGURE 3. The bolts used to attach the front securement point to the wheelchair frame failed under bending and shear loading. However, these bolts were later replaced with Grade 8 bolts, which withstood the loading from the rear impact. An additional aspect of front securement point design, aside from the hardware grade is the geometry of the front securement point attachment point. The securement point is a designated reference point on the wheelchair frame where the tiedown hook is attached to secure the wheelchair during transport. There are specific design requirements for the securement point geometry and location in ANSI/RESNA WC19. The tested wheelchair features a design of the front securement point that is offset from the wheelchair frame. This design allows for increased bending and shear loading of the hardware by increasing the moment arm at the bolt-frame interface. The rear securement point, on the other hand, is characterized with a design that aligns it with the wheelchair frame. FIGURE 38 illustrates the difference in geometric design in front and rear securement points.

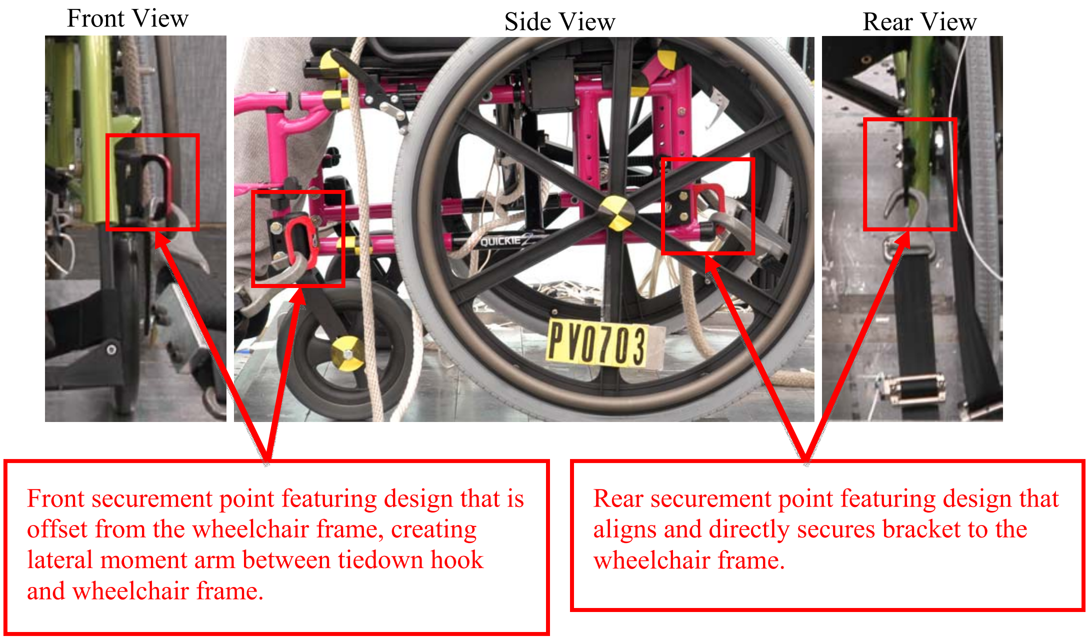

FIGURE 38. Design of Front and Rear Securement Points.

While the front securement point attachment point design and hardware may have been robust enough to withstand front securement point loading in frontal impact (as small as 100 N) (Bertocci, G. E., Hobson, D. A. et al., 1996), the loading associated with rear impact (7851 N) caused catastrophic failure (Salipur, Z., Bertocci, G. E. et al., 2007). Still, a relatively fast "in the field" upgrade of the bolt hardware grade produced a front securement point assembly that was able to withstand rear impact level loading. It can be assumed that a redesign of the interface of the front securement point to the wheelchair frame to more closely resemble the design of the rear securement point would further increase the front securement crashworthiness in rear impact.

The second mode of failure discovered in initial sled testing was seatback failure, as shown in FIGURE 4. The seatback canes failed under bending, caused by the ATD's rearward excursion and loading of the seatback. This is due to the dynamics of a rear impact, where as in a frontal impact the ATD primarily loads the occupant restraints and only loads the seatback in the rebound phase of a frontal impact event. However, in a rear impact the seatback serves as the primary means of restraining or containing the occupant in the wheelchair seat. Nonetheless, the seatback canes were each successfully reinforced by insertion of 610 mm long, 9.5 mm diameter solid steel rods, which demonstrated that the seatback could be reinforced to become rear impact crashworthy. Solid steel rod was used in the reinforcement of the seatback canes to assure successful subsequent tests and to identify additional failure mechanisms, but robust round tubing would provide a better ratio of weight to structural integrity. Additional testing would be needed to determine an optimal ratio that would minimize weight, but still provide a rear impact crashworthy seatback.

The third failure mechanism in initial sled testing illustrated in FIGURE 5 was frame failure. Frame failure occurred at the welds of the frame's interface to the seatback, as well as at the interface between individual frame members. To address wheelchair frame failure, the insertion of 11.6 mm diameter steel rods into the frame tubing resulted in a reinforced frame that was crashworthy under rear impact conditions. As with the seatback reinforcement, further research with varying tube diameter of the wheelchair frame could yield a desirable weight-strength ratio. The addition of solid steel rod reinforcement in the seatback and wheelchair frame increased the wheelchair weight from 20.5 kg to 25.1 kg (+4.6 kg or +22.4%). It is important to minimize this weight increase, because wheelchairs are primarily used a mobility devices, while still making the wheelchair crashworthy in rear impact.

A major limitation of the wheelchair failure mechanisms findings is that they are specific to the sled test scenario. Higher rear impact severity is expected to produce additional and more severe failure modes. A heavier ATD, such as the 95th percentile Hybrid III ATD would perhaps also cause higher loading on the wheelchair, which may lead to added and more severe failures.

The specific wheelchair design tested in this study is the most influential factor for failure mechanisms. A different wheelchair may exhibit different modes and severities of failure under rear impact conditions. A study by Manary, et al. (2007) summarizes common wheelchair failure mechanisms for a variety of wheelchairs subjected to rear impact. The two most common failure modes found were seatback and front securement point failure. However, a sled testing conducted by Fuhrman, et al. (2007) suggests that pediatric wheelchairs considered crashworthy in frontal impact may also be crashworthy in rear impact. This may be due to the lighter pediatric (Hybrid III 6-yr-old) ATD used in the study. Further research is necessary to develop rear impact crashworthy wheelchairs, but the findings from this study can aid manufacturers to advance wheelchair designs in this direction. To achieve this front securement points should be secured to the wheelchair frame similar to the rear securement points using high grade hardware, while seatback canes and wheelchair frame members need to be designed with sufficiently strong tubing that can withstand loads brought on by a rear impact.

b. Completely reinforced wheelchair (for developing/validating computer model)

After the primary failure mechanisms were identified and eliminated through front securement point, seatback, and frame reinforcement, the structural integrity of the wheelchair could be maintained during additional rear impact sled tests. Since the wheelchair did not fail in these subsequent sled tests, the tests were considered 'successful' for the purpose of computer model development and validation.

The wheelchair model chosen for model development and sled testing is a commercial ANSI/RESNA WC19, folding, X-braced, manual wheelchair. This wheelchair featured a sling seat with foam cushion and a sling seatback. It was chosen to fit the anthropometrics of the 50th percentile Hybrid III ATD in collaboration with a wheelchair supplier that identified the most common and popular configuration of the wheelchair. By using this wheelchair configuration, the outcomes of this research may have the most widespread implications possible.

The 50th percentile Hybrid III has been developed to represent the anthropometrics of a healthy mid-sized male in the U.S. Persons with disabilities may differ anatomically from the healthy population represented by the Hybrid III ATD. Due to a lack of mobility, the population of persons with disabilities may have an increased average mass. Furthermore, they may not have the level of trunk, neck, and head stability as able-bodied persons. Consequently, the 50th percentile Hybrid III may not represent all wheelchair users. However, no ATDs have been developed to-date that represent people with disabilities. Despite this limitation, the mid-sized male Hybrid III has been chosen for this study because of its improved biofidelity over previous ATD models. The BioRID and RID2 ATDs were not deemed appropriate for this research application, since they were designed to study lower severity rear impact crashes (Schmitt, K. U., Niederer, P. F. et al., 2004).

B. Computer Model Development

The computer model developed using MADYMO^{TM} simulation software was based on the successful sled tests conducted after the wheelchair was reinforced and failure mechanisms were eliminated. While the original wheelchair configuration may have been altered through the reinforcement, this was necessary to assure three repeatable and successful sled tests, which were used for model development. To assure an accurate representation of the sled test scenario in the model, key measurements were collected with respect to the wheelchair, its position relative to the sled, WTORS and ATD. A similar process was previously performed in a study by Ha et al.(2007). The wheelchair used in sled testing and to be represented in the model consists of many components and is relatively complex. However, the wheelchair frame was represented by one body and 15 ellipsoid surfaces in the model for simplicity purposes. The wheelchair components' inertial properties were determined and represented in the model. The front securement points were modeled using translational joints to model wheelchair frame deformation (FIGURE 7). The seat was modeled using 1 body and an ellipsoid surface, connected to the wheelchair frame by a translational joint in the x (fore-aft) direction. This allows the ATD to translate with the seat horizontally in the fore-aft direction and models the ATD's penetration into the sling seat in the x-direction, as in the sled testing.

Since the seatback serves as the primary means of restraining the ATD during rear impact, it presented the greatest challenge in modeling. The seatback consists of two seatback canes that are extended from the frame. The seatback canes are connected with a sling-type seatback, which forms the seatback support surface. In the model the seatback surface is represented with two individual bodies and ellipsoids, both connected to the seat via a translational-revolute joint. Each of these ellipsoid surfaces may then translate in the x-direction and rotate in the x-z plane, while also allowing for surface penetration by the ATD's torso. This multi-body and multi-degree-of-freedom joint setup allowed for definition of a variety of stiffness and damping characteristics. It was necessary to vary stiffness of the seatback ellipsoid surfaces and joints since the wheelchair seatback was stiffer at the bottom than the top. The wheelchair tiedowns were modeled using belt segments for simplicity purposes, while the lap and shoulder belts were both represented by finite element belts to minimize slipping between the belt and ATD. Minimization of slipping could be achieved with finite element belts, since an increased number of finite elements in the belt allowed for more contacts points with the ATD.

The 50th percentile Hybrid III ellipsoid ATD was developed by the software manufacturer, TNO, and was imported from the provided database. TNO validated this particular ellipsoid model using frontal impact crash testing (48 km/h, 20 g), but the validation process involved only two sled tests and did not statistically compare the model to the sled test outcome measures, but relied on 'engineering judgment' to confirm validity (TNO, 2007).

The imported model of the ATD was amended by adding an additional ellipsoid to the upper torso and adding a contact between this ellipsoid and the ATD head. This was done because the ATD in sled testing had a more prominent protrusion at the lower neck. Also, in all the sled tests the ATD head made contact with the posterior upper torso and the imported ATD in the model lacked this head-torso contact, because the ATD in the model was only validated in frontal impact. Normally, the ATD's head would not contact the posterior upper torso in frontal impact, but only the anterior torso as the chin contacts the chest.

The model development was closely linked to the validation process. At first, the model was developed as simple as possible, but grew more complex with additional joints, bodies, and ellipsoids during the validation process.

C. Computer Model Validation

The initial validation of the computer model was based on assuring that the wheelchair and ATD kinematics in the model were visually analogous to those in the sled tests. This process required that key events occurred at the same point in time and that both wheelchair and ATD excursions in the model matched those from the sled tests. The frame sequence in FIGURE 8 shows that the model kinematics (bottom) reasonably match the sled kinematics (top) at various points in time during the rear impact. The first frame at t = 0 ms indicates the beginning of the deceleration pulse and therefore the point in time when the rear impact event starts. At t = 120 ms, the ATD loads the seatback and the front casters of the wheelchair rise off of the sled platform. The maximum head excursion occurs around 150 ms, and the ATD starts moving forward loading the occupant restraints at approximately 230 ms in the rebound phase of the event. The rear impact event is finished around 300 ms. Overall the model kinematics of the wheelchair and ATD reasonably match those of the sled tests. Ultimately this approach in model validation should increase the likelihood that forces and accelerations between the model and sled test match.

Next, the key model outcome measure time histories were validated. FIGURE 9 shows a relatively good fit of the model front tiedown loading time history with respect to the max-min corridor established using the sled test front tiedown time histories. The only point in the time history when the model front tiedown loading slightly deviates outside of the max-min corridor is around 100 ms. Model front tiedown loading history is symmetrical across the left and right side of the wheelchair, and FIGURE 10 compares the model-predicted loading time histories with the individual sled tests (both left and right front tiedowns shown for each sled test). The double peak exhibited by the model front tiedown loading is also evident in sled tests 2 and 3 (both left and right front tiedowns). In sled test 2, the double peaks are less prominent than that from the model, while sled test 3 double peaks are as prominent as the model's second peak, but occur about 12 ms later. One possible explanation for the occurrence of the second peak is that the front tiedowns are reloaded immediately after unloading begins, as the stitching in the seatback begins to rip and allows the ATD more rearward excursion. This was represented in the model with a combination of varying translational and rotational joint and seatback surface stiffnesses. Ultimately, the model's front tiedown loading can be considered validated through the sled tests, since all four of the statistical test criteria have been satisfied (TABLE IV).

Loading of the lap belt was the only occupant restraint belt considered as an outcome measure for validation, because shoulder belt loading was negligible in sled testing, as it is in the model. FIGURE 11 shows a relatively good match between the model lap belt loading time history and the lap belt max-min corridor from the three sled tests. The peak lap belt load generated from the model is lower than in the sled tests. Due to rear impact dynamics, the seatback serves as the primary occupant restraint mechanism, while the lap belt is only loaded in the rebound phase of the rear impact event. The sled test maximum lap belt loading of 1865 N in rear impact is substantially lower than the mean peak lap belt load of 12760 N found in a frontal impact study by Leary et al. (2001) The lap belt loading outcome measure can be considered validated, since three out of four statistical test criteria have been met (TABLE IV).

While FIGURE 13 may suggest that wheelchair acceleration in the x-direction does not fall within the max-min corridor most of the time, FIGURE 14 shows how the time histories from the individual sled tests differ from another. Due to the nature of the wheelchair acceleration sensitivity, variation between the individual sled test time histories is evident. However, the general shapes of all the wheelchair time histories are similar, with the peak occurring between 30 and 75 ms and leveling off again between 90 and 100 ms. The statistical analysis comparing individual sled test wheelchair acceleration time histories showed that there is substantial difference between the individual sled tests (TABLE V). While the model's wheelchair acceleration meets two of four statistical test criteria, sled tests #2 and #3 only meet three out of four test criteria when compared to the mean sled test wheelchair acceleration. As shown in TABLE V, all the peaks occurred within 20.5% of the mean wheelchair signal, but some are outside of the +/-5ms time window. This may suggest that the time window chosen for the criteria could be widened, especially since wheelchair acceleration time histories in two out of three sled tests do not meet this criteria when compared to the mean sled test wheelchair acceleration. However, when the model wheelchair acceleration is compared to sled test #2, three of four statistical test criteria are satisfied (TABLE VI). This implies that when the wheelchair acceleration in the model is compared to the wheelchair acceleration from an individual sled test, the wheelchair acceleration time history is valid.

The ATD resultant head acceleration outcome measure can be considered validated since FIGURE 15 shows a large portion of the time history falls within the max-min corridor, and FIGURE 16 shows that the model's ATD head acceleration time history matches the time histories of ATD head accelerations from the individual sled test reasonably well. This is further substantiated by the statistical analysis, as all four test criteria are satisfied in a comparison of the model ATD resultant head acceleration to the mean ATD head acceleration from the sled tests.

The ATD resultant chest acceleration can also be considered validated, since the model time history falls within the max-min corridor for a substantial portion of time history (FIGURE 17). FIGURE 18 shows that the ATD resultant chest acceleration follows the chest acceleration time histories from the individual sled tests reasonably well. The only portion of the time history where the model deviates from the sled tests is around 90 ms. The model's time history lacks a local minimum, which the sled test exhibits between 80-90 ms. A possible explanation for this is the limitation associated with the arms-seatback contact. Normally when the arms move rearward and contact the seatback, the seatback experiences additional loading and more deformation, which in turn decreases chest acceleration. The contact between the ATD torso and the seatback is defined in order to assure that the time histories for ATD chest acceleration match over the majority of the time period. The model's simplicity is a limitation and in this case causes a local deviation in the chest acceleration time history. However the results from the statistical analysis in TABLE IV show that three of four statistical criteria are met. This indicates that the model's ATD chest acceleration can be considered validated.

FIGURES 19 and 20 show the model's ATD resultant pelvic acceleration matches well with the pelvic acceleration time histories from sled testing. The pelvic acceleration in the model can be considered validated, since all four of the statistical criteria have been satisfied.

Initially, the methodology for model validation included an additional sled test for the verification of the model. For verification of a model, a relevant change is made in the sled test first, then in the model. The model then must predict the outcome to be considered verified. The verification sled test consisted of moving the wheelchair center of gravity by shortening the wheelbase of the wheelchair. This wheelchair configuration change may have resulted in increased front securement point loading resulting in front securement point hardware failure, despite the reinforcement. This unfortunate failure rendered the data from the verification sled test useless. Lack of additional funding prevented another attempt of model verification. Future research and use of the model should include verification to further strengthen the model predictability.

Overall, the model validation in this study can be considered relatively comprehensive. According to the literature review of previous wheelchair transportation related research (BACKGROUND, Section H), early computer models validations were limited. Even though Paskoff's rear impact model of a 50th percentile ATD seated in an adult manual wheelchair was able to describe occupant kinematics and forces to some extent, the model was not validated in rear impact using dynamic crash testing (Paskoff, G., 1995).

Bertocci, et al. (1999) validated their model of a mid-sized ATD in a commercial powered wheelchair subjected to frontal impact utilizing data from two sled test runs. First, the gross motions of the occupant and wheelchair in the model were compared to those from sled testing. Peak values and general time history profiles of the following model parameters were compared to sled test results: WTORS loads, resultant head, chest, and wheelchair accelerations, along with head and front wheel excursions. Only limited comparisons were employed in the validation process, including peak value and range percent difference between the model and sled test results for the outcome measures.

Leary and Bertocci's first attempt to validate their frontal impact model of a 50^{th} percentile ATD in an adult manual wheelchair was to compare gross occupant and wheelchair kinematics visually to sled test videos. The time histories of various outcome measures were then also compared to those in the sled test: shoulder belt loading, lap belt loading, (rear) tiedown loading, wheelchair acceleration, ATD chest acceleration, and ATD pelvic acceleration. Validation criteria were established as having "relatively similar" peak values and "profile fit" between simulation and sled test. No statistical techniques were utilized for validation.(Leary, A. and Bertocci, G. E., 2001).

A more recent frontal impact model of a pediatric wheelchair occupied by a 6-year-old ATD by Ha and Bertocci featured a more rigorous validation method. In the validation process, a visual comparison of the sled test videos and the model kinematic output was conducted (Ha, D. R., Bertocci, G. E. et al., 2007). The authors also compared the trends and peaks of outcome measure time histories generated from the model to those acquired during sled testing. The outcome measures used in the comparison were wheelchair acceleration, wheelchair rear tiedown forces, occupant restraint shoulder and lap belt forces, and ATD chest and head accelerations. Additionally, a comparison between the model and sled test peak horizontal excursions was made for the wheelchair, ATD knee, and ATD head in the forward direction. The statistical analysis used in the validation process consisted of determining percent of peak difference, Pearson's correlation coefficient (r), and performing a linear regression analysis of model and sled test peak values. The statistical analysis results were compared to initially defined criteria and to those from studies conducted previously.

Another recent model of a mid-sized ATD occupying an adult manual wheelchair in frontal impact by Dsouza and Bertocci underwent a rigorous validation process (Dsouza, R. and Bertocci, G. E., 2008). In the first step of this model validation process, the model-predicted gross kinematics of wheelchair and ATD were visually compared to those recorded from high-speed sled test videos. Secondly, the model's predicted time histories of force and acceleration data were super-imposed over respective time history min/max corridors from the sled tests. Various model parameters were tuned until time history plots shared similar trends between the model and sled tests. Finally, this study used statistical analysis to quantify the association between model and sled test outcome measures. The five statistical tests used were mean value ratio, Pearson's correlation coefficient (r), coefficient of determination (r^2), mean absolute percentage error, and standard deviation of the mean percentage error. The mean signal from each parameter in the two sled tests was used in the statistical comparison.

The validation process for this rear impact model is closest in resemblance to the Dsouza and Bertocci model validation (Dsouza, R. and Bertocci, G. E., 2008). Both studies utilize multiple statistical tests to quantify how well the time history curves of key model outcome measures match those of the sled tests. This rigorous validation process is something that the other models lack, with the exception of the Ha and Bertocci model (Ha, D. R., Bertocci, G. E. et al., 2007). While the statistical tests in both the Dsouza and Bertocci (2008) study and in this rear impact study may quantify how well two curves match one another, the fact that Dsouza and Bertocci utilize both Pearson's correlation coefficient (r) and the coefficient of determination (r^2) seems redundant and superfluous, as the latter is dependent on the former. The Dsouza and Bertocci model also lacks a validation of peak values, which may be important since peak values of loading are used to establish design criteria. All other studies that may have used peak values of key outcome as a validation criterion, did not investigate when the peak occurred, which is something that this rear impact study attempted to do.

D. Parametric Sensitivity Analysis

The parametric ranges used in the sensitivity analysis shown in TABLE VII were chosen to investigate a 'worst-case scenario' and their effect on key model outcome measures associated with wheelchair and WTORS integrity. For the parametric sensitivity analysis investigating impact severity, the extreme bounds of the proposed ISO rear impact standard corridor were chosen (FIGURE 1), since this increased impact severity was expected to present a worst-case scenario. As the results showed, the higher impact severity had a relatively large effect on all outcome measures except normal seat loading, and shoulder belt loading. In most cases the higher impact severity had the largest effect on the model outcome measures usually causing the highest loads and deflections. However, in the case of lap belt loading, the increased impact severity yielded a negligible lap belt load of 33 N (FIGURE 36), because the ATD did not rebound into the lap belt due to a computational limitation. As evident by the increased normal seatback loading of 8185 N (FIGURE 25), the higher impact severity causes the ATD to increase load on the seatback. In the model, the seatback surface is modeled with two ellipsoid surfaces with a thickness of 20 mm. If there is enough seatback penetration that the ATD torso passes through the 20 mm think seatback, the model cannot calculate the ATD-seatback contact forces which ultimately allows the ATD to pass through the seatback surface ellipsoids, preventing a rebound into the lap belt.

To investigate the effect of a larger wheelchair occupant, the ATD's inertial properties were increased to those of the 95th percentile Hybrid III. As the results from the parametric sensitivity analysis show, the heavier mass ATD caused relatively moderate increases in wheelchair loading. This is evident throughout the parametric sensitivity analysis given that the heavier ATD never caused the highest loading or deflection in a wheelchair/WTORS outcome measures. FIGURES 30 and 37 show that the 95th percentile ATD had no effect on front wheel loading and shoulder belt loading.

Because the baseline model vertical front securement point location was at the bottom of the wheelchair frame, options to vary its location were limited. Therefore the two additional locations of the front securement point investigated in the parametric analysis were at the mid-level and highest point of the wheelchair frame. The parametric sensitivity analysis results showed that in the case of seatback deflection (FIGURE 24), seatback normal load (FIGURE 25), wheelchair pitch (FIGURE 29), lap belt, and shoulder belt loading, (FIGURES 36, and 37), the front securement point location had a negligible effect. However, the maximum height of the front securement point caused the overall worst-case scenario for front wheel loading (6918 N, FIGURE 30). This high loading was not caused by the front casters making contact during the wheelchair rebound back to the sled platform, but during the primary impact. In this scenario, the front securement point height was above the wheelchair CG (highest point on the wheelchair frame) and the front of the wheelchair rotated downward during the primary event, pushing the front casters onto the ground. Increased front securement point height had only moderate effects on all other outcome measures.

The seatback tilt was varied in the parametric sensitivity analysis from its baseline value of 2 deg up to 30 deg in the posterior direction relative to the vertical, in increments of 5 deg. The upper limit of 30 deg was based on the ANSI/RESNA WC19 standard, which requires that reclining wheelchairs be tested with the seatback reclined at a maximum of 30 deg (ANSI/RESNA, 2000). The results from the parametric sensitivity analysis show that increased seatback tilt decreased seatback deflection (FIGURE 24), as well as lap belt loading (FIGURE 36). This suggests that wheelchairs with higher seatback tilt would cause less seatback deflection and reduce the occupants rebound in rear impact. The trade off is evident in FIGURE 26, where a substantial increase in seatback shear loading is caused by increasing seatback tilt. FIGURE 27 shows seatback normal loading only reduced marginally with increasing seatback tilt. This could be due to the ATD's increase in distance to the seatback and therefore increase in momentum before contact with the seatback. This increase in momentum also caused an increase in wheelchair pitch rearward (FIGURE 29). All other outcome measures were only marginally or moderately affected by an increase in seatback tilt. However, since the seat angle was not changed with the seatback angle, these findings may not be applicable for tilt-in-space wheelchairs that usually feature a relatively fixed seat-seatback angle.

In the parametric sensitivity analysis, seat stiffness was varied based on published seat stiffness values for various types of commercial seating systems obtained through quasi-static testing (Bertocci, G., Ha, D. et al., 2001; Ha, D., Bertocci, G. et al., 2002). The seating systems' stiffness ranged from relatively soft sling seats to relatively rigid drop seats. The entire stiffness range was utilized in the parametric sensitivity analysis in increments of 25% (FIGURE 21). The results show that, in rear impact, seat stiffness has an overall relatively negligible effect on wheelchair loading, seatback deflections, and WTORS. However in contrast, in frontal impact, as the occupant moves forward and loads the lap and shoulder belt, the seat plays and integral role in preventing submarining and keeps the occupant safe. ANSI/RESNA WC19 requires structural stability of the seat during dynamic frontal impact testing. This is also why the goal of the previously mentioned studies (Bertocci, G., Ha, D. et al., 2001; Ha, D., Bertocci, G. et al., 2002) was to assess whether commercial seating systems could withstand loading imposed by a frontal impact. Because of rear impact dynamics, seat stiffness does not play a key factor in wheelchair/WTORS loading.

The seatback stiffness was varied similarly based on published seatback stiffness values [REF]; also in increments of 25% of the range. FIGURE 22 reveals that the model seatback stiffness needed to validate the model was lower than those in the published range. The modeled wheelchair featured a sling seatback, while the seatbacks in the published range were stiffer.

Seatback stiffness had a substantial effect on normal seatback loading (FIGURE 25) causing loads as high as 7933 N, as well as normal seat loading (FIGURE 27) with loads up to 3130 N. Shear seat loading in the model wheelchair was reduced to 5489 N (FIGURE 28) with increased seatback stiffness, while rearward wheelchair pitch dropped to 7.0 deg (FIGURE 29). Lap and shoulder belt loading rose to 1464 N and 622 N, respectively (FIGURES 36 and 37). These results are caused from the ATD's decreased rearward excursion and increased rebound, brought about by the stiffer seatback. Since injury criteria were not investigated as a part of this study, the effects of seatback stiffness on occupant safety are yet to be determined.

The final parameter investigated in the parametric sensitivity analysis was the seat-seatback joint stiffness and its effect on key wheelchair/WTORS outcome measures.

The published range (van Roosmalen, L., Bertocci, G. et al., 2000) was again divided in 25% increments and the results show that seat-seatback joint stiffness had a relatively negligible effect on all key wheelchair/WTORS parameters. One reason for this may be that the range investigated was not large enough, since only three seating systems were investigated by van Roosmalen, et al. (2000) However, the same trends could normally be expected as were found with varying seatback stiffness.

A study by Bertocci, et al. (1996) developed design criteria for transit wheelchairs, based on dynamic loading in frontal impact. In this study, the authors used a validated computer model of a powered wheelchair and a 50th percentile ATD restrained with a wheelchair-anchored lap belt and vehicle anchored shoulder belt to establish early transit wheelchair design guidelines for frontal impact. One of the major findings of this study was that locating the rear securement vertically at or near the wheelchair's center of gravity can produce beneficial crash results, minimizing wheelchair and WTORS loading. This is because deviation from the wheelchair center of gravity causes the wheelchair to rotate and increases loading on the front and rear wheels, lap and shoulder belt, as well as the seat. Similarly in this study of rear impact, the parametric sensitivity analysis shows evidence of rearward wheelchair rotation with increasing front securement height. This suggests that the baseline front securement point height may be closest to the wheelchair center of gravity. Bertocci, et al. (1996) also report associated loading information when the rear securement point is located at the most beneficial location (at or near the wheelchair center of gravity). TABLE IX below summarizes design guidelines from the frontal impact study by Bertocci et al. and compares them to the maximum loads in this study's parametric sensitivity analysis.

TABLE IX

COMPARISON OF FRONTAL IMPACT DESIGN GUIDELINES AND PEAK LOADS FROM THE REAR IMPACT PARAMETRIC SENSITIVITY ANALYSIS.

Outcome Measure	Frontal Impact	Rear Impact
Lap Belt Loading	**8273 N**	1464 N
Seat Resultant Loading	16680 N	**16764 N**
Front Wheel Loading	5695 N	**6918 N**
Rear Wheel Loading	**7990 N**	7940 N
Front Securement Point Loading	100 N	**15093 N**
Rear Securement Point Loading	**21033 N**	1782 N

BOLD - denotes higher loading
Note: Frontal impact design guidelines from Bertocci, et al. (1996) are based upon a powered wheelchair.

Since rear impact and frontal impact dynamics are different, loading on various wheelchair components may also differ in these scenarios. It is worth noting that the frontal impact design guidelines are based on findings using a heavier, powered wheelchair (85 kg) and a more severe frontal impact crash pulse. However, in general when designing a crashworthy wheelchair and/or WTORS, both frontal and rear impact guidelines need to be observed and combined to form the most stringent criteria for design.

TABLE X below summarizes the maximum loads found in both previous frontal impact studies (Bertocci, et al. 1996; Leary and Bertocci, 2001) and this rear impact investigation. Most importantly, TABLE X depicts design guidelines for wheelchair and

WTORS for use by manufacturers to aid in creating products that are crashworthy in both frontal and rear impact.

TABLE X

DESIGN GUIDELINES FOR WHEELCHAIR AND WTORS MANUFACTURERS TO CREATE CRASHWORTHY PRODUCTS IN FRONTAL AND REAR IMPACT.

Wheelchair / WTORS component	Minimum Design Load
Seat	3130 N (normal) 16469 N (shear)
Seatback	8185 N (normal) 3441 N (shear)
Front Wheel	6918 N
Rear Wheel	7990 N
Front Securement Point	15093 N
Rear Securement Point	21033 N
Lap Belt	8273 N
Shoulder Belt	9786 N
Front Tiedown	15093 N
Rear Tiedown	21033 N

The loads shown in TABLE X above should be considered as the minimal design loads, as wheelchair and WTORS manufacturers should incorporate adequate factors of safety when they design products for the crash environment. Wheelchair and WTORS manufacturers should account for weight and configuration of individual wheelchairs as well as the weight of intended users when designing and introducing crashworthy products into the marketplace.

It is important to note that the test protocol and crash pulse used in this study are from a proposed ISO rear impact standard (ISO, 2006), which has not yet been adopted by ISO. Another limitation of this study is that one type of manual wheelchair make and model was used for all sled tests and model development/validation; other manual wheelchairs may generate different loading and kinematics. ATD neck loading and moments were not considered in the model validation.

Also notable is that the parametric sensitivity analysis was performed by varying only one parameter at a time. Varying more than one parameter in the analysis may lead to different results. The effect of an increase in wheelchair mass was not investigated, but a power wheelchair, having higher mass is anticipated to produce higher wheelchair and WTORS loads. Other variables that may affect loads include securement point location and geometry, ATD mass, and crash pulse severity. There are additional limitations associated with the model. The model validation was limited to only three sled tests, and did not include verification of the model. The statistical analysis conducted to quantify validation was limited to four statistical tests; additional statistical tests may better demonstrate model validity or the lack there of. In the parametric sensitivity analysis, the addition of more parameters may yield additional insight and aid in refining the design guidelines. However, the parameters chosen were thought to have the most influence on wheelchair components and WTORS loading.

This study is important, because it evaluates the effect of rear impacts on wheelchairs and WTORS. Most importantly, this study provides wheelchair and WTORS manufacturers with information on failure mechanisms in rear impact, as well as establishes design guidelines to help manufacturers design and introduce rear impact crashworthy products into the marketplace. Future work will focus on increasing the computer model's predictability through verification testing. Another study will also use this model to investigate injury risk associated with wheelchair occupants subjected to rear impact.

VI. CONCLUSION

The most common wheelchair failure mechanisms found during rear impact sled testing were front securement point hardware failure (shearing bolts), seatback failure, and frame failure. With the use of higher quality hardware, while avoiding a front securement point design that is offset from the wheelchair frame, this primary failure mode can be eliminated. Seatback and wheelchair frame failures can be eliminated by reinforcement of the seatback and wheelchair frame. This study showed that a frontal impact crashworthy WC19 wheelchair, which initially failed in rear impact, could easily be modified to become rear impact crashworthy. However, the study did not focus on optimizing reinforcement, so further research is needed to find an acceptable balance of increased structural integrity and added weight to the wheelchair.

The computer model developed in this study was simulating a rear impact event of an adult manual wheelchair occupied by a 50^{th} percentile ATD. The model was successfully validated using visual comparison of wheelchair and ATD kinematics, comparison of key outcome measure time histories between the model and sled tests, as well as statistical analyses to quantify the level of validity. Even though the validation process was relatively rigorous compared to previous studies and models, the model in this study was determined to be validated and a reasonable predictor of rear impact involving a manual wheelchair and a seated 50^{th} percentile ATD. Moreover, this model may later be used to investigate injury risks associated with mid-sized adults seated in wheelchairs, subjected to a rear impact.

The parametric sensitivity analysis conducted as a part of this study yielded rear impact design guidelines for wheelchair and WTORS manufacturers, which will aid in the development, design, and ultimately introduction of rear impact crashworthy wheelchairs and WTORS. The guidelines include worse case wheelchair and WTORS loading that can be used in the design of rear impact crashworthy products. However, the design guidelines from this study must be combined with previously published frontal impact design guidelines to create the most stringent design criteria capable of withstanding loads encountered in both frontal and rear impact events.

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<u>Academic</u>

1/2006 – present Injury Risk Assessment and Prevention (iRAP) Laboratory, University of Louisville, Graduate Research Assistant
Conduct research in Injury Biomechanics, particularly Wheelchair Transportation Safety

- Investigate wheelchair and wheelchair tiedown integrity during rear impact collisions using various techniques, including sled impact testing and computer simulation. Project funded by Paralyzed Veterans of America (PVA) grant.
    - planned, coordinated, and conducted rear impact sled tests at the University of Michigan
    - development and validation of computer simulation wheelchair model using MADYMO
    - parametric sensitivity analysis to yield wheelchair and wheelchair tiedown manufacturer design guidelines

5/2008 – 7/2008 University of Michigan Transportation Research Institute (UMTRI), Biosciences Division, University of Michigan, Ann Arbor, MI

Graduate Student Intern

- Primary project: assembling first draft of annex to ISO 7176-19 standard titled: *"Wheeled mobility devices for use as seats in motor vehicles – Forward facing mobility aids in rear impact"*
- Aid in daily operation of running an impact sled laboratory.
- Helped with in-depth crash investigations of motor vehicle accidents.
- Mentored undergraduate research student responsible for developing instrumentation of surrogate seating system.

<u>Non-Academic</u>

9/2005 - 1/2006 Alcoa, Louisville, KY
Part-Time Mechanical Engineering Co-op
Supported chief maintenance engineer in assuring smooth, continuous plant operations

- Daily responsibilities:
  - Develop and provide CAD drawings using Auto CAD
  - Manage kick-outs to assure continuous and complete shipment of customer products.
- Major Projects undertaken:
  - preventive maintenance program for a range of equipment in entire plant
  - winter shutdown maintenance on laminators and slitters

8/2003 - 6/2005 Vacuum Depositing Inc. (VDI), Louisville, KY
Full-Time / Part-Time Engineering Co-op Student
Supported president and vice president of Engineering in assuring smooth, continuous plant operations

- Daily responsibilities:
  - information technology (IT) support for entire facility including network installation and computer installation/upgrades (familiar with small business networking)
  - database support in MS Access through data entry management and development/modification of reports and queries
- Major projects undertaken:
  - design and implementation of class 10K clean-room to increase quality control
  - preventive maintenance program for a range of equipment in entire plant
  - Aided ISO manager in ISO recertification by establishing in-house records required for compliance
  - Rebuilding MS Access database for more efficient and accurate production oversight and quality control

- Rebuilding and expansion of IT network to accommodate new MS Access database
- Vapor coater remodeling with newest webbing technology (including chilled drum), wire drives, and density control system.

Professional/Scientific Societies and Extracurricular Activities

2007- present	ANSI/RESNA Standards Committee on Wheelchairs and Transportation (COWHAT) – Voting Member
2006 – present	Pi Tau Sigma, Mechanical Engineering Society – Member
2004 – present	Tau Beta Pi Engineering Honor Society – Member
2002 – present	American Society of Mechanical Engineers (ASME) – Member
2006 – 2008	Biomedical Engineering Society (BMES) – President, Member
2005 – 2007	Society of Automotive Engineers (SAE) Formula – Member
2002 – 2004	University of Louisville Intramural Soccer – Captain
2000 – 2001	Tutor and Guide for Big Brother Program – Volunteer

Honors and Awards

2008	Honorable Mention (PhD Level) at the Engineering Exposition (E-Expo) Poster Presentation. University of Louisville Speed Scientific School, Louisville, KY.
2007	Winner of the Student Scientific Paper Competition at annual conference of Rehabilitation Engineering and Assistive Technology Society of North America (RESNA), Phoenix, AZ.
2007	Elisabeth M. And Winchell M. Parsons Graduate Scholarship – competitive, national award granted by the American Society of Mechanical Engineers (ASME) Auxiliary to top 1-2 students in U.S. pursuing a Ph.D. in Mechanical Engineering.
2007	University of Louisville Grosscurth Fellowship – fellowship awarded by the J.B. Speed School of Engineering for pursuing a Doctorate of Philosophy in engineering.

2006 — Marjorie Roy Rothermel Graduate Scholarship – competitive, national award granted by the American Society of Mechanical Engineers (ASME) Auxiliary to top eight graduate students in U.S.

2003 — Burton Scholarship – competitive award granted by University of Louisville, J. B. Speed School of Engineering to one undergraduate student.

Skills

Computer — Windows, MS Office Pro, Visual BASIC (VB), MATLAB, C++, AutoCAD, Solid Edge, ANSYS, HTML, Pascal, QBASIC, ATB 3[i], MADYMO, LabVIEW

Machining/ Maintenance — Basic tooling (Lathe, and Mill)
Basic maintenance of various industrial equipment including vapor coaters, sputterers, laminators, and slitters

Language — Multilingual (oral and written) in English, German, and Serbo-Croatian

Publications

Salipur Z, Bertocci G. Development and Validation of Rear Impact Computer Simulation Model of an Adult Manual Transit Wheelchair with a Seated Occupant. Proceedings of the Annual RESNA 2008 Conference. June 2008.

Salipur Z, Bertocci G, Manary M, Ritchie N. Wheelchair Tiedown and Occupant Restraint System Loading Associated with an Adult Manual ANSI WC-19 Transit Wheelchair with a Seated 50th percentile ATD Exposed to Rear Impact. Proceedings of the Annual RESNA 2007 Conference. June 2007.

Manary M, Bezaire B, Bertocci G, **Salipur Z**, Schneider L. Crashworthiness of Forward-Facing Wheelchairs under Rear Impact Conditions. Proceedings of the Annual RESNA 2007 Conference. June 2007.

Presentations / Dissemination

06/2008 — Annual Conference of Rehabilitation Engineering and Assistive Technology Society of North America (RESNA), Washington, D.C.
Poster - *Development and Validation of Rear Impact Computer Simulation Model of an Adult Manual Transit Wheelchair with a Seated Occupant*

03/2008	Engineering Exposition (E-Expo), University of Louisville Speed Scientific School, Louisville, KY. Poster - *Development and Validation of Rear Impact Computer Simulation Model of an Adult Manual Transit Wheelchair with a Seated Occupant*
10/2007	Alumni Association Homecoming Banquette, University of Louisville Speed Scientific School, Louisville, KY. Poster - *Transit Wheelchair Performance and Tiedown Loading in Rear Impact*
06/2007	Annual Conference of Rehabilitation Engineering and Assistive Technology Society of North America (RESNA), Phoenix, AZ. Poster - *Wheelchair Tiedown and Occupant Restraint System Loading Associated with an Adult Manual ANSI WC19 Transit Wheelchair with a Seated 50th Percentile ATD Exposed to Rear Impact*
06/2007	Annual Conference of Rehabilitation Engineering and Assistive Technology Society of North America (RESNA), Phoenix, AZ. Platform Presentation - *Wheelchair Tiedown and Occupant Restraint System Loading Associated with an Adult Manual ANSI WC19 Transit Wheelchair with a Seated 50th Percentile ATD Exposed to Rear Impact*
04/2007	Biomedical Engineering Society, University of Louisville Student Chapter – Professional Development Forum Platform Presentation - *Transit Wheelchair Performance and Tiedown Loading in Rear Impact*
03/2007	Engineering Exposition (E-Expo), University of Louisville Speed Scientific School, Louisville, KY. Poster - *Transit Wheelchair Performance and Tiedown Loading in Rear Impact*
03/2007	American Society of Mechanical Engineers (ASME) / American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Louisville Professional Chapters, Professional Development, Louisville, KY. Platform Presentation - *Transit Wheelchair Performance and Tiedown Loading in Rear Impact*

Teaching / Mentoring

Spring 2007 – present Jefferson County Public Schools Adult Education – *German for Beginners*

Summer 2008 Graduate student mentor for undergraduate research student at University of Michigan Transportation Research Institute (UMTRI). Project: Developing instrumentation of surrogate seating system.

Spring 2008 Graduate student mentor for senior Capstone Design Project Group
Project: *Designing Assistive Technology: A Basketball Shooter to allow wheelchair users with limited mobility to play basketball*

Research

Graduate

1/2006 – present Development and Validation of Computer Simulation Model of Wheelchairs in Rear Impact Collisions and Design Improvement Proposal
Principal Investigator: Dr. Gina Bertocci, University of Louisville.
Funded by Paralyzed Veterans of America

Undergraduate

8/2005 - 12/2005 Investigation of Conveyer Belt Pulley for Cylicron Inc.
Mentor: Dr. Keith Sharp
Undergraduate Capstone Project. As a result of successful project, Cylicron awarded $2000 grant to the University of Louisville

References

Available upon request

ANNEX A

TABLE A.I.
COMPLETE PARAMETRIC SENSITIVITY ANALYSIS RESULTS

		WHEELCHAIR										WTORS			
Run #	Model Parameter Varied / Description	Seatback Deflection (deg)	Seatback Loading, Normal (N)	Seatback Loading, Shear (N)	Seat Pan Loading, Normal (N)	Seat Pan Loading, Shear (N)	WC pitch (deg)	Front Wheel Loading (N)	Rear Wheel Loading (N)	Front Sec Pt Loading (N)	Rear Sec Pt Loading (N)	Front TD Loading (N)	Rear TD Loading (N)	LB Loading (N)	SB Loading (N)
0	Origianal, validated model configuration	13.2	3270	2246	1772	7710	13.5	814	4499	7366	709	7366	709	1023	0
1	Higher impact severity	27.6	8185	3441	1988	16469	19.0	2094	7940	15093	1782	15093	1782	33	0
2	Replaced ATD with 95th percentile HIII	16.2	3572	2896	1977	9271	14.7	819	5307	7943	1006	7943	1006	831	0
3	Front sec pt up 7 cm (half way)	12.7	3430	2067	1011	4448	13.8	4647	3522	8652	1026	8652	1026	1043	0
4	Front sec pt up 14 cm (to max)	12.1	3499	1544	1113	4592	12.6	6918	2384	8820	994	8820	994	963	0
5	Seatback tilt 5 deg	12.6	3124	2253	1726	7747	14.4	827	4423	7282	726	7282	726	1041	0
6	Seatback tilt 10 deg	11.4	2916	2381	1754	8049	15.7	884	4472	7206	708	7206	708	964	0
7	Seatback tilt 15 deg	9.8	3161	2523	1816	8557	16.3	961	4457	7094	764	7094	764	685	0
8	Seatback tilt 20 deg	8.4	3299	2613	1888	8867	16.5	1005	4574	7037	872	7037	872	292	0
9	Seatback tilt 25 deg	6.9	3315	2891	1922	8940	17.1	1028	4816	7022	954	7022	954	79	0
10	Seatback tilt 30 deg	5.5	3076	3170	1912	9045	17.3	1032	4975	7013	992	7013	992	18	0
11	Seat stiffness 0 %	11.8	7768	2465	2963	5483	7.0	2256	4996	8232	750	8232	750	1385	622
12	Seat stiffness 25 %	11.8	7898	2472	2930	5532	7.1	2264	5016	8223	752	8223	752	1365	615
13	Seat stiffness 50 %	12.0	7933	2485	2960	5576	7.2	1410	5075	8200	756	8200	756	1417	613
14	Seat stiffness 75 %	12.2	7875	2549	3130	5721	7.5	2410	5093	8105	761	8105	761	1461	586
15	Seat stiffness 100 %	13.3	4553	2176	1573	6918	12.1	730	4721	7566	707	7566	707	1464	72
16	Seatback stiffness 0%	13.3	4553	2176	1573	6918	12.1	730	4721	7566	707	7566	707	1464	72
17	Seatback stiffness 25%	12.2	7875	2549	3130	5721	7.5	2410	5093	8105	761	8105	761	1461	586
18	Seatback stiffness 50%	12.0	7933	2485	2960	5576	7.2	1410	5075	8200	756	8200	756	1417	613
19	Seatback stiffness 75%	11.8	7898	2472	2930	5532	7.1	2264	5016	8223	752	8223	752	1365	615
20	Seatback stiffness 100%	11.8	7768	2465	2963	5483	7.0	2256	4996	8232	750	8232	750	1385	622
21	Seat-Seatback stiffness 0 %	12.7	3288	2247	1770	7695	13.0	806	4404	7367	688	7367	688	1006	0
22	Seat-Seatback stiffness 25 %	12.6	3299	2245	1767	7691	13.4	806	4404	7368	712	7368	712	1040	0
23	Seat-Seatback stiffness 50 %	12.5	3300	2245	1764	7690	13.5	806	4404	7368	720	7368	720	1052	0
24	Seat-Seatback stiffness 75 %	12.5	3301	2244	1767	7690	13.5	806	4403	7368	723	7368	723	1052	0
25	Seat-Seatback stiffness 100 %	12.5	3301	2242	1773	7690	13.3	806	4402	7368	703	7368	703	1019	0
	MAX	27.6	8185	3441	3130	16469	19.0	6918	7940	15093	1782	15093	1782	1464	622
	MIN	5.5	2916	1544	1011	4448	7.0	730	2384	7013	688	7013	688	18	0

ANNEX B

MADYMO™ Code


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<MADYMO
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  >
  <TYPEDEFS>
    <INCLUDE
      FILE="typedefs.xml"
    />
  </TYPEDEFS>
  <RUNID>
<![CDATA[
Hybrid III 50th %-ile model
ellipsoid model in default position
]]>
    <PRODUCT_INFORMATION
      DESCRIPTION="MADYMO Hybrid III 50th percentile ellipsoid dummy"
      FILE="d_hyb36yel_usr.xml (user-file)"
      VERSION="2.6"
      DATE="$Date: 2005/11/14 12:43:23 $"
      STATE="$State: R63 $"
      >
      <COPYRIGHT>
<![CDATA[
Developed by TNO

(c) 2005 TNO
 P.O. Box 6033, 2600 JA Delft, The Netherlands

All rights reserved

MADYMO software programs and MADYMO models are confidential
information and proprietary products of TNO, Delft, The Netherlands.
The terms and conditions governing the licensing of MADYMO software
and models consist solely of those set forth in the written
contracts between TNO or TNO authorized third parties and its
customers. The software and models may only be used or copied in
accordance with the terms of these contracts.
]]>
      </COPYRIGHT>
    </PRODUCT_INFORMATION>
  </RUNID>
  <CONTROL_ALLOCATION
    NR_PROC="1"
    I_SIZE="1000000"
    R_SIZE="2000000"
    C_SIZE="100000"
  />
  <CONTROL_ANALYSIS.TIME
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    TIME_END="0.3"
    TIME_STEP="2.500000E-005"
    INT_MTH="EULER"
    ANALYSIS_TYPE="DYNAMIC"
    CONSTRAINT_TOL="1.000000E-009"
    RAMP="0.0 0.1"
    RACO="0.01 0.1"
  />
  <CONTROL_OUTPUT
    FILTER_IGNORE="OFF"
    PADDING_TIME="0.01"
    TIME_STEP="1.000000E-004"
    TIME_STEP_ANI="0.0005"
    WRITE_DEBUG="NONE"
    >
```

```
    <TIME_HISTORY_MB
      DESCRIPTION="Output signals Hybrid III 50th percentile ellipsoid dummy model"
      SYSTEM="/Hybrid_III_50th"
      BODY_OUTPUT_LIST="ALL"
      BODY_REL_OUTPUT_LIST="ChestDeflection_dis ChestDeflection_vel_CFC180
                   ChestDeflection_vel_CFC600"
      JOINT_CONSTRAINT_OUTPUT_LIST="LumbarSpineLow_lce_F
                         LumbarSpineLow_lce_T NeckLow_lce_F
                         NeckLow_lce_T NeckUp_lce_F_CFC600
                         NeckUp_lce_F_CFC1000 NeckUp_lce_T
                         FemurL_lce_F FemurL_lce_T FemurR_lce_F
                         FemurR_lce_T"
      BELT_OUTPUT_LIST="ALL"
      >
      <COMMENT>
<![CDATA[
Available output signals

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Pelvis_acc
ThoraxT4_acc
HeadCG_acc
SternumUp_acc
SternumLow_acc
ThoraxT1_acc
ThoraxUp_acc
ThoraxLow_acc
     BODY_REL_OUTPUT_LIST
ChestDeflection_dis
ChestDeflection_vel_CFC180
ChestDeflection_vel_CFC600

    JOINT_CONSTRAINT_OUTPUT_LIST
LumbarSpineLow_lce_F
LumbarSpineLow_lce_T
NeckLow_lce_F
NeckLow_lce_T
NeckUp_lce_F_CFC600
NeckUp_lce_F_CFC1000
NeckUp_lce_T
FemurL_lce_F
FemurL_lce_T
FemurR_lce_F
FemurR_lce_T
]]>
      </COMMENT>
    </TIME_HISTORY_MB>
    <TIME_HISTORY_MB
      DESCRIPTION="Output signals from lap belt"
      SYSTEM="/Lap_Belt_sys"
      BELT_OUTPUT_LIST="1"
    />
    <TIME_HISTORY_MB
      DESCRIPTION="Output signals from shoulder belt"
      SYSTEM="/Shoulder_Belt_sys"
      BELT_OUTPUT_LIST="2"
    />
    <TIME_HISTORY_MB
      DESCRIPTION="Output signals from tiedowns"
      SYSTEM="/tiedowns_sys"
      BELT_OUTPUT_LIST="LFront_tiedown_output LRear_tiedown_output
                  RFront_tiedown_output RRear_tiedown_output"
    />
    <TIME_HISTORY_MB
      DESCRIPTION="Output signals from WC"
      SYSTEM="/wheelchair_system"
      BODY_OUTPUT_LIST="ALL"
      JOINT_DOF_OUTPUT_LIST="ALL"
      JOINT_CONSTRAINT_OUTPUT_LIST="ALL"
    />
```

```
    <TIME_HISTORY_CONTACT
      DESCRIPTION="Contact ouputs"
      CONTACT_OUTPUT_LIST="ALL"
    />
    <TIME_HISTORY_MB
      DESCRIPTION="Output signals from sled"
      SYSTEM="/sled_system"
      BODY_OUTPUT_LIST="sled_acc_output sled_velocity_output"
    />
    <ANIMATION
      EXTENDED="ON"
    />
    <TIME_HISTORY_INJURY
      INJURY_LIST="ALL"
    />
    <TIME_DURATION_INJURY
      INJURY_LIST="ALL"
    />
  </CONTROL_OUTPUT>
  <SYSTEM.REF_SPACE
    ID="1"
    NAME="sled_track"
    >
    <SURFACE.PLANE
      ID="1"
      NAME="track_surface"
      POINT_1="0.0 0.0 -0.01"
      POINT_2="4.5 0.0 -0.01"
      POINT_3="4.5 1.88 -0.01"
    />
  </SYSTEM.REF_SPACE>
  <SYSTEM.MODEL
    ID="2"
    NAME="sled_system"
    >
    <COMMENT>
<![CDATA[
**ECM Do not edit or delete the following lines
**ECM Following lines gives the configuration table
**ECM of the current system
**ECM 1
]]>
    </COMMENT>
    <POINT_OBJECT.MB
      NAME="LFront_sled_secure_pnt"
      BODY="sled_body"
      POS="-0.665 -0.3475 0.0"
      ID="1"
    />
    <POINT_OBJECT.MB
      NAME="RFront_sled_secure_pnt"
      BODY="sled_body"
      POS="-0.665 0.3475 0.0"
      ID="2"
    />
    <POINT_OBJECT.MB
      NAME="LRear_sled_secure_pnt"
      BODY="sled_body"
      POS="0.712 -0.21 0.0"
      ID="3"
    />
    <POINT_OBJECT.MB
      NAME="RRear_sled_secure_pnt"
      BODY="sled_body"
      POS="0.712 0.21 0.0"
      ID="4"
    />
    <POINT_OBJECT.MB
      NAME="D_ring_pnt"
      BODY="sled_body"
```

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    POS="0.3574 0.381 1.0033"
    ID="5"
  />
  <POINT_OBJECT.MB
    NAME="LFloor_anchor_pnt"
    BODY="sled_body"
    POS="0.6 0.2 0.0"
    ID="6"
  />
  <POINT_OBJECT.MB
    NAME="RFloor_anchor_pnt"
    BODY="sled_body"
    POS="0.6 -0.2 0.0"
    ID="7"
  />
  <OUTPUT_BODY
    NAME="sled_velocity_output"
    ID="1"
    SIGNAL_TYPE="LIN_VEL"
    FILTER="NONE"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="sled_body"
      POS="0.0 0.0 0.0"
    />
  </OUTPUT_BODY>
  <OUTPUT_BODY
    NAME="sled_acc_output"
    ID="3"
    SIGNAL_TYPE="LIN_ACC"
    FILTER="CFC60"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="sled_body"
      POS="0.0 0.0 0.0"
    />
  </OUTPUT_BODY>
  <OUTPUT_BODY
    NAME="sled_position_output"
    ID="2"
    SIGNAL_TYPE="LIN_DISP"
    FILTER="NONE"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="sled_body"
      POS="0.0 0.0 0.0"
    />
  </OUTPUT_BODY>
  <BODY.RIGID
    CENTRE_OF_GRAVITY="0.0 0.0 0.0"
    MASS="10000"
    INERTIA="500 1.000000E+003 1.000000E+003 0.0 0.0 0.0"
    ID="1"
    NAME="sled_body"
  />
  <SURFACE.PLANE
    BODY="sled_body"
    ID="1"
    NAME="sled_surface"
    POINT_1="-1.07 -0.94 0.0"
    POINT_2="1.07 -0.94 0.0"
    POINT_3="1.07 0.94 0.0"
  />
  <JOINT.TRAN
    ID="1"
    NAME="sled_joint"
    >
    <CRDSYS_OBJECT_1.MB
      POS="0.0 0.0 0.0"
    />
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    <CRDSYS_OBJECT_2.MB
      BODY="sled_body"
      POS="-1.07 -0.94 0.0"
    />
  </JOINT.TRAN>
  <INITIAL.JOINT_VEL
    JOINT="sled_joint"
    V1="4.208333"
  />
  <GROUP_MB
    ID="1"
    NAME="sled_mbg"
    SURFACE_LIST="sled_surface"
  />
</SYSTEM.MODEL>
<SYSTEM.MODEL
  ID="3"
  NAME="wheelchair_system"
  >
  <COMMENT>
<![CDATA[
**ECM Do not edit or delete the following lines
**ECM Following lines gives the configuration table
**ECM of the current system
**ECM 1   5   1
**ECM 2   5   1
**ECM 3   5   1
**ECM 4   5   1
**ECM 7   6   5   1
**ECM 8   5   1
**ECM 9   5   1
**ECM 10   5   1
**ECM 11   5   1
**ECM 12   5   1
]]>
  </COMMENT>
  <POINT_OBJECT.MB
    NAME="LFront_WCsecurement_pnt"
    BODY="LF_sec_pt_body"
    ID="1"
    POS="0.0 0.0 0.0"
  />
  <POINT_OBJECT.MB
    NAME="RFront_WCsecurement_pnt"
    BODY="RF_sec_pt_body"
    ID="2"
    POS="0.0 0.0 0.0"
  />
  <POINT_OBJECT.MB
    NAME="LRear_WCsecurement_pnt"
    BODY="LR_sec_pt_body"
    ID="3"
    POS="0.0 0.0 0.0"
  />
  <POINT_OBJECT.MB
    NAME="RRear_WCsecurement_pnt"
    BODY="RR_sec_pt_body"
    ID="4"
    POS="0.0 0.0 0.0"
  />
  <BODY.RIGID
    ID="1"
    INERTIA="0.045937 0.091873 0.045937 0.0 0.0 0.0"
    MASS="2.2"
    NAME="RRear_wheel_body"
  />
  <BODY.RIGID
    ID="2"
    INERTIA="0.045937 0.091873 0.045937 0.0 0.0 0.0"
    MASS="2.2"
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  NAME="LRear_wheel_body"
/>
<BODY.RIGID
  ID="3"
  INERTIA="2.880000E-004 5.770000E-004 2.880000E-004 0.0 0.0 0.0"
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/>
<BODY.RIGID
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  INERTIA="2.880000E-004 5.770000E-004 2.880000E-004 0.0 0.0 0.0"
  MASS="0.3"
  NAME="LFront_Wheel_body"
/>
<BODY.RIGID
  ID="5"
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  MASS="15.5"
  NAME="frame_cg_body"
/>
<BODY.RIGID
  ID="6"
  INERTIA="0.01922 0.02888 0.0481 0.0 0.0 0.0"
  MASS="2.4"
  NAME="wcseat_body"
/>
<BODY.RIGID
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  NAME="wcback_body"
/>
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  ID="13"
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  NAME="wcback_top_body"
/>
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  NAME="accelerometer"
/>
<BODY.RIGID
  ID="9"
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  MASS="0.1"
  NAME="RF_sec_pt_body"
/>
<BODY.RIGID
  ID="10"
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  MASS="0.1"
  NAME="LF_sec_pt_body"
/>
<JOINT.TRAN
  ID="11"
  NAME="RF_sec_pt_joint"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="frame_cg_body"
    POS="0.265 -0.295 -0.165"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="RF_sec_pt_body"
    POS="0.0 0.0 0.0"
  />
</JOINT.TRAN>
<RESTRAINT.JOINT
```

```
      ID="12"
      JOINT="RF_sec_pt_joint"
      NAME="RF_sec_pt_jnt_restraint"
      Q1_CHAR="front_sec_pt_char"
    />
    <JOINT.TRAN
      ID="12"
      NAME="LF_sec_pt_joint"
      >
      <CRDSYS_OBJECT_1.MB
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        POS="0.265 0.295 -0.165"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="LF_sec_pt_body"
        POS="0.0 0.0 0.0"
      />
    </JOINT.TRAN>
    <RESTRAINT.JOINT
      ID="13"
      JOINT="LF_sec_pt_joint"
      NAME="LF_sec_pt_jnt_restraint"
      Q1_CHAR="front_sec_pt_char"
    />
    <CHARACTERISTIC.LOAD
      ID="53"
      NAME="front_sec_pt_char"
      LOAD_FUNC="front_sec_pt_loading"
      UNLOAD_FUNC="front_sec_pt_unloading"
      HYS_MODEL="1"
      HYS_SLOPE="5e6"
      ELAS_LIMIT="0.005"
      DAMP_COEF="500"
    />
    <FUNCTION.XY
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      NAME="front_sec_pt_loading"
      >
      <TABLE
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        >
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| XI     YI |
0        0
0.080    4000
0.110    8000
0.120   12000
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="63"
      NAME="front_sec_pt_unloading"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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| XI     YI |
0        0
0.170     50
0.185    500
]]>
      </TABLE>
    </FUNCTION.XY>
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      MASS="0.1"
      NAME="RR_sec_pt_body"
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    />
    <BODY.RIGID
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      INERTIA="1.000000E-003 1.000000E-003 1.000000E-003 0.0 0.0 0.0"
      MASS="0.1"
      NAME="LR_sec_pt_body"
    />
    <JOINT.TRAN
      ID="13"
      NAME="RR_sec_pt_joint"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="frame_cg_body"
        POS="-0.295 -0.193 -0.145"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="RR_sec_pt_body"
        POS="0.0 0.0 0.0"
      />
    </JOINT.TRAN>
    <RESTRAINT.JOINT
      ID="15"
      JOINT="RR_sec_pt_joint"
      NAME="RR_sec_pt_jnt_restraint"
      Q1_CHAR="rear_sec_pt_char"
    />
    <JOINT.TRAN
      ID="14"
      NAME="LR_sec_pt_joint"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="frame_cg_body"
        POS="-0.295 0.193 -0.145"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="LR_sec_pt_body"
        POS="0.0 0.0 0.0"
      />
    </JOINT.TRAN>
    <RESTRAINT.JOINT
      ID="14"
      JOINT="LR_sec_pt_joint"
      NAME="LRsec_pt_jnt_restraint"
      Q1_CHAR="rear_sec_pt_char"
    />
    <CHARACTERISTIC.LOAD
      ID="57"
      NAME="rear_sec_pt_char"
      LOAD_FUNC="rear_sec_pt_loading"
      DAMP_COEF="50"
    />
    <FUNCTION.XY
      ID="57"
      NAME="rear_sec_pt_loading"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI              YI      |
    0.00000000E+000     0.00000000E+000
    0.50000000E-000     6.00000000E+003
]]>
      </TABLE>
    </FUNCTION.XY>
    <SURFACE.ELLIPSOID
      CHAR="rwh_contact"
      DEGREE="2"
      ID="1"
      NAME="RRear_wheel_surface"
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  SEMI_AXIS="0.3048 0.032 0.3048"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="RRear_wheel_body"
    POS="0.0 0.0 0.0"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  CHAR="rwh_contact"
  DEGREE="2"
  ID="2"
  NAME="LRear_wheel_surface"
  SEMI_AXIS="0.3048 0.032 0.3048"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="LRear_wheel_body"
    POS="0.0 0.0 0.0"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  CHAR="fwh_contact"
  DEGREE="2"
  ID="3"
  NAME="RFront_wheel_surface"
  SEMI_AXIS="0.10115 0.024 0.10115"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="RFront_wheel_body"
    POS="0.0 0.0 0.0"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  CHAR="fwh_contact"
  DEGREE="2"
  ID="4"
  NAME="LFront_wheel_surface"
  SEMI_AXIS="0.10115 0.024 0.10115"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="LFront_Wheel_body"
    POS="0.0 0.0 0.0"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  CHAR="wcseat_contact"
  DEGREE="8"
  ID="5"
  NAME="wcseat_surface"
  SEMI_AXIS="0.26 0.2 0.015"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="wcseat_body"
    POS="0.0 0.0 0.0"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  NAME="wcback_surface"
  DEGREE="8"
  ID="6"
  CHAR="wcback_contact"
  SEMI_AXIS="0.01 0.2286 0.150"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="wcback_body"
    POS="0.0 0.0 -0.150"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  NAME="wcback_top_surface"
  DEGREE="8"
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ID="69"
CHAR="wcback_contact"
SEMI_AXIS="0.01 0.2286 0.150"
>
<CRDSYS_OBJECT_1.MB
BODY="wcback_top_body"
POS="0.012 0.0 0.150"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
CHAR="footrest_contact"
DEGREE="8"
ID="7"
NAME="footrest_surface"
SEMI_AXIS="0.076 0.22 0.0025"
>
<CRDSYS_OBJECT_1.MB
BODY="frame_cg_body"
ORIENT="foot_ori"
POS="0.59 0.0 -0.3"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
DEGREE="2"
ID="8"
NAME="frame_cg_surface"
SEMI_AXIS="0.015 0.015 0.015"
>
<CRDSYS_OBJECT_1.MB
BODY="frame_cg_body"
POS="0.0 0.0 0.0"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
DEGREE="2"
ID="9"
NAME="accelerometer_surface"
SEMI_AXIS="0.005 0.005 0.005"
>
<CRDSYS_OBJECT_1.MB
BODY="accelerometer"
POS="0.0 0.0 0.0"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
DEGREE="8"
ID="50"
NAME="r_hor1"
SEMI_AXIS="0.3 0.0127 0.0127"
>
<CRDSYS_OBJECT_1.MB
BODY="frame_cg_body"
POS="0.02 -0.215 -0.165"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
DEGREE="8"
ID="51"
NAME="l_hor1"
SEMI_AXIS="0.3 0.0127 0.0127"
>
<CRDSYS_OBJECT_1.MB
BODY="frame_cg_body"
POS="0.02 0.215 -0.165"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
DEGREE="8"
ID="52"
NAME="r_hor2"

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    SEMI_AXIS="0.28 0.0127 0.0127"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="0.045 -0.215 0.045"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="53"
    NAME="l_hor2"
    SEMI_AXIS="0.28 0.0127 0.0127"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="0.045 0.215 0.045"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="56"
    NAME="r_ver2"
    SEMI_AXIS="0.0127 0.0127 0.095"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="-0.12 -0.2164 -0.06"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="57"
    NAME="l_ver2"
    SEMI_AXIS="0.0127 0.0127 0.095"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="-0.12 0.2164 -0.06"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="58"
    NAME="r_ver3"
    SEMI_AXIS="0.0127 0.0127 0.095"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="0.305 -0.2164 -0.06"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="59"
    NAME="l_ver3"
    SEMI_AXIS="0.0127 0.0127 0.089"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="0.305 0.2164 -0.06"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="60"
    NAME="r_ver4"
    SEMI_AXIS="0.0127 0.0127 0.38"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
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```
      POS="-0.243 -0.2164 0.225"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="61"
    NAME="l_ver4"
    SEMI_AXIS="0.0127 0.0127 0.38"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="-0.243 0.2164 0.225"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="62"
    NAME="r_leg"
    SEMI_AXIS="0.0127 0.0127 0.175"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      ORIENT="leg_ori"
      POS="0.44 -0.2164 -0.16"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="63"
    NAME="l_leg"
    SEMI_AXIS="0.0127 0.0127 0.175"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      ORIENT="leg_ori"
      POS="0.44 0.2164 -0.16"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="64"
    NAME="mid1"
    SEMI_AXIS="0.0127 0.25 0.0127"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      ORIENT="brace_ori1"
      POS="0.015 0.0 -0.06"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="65"
    NAME="mid2"
    SEMI_AXIS="0.0127 0.25 0.0127"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      ORIENT="brace_ori2"
      POS="0.03 0.0 -0.06"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    CHAR="armrest_contact"
    DEGREE="8"
    ID="67"
    NAME="r_arm"
    SEMI_AXIS="0.1778 0.0095 0.0095"
    >
    <CRDSYS_OBJECT_1.MB
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    BODY="frame_cg_body"
    POS="-0.0603 -0.2464 0.305"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  CHAR="armrest_contact"
  DEGREE="8"
  ID="68"
  NAME="l_arm"
  SEMI_AXIS="0.1778 0.0095 0.0095"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="frame_cg_body"
    POS="-0.0603 0.2464 0.305"
  />
</SURFACE.ELLIPSOID>
<DISABLE>
  <SURFACE.ELLIPSOID
    DEGREE="8"
    ID="69"
    NAME="heel_loops"
    SEMI_AXIS="0.01 0.23 0.035"
    CHAR="heel_loops_contact"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      ORIENT="leg_ori"
      POS="0.455 0.0 -0.28"
    />
  </SURFACE.ELLIPSOID>
</DISABLE>
<JOINT.FREE
  ID="1"
  NAME="CG_ref_joint"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="/sled_system/sled_body"
    POS="0.0 0.0 0.395"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="frame_cg_body"
    POS="0.0 0.0 0.0"
  />
</JOINT.FREE>
<JOINT.TRAN
  ID="17"
  NAME="wcseat_joint"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="frame_cg_body"
    POS="0.0535 0.0 0.06"
    ORIENT="seat_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="wcseat_body"
    POS="0.0 0.0 0.0"
  />
</JOINT.TRAN>
<RESTRAINT.JOINT
  ID="17"
  JOINT="wcseat_joint"
  NAME="wcseat_jnt_restraint"
  Q1_CHAR="wcseat_jnt_char"
/>
<CHARACTERISTIC.LOAD
  ID="60"
  NAME="wcseat_jnt_char"
  LOAD_FUNC="wcseat_jnt_loading"
  DAMP_COEF="800.0"
/>
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    <FUNCTION.XY
      ID="62"
      NAME="wcseat_jnt_loading"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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|     XI              YI      |
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    1.00000000E-001     1.20000000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <JOINT.TRAN_REVO
      ID="10"
      NAME="wcback_joint"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="wcseat_body"
        POS="-0.275 0.0 0.055"
        ORIENT="back_ori"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="wcback_body"
        POS="0.0 0.0 -0.25"
        ORIENT="wcback_ori"
      />
    </JOINT.TRAN_REVO>
    <RESTRAINT.JOINT
      ID="9"
      JOINT="wcback_joint"
      Q1_CHAR="wcback_tilt_char"
      Q2_CHAR="wcback_trans_char"
    />
    <CHARACTERISTIC.LOAD
      ID="56"
      NAME="wcback_trans_char"
      LOAD_FUNC="wcback_trans_load"
      DAMP_COEF="800.0"
    />
    <FUNCTION.XY
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      NAME="wcback_trans_load"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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]]>
      </TABLE>
    </FUNCTION.XY>
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      NAME="wcback_tilt_char"
      LOAD_FUNC="wcback_tilt_load"
      DAMP_COEF="800.0"
    />
    <FUNCTION.XY
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      NAME="wcback_tilt_load"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|     XI              YI      |
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    0.00000000E+000      0.00000000E+000
    5.00000000E-001      1.00000000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <JOINT.TRAN_REVO
      ID="18"
      NAME="wcback_top_joint"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="wcseat_body"
        POS="-0.300 0.0 0.320"
        ORIENT="back_ori"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="wcback_top_body"
        POS="0.0 0.0 0.0"
        ORIENT="wcback_ori"
      />
    </JOINT.TRAN_REVO>
    <RESTRAINT.JOINT
      ID="18"
      JOINT="wcback_top_joint"
      Q1_CHAR="wcback_top_tilt_char"
      Q2_CHAR="wcback_top_trans_char"
    />
    <CHARACTERISTIC.LOAD
      ID="61"
      NAME="wcback_top_trans_char"
      LOAD_FUNC="wcback_top_trans_load"
      DAMP_COEF="800.0"
    />
    <FUNCTION.XY
      ID="64"
      NAME="wcback_top_trans_load"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                YI      |
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]]>
      </TABLE>
    </FUNCTION.XY>
    <CHARACTERISTIC.LOAD
      ID="62"
      NAME="wcback_top_tilt_char"
      LOAD_FUNC="wcback_tilt_load"
      DAMP_COEF="800.0"
    />
    <FUNCTION.XY
      ID="65"
      NAME="wcback_top_tilt_load"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                YI      |
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    5.00000000E-001      1.00000000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <JOINT.FREE
      ID="4"
      NAME="accelerometer_joint"
      STATUS="LOCK"
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    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="0.027 0.01 -0.015"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="accelerometer"
      POS="0.0 0.0 0.0"
    />
  </JOINT.FREE>
  <JOINT.TRAN_REVO
    ID="15"
    NAME="RRear_wh_joint"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="-0.215 -0.285 -0.09"
      ORIENT="rear_wh_joint_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="RRear_wheel_body"
      POS="0.0 0.0 0.0"
    />
  </JOINT.TRAN_REVO>
  <RESTRAINT.JOINT
    ID="10"
    JOINT="RRear_wh_joint"
    Q2_CHAR="rear_wh_trans_chr"
  />
  <JOINT.TRAN_REVO
    ID="16"
    NAME="LRear_wh_joint"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="frame_cg_body"
      POS="-0.215 0.285 -0.09"
      ORIENT="rear_wh_joint_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="LRear_wheel_body"
      POS="0.0 0.0 0.0"
    />
  </JOINT.TRAN_REVO>
  <RESTRAINT.JOINT
    ID="16"
    JOINT="LRear_wh_joint"
    Q2_CHAR="rear_wh_trans_chr"
  />
  <CHARACTERISTIC.LOAD
    ID="59"
    NAME="rear_wh_trans_chr"
    LOAD_FUNC="rear_wh_trans_load"
    DAMP_COEF="800.0"
  />
  <FUNCTION.XY
    ID="61"
    NAME="rear_wh_trans_load"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|      XI                 YI      |
    0.00000000E+000     0.00000000E+000
    1.00000000E-002     1.00000000E+004
]]>
    </TABLE>
  </FUNCTION.XY>
  <JOINT.REVO
    ID="8"
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  NAME="RFront_wh_joint"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="frame_cg_body"
    POS="0.24 -0.255 -0.295"
    ORIENT="wheel_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="RFront_wheel_body"
    POS="0.0 0.0 0.0"
    ORIENT="wheel_ori"
  />
</JOINT.REVO>
<JOINT.REVO
  ID="9"
  NAME="LFront_wh_joint"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="frame_cg_body"
    POS="0.24 0.255 -0.295"
    ORIENT="wheel_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="LFront_Wheel_body"
    POS="0.0 0.0 0.0"
    ORIENT="wheel_ori"
  />
</JOINT.REVO>
<INITIAL.JOINT_POS
  R3="3.1416"
  D1="0.0"
  D2="0.0"
  D3="0.0"
  JOINT="CG_ref_joint"
/>
<ORIENTATION.SUCCESSIVE_ROT
  AXIS_1="Z"
  ID="1"
  NAME="wheel_ori"
  R1="-1.5708"
/>
<ORIENTATION.SUCCESSIVE_ROT
  AXIS_1="Y"
  ID="2"
  NAME="leg_ori"
  R1="-0.5236"
/>
<ORIENTATION.SUCCESSIVE_ROT
  AXIS_1="Y"
  ID="3"
  NAME="foot_ori"
  R1="-0.43633"
/>
<ORIENTATION.SUCCESSIVE_ROT
  AXIS_1="Y"
  ID="4"
  NAME="seat_ori"
  R1="-0.069813"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="5"
  NAME="back_ori"
  AXIS_1="Z"
  R1="3.1416"
/>
<ORIENTATION.SUCCESSIVE_ROT
  AXIS_1="X"
  ID="6"
  NAME="brace_ori1"
  R1="0.45379"
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```
/>
<ORIENTATION.SUCCESSIVE_ROT
  AXIS_1="X"
  ID="7"
  NAME="brace_ori2"
  R1="-0.45379"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="8"
  NAME="wcback_ori"
  AXIS_1="Z"
  R1="3.1416"
  AXIS_2="Y"
  R2="-0.0405"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="9"
  NAME="rear_wh_joint_ori"
  AXIS_1="Y"
  R1="1.5708"
/>
<CHARACTERISTIC.CONTACT
  CONTACT_MODEL="FORCE"
  ID="1"
  NAME="rwh_contact"
  LOAD_FUNC="rear_wheel_load"
/>
<CHARACTERISTIC.CONTACT
  CONTACT_MODEL="FORCE"
  ID="2"
  LOAD_FUNC="front_wheel_load"
  NAME="fwh_contact"
  DAMP_COEF="1.000000E+003"
/>
<CHARACTERISTIC.CONTACT
  CONTACT_MODEL="FORCE"
  ID="3"
  LOAD_FUNC="wcseat_load"
  NAME="wcseat_contact"
/>
<CHARACTERISTIC.CONTACT
  CONTACT_MODEL="FORCE"
  ID="4"
  LOAD_FUNC="wcback_load"
  NAME="wcback_contact"
/>
<CHARACTERISTIC.CONTACT
  CONTACT_MODEL="FORCE"
  ID="5"
  LOAD_FUNC="footrest_load"
  NAME="footrest_contact"
/>
<CHARACTERISTIC.CONTACT
  CONTACT_MODEL="FORCE"
  ID="6"
  LOAD_FUNC="armrest_load"
  NAME="armrest_contact"
/>
<CHARACTERISTIC.CONTACT
  CONTACT_MODEL="FORCE"
  ID="7"
  LOAD_FUNC="tiepoint_load"
  NAME="tiepoint_contact"
/>
<CHARACTERISTIC.CONTACT
  CONTACT_MODEL="FORCE"
  NAME="heel_loops_contact"
  ID="54"
  LOAD_FUNC="heel_loops_load"
/>
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    <FUNCTION.XY
      ID="4"
      NAME="heel_loops_load"
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|     XI              YI      |
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    1.50000000E-001    5.00000000E+001
    1.75000000E-001    1.00000000E+003
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
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      NAME="rear_wheel_load"
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      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|     XI              YI      |
    0.00000000E+000    0.00000000E+000
    10.0000000E-002    2.00000000E+004
]]>
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    </FUNCTION.XY>
    <FUNCTION.XY
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      NAME="front_wheel_load"
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        TYPE="XY_PAIR"
        >
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|     XI              YI      |
    0.00000000E+000    0.00000000E+000
    1.20000000E-001    2.00000000E+004
]]>
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    </FUNCTION.XY>
    <FUNCTION.XY
      ID="3"
      NAME="wcseat_load"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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    0.00000000E+000    0.00000000E+000
    1.00000000E-001    1.23000000E+003
    1.20000000E-001    2.16900000E+003
    2.50000000E-001    1.85040000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="53"
      NAME="wcback_load"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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|     XI              YI      |
    0.00000000E+000    0.00000000E+000
    1.00000000E-001    5.00000000E+002
```

```
    2.00000000E-001      1.00000000E+003
    1.00000000E+000      1.00000000E+004
    1.80000000E+000      1.90000000E+004]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="5"
      NAME="footrest_load"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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|      XI                 YI      |
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    1.00000000E-001      2.00000000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="6"
      NAME="armrest_load"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                 YI      |
    0.00000000E+000      0.00000000E+000
    1.50000000E-001      1.00000000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="7"
      NAME="tiepoint_load"
      >
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        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                 YI      |
    0.00000000E+000      0.00000000E+000
    1.00000000E-002      2.00000000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
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      NAME="rear_wh_surfaces"
      SURFACE_LIST="LRear_wheel_surface RRear_wheel_surface"
    />
    <GROUP_MB
      ID="2"
      NAME="front_wh_surfaces"
      SURFACE_LIST="LFront_wheel_surface RFront_wheel_surface"
    />
    <GROUP_MB
      ID="3"
      NAME="wcseat_contact_surface"
      SURFACE_LIST="wcseat_surface"
    />
    <GROUP_MB
      ID="4"
      NAME="wcback_contact_surface"
      SURFACE_LIST="wcback_surface wcback_top_surface"
    />
    <GROUP_MB
      ID="9"
      NAME="top-wcback_contact_surface"
```

```
  SURFACE_LIST="wcback_top_surface"
/>
<GROUP_MB
  ID="5"
  NAME="footrest_contact_surface"
  SURFACE_LIST="footrest_surface"
/>
<GROUP_MB
  ID="6"
  NAME="armrest_surfaces"
  SURFACE_LIST="l_arm r_arm"
/>
<GROUP_MB
  ID="7"
  NAME="tiepoint_contact_surface"
  SURFACE_LIST="ALL"
/>
<OUTPUT_BODY
  ID="1"
  NAME="WC_lin_accel_output"
  SIGNAL_TYPE="LIN_ACC"
  FILTER="CFC60"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="accelerometer"
    POS="0.0 0.0 0.0"
  />
</OUTPUT_BODY>
<OUTPUT_BODY
  NAME="WC_velocity_output"
  ID="2"
  SIGNAL_TYPE="LIN_VEL"
  FILTER="NONE"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="accelerometer"
    POS="0.0 0.0 0.0"
  />
</OUTPUT_BODY>
<OUTPUT_BODY
  ID="4"
  NAME="seatback_lin_dsip_output"
  SIGNAL_TYPE="LIN_DISP"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="wcback_body"
    POS="0.0 0.0 0.0"
  />
</OUTPUT_BODY>
<OUTPUT_BODY
  ID="7"
  NAME="seatback_top_lin_dsip_output"
  SIGNAL_TYPE="LIN_DISP"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="wcback_top_body"
    POS="0.0 0.0 0.0"
  />
</OUTPUT_BODY>
<OUTPUT_BODY
  ID="5"
  NAME="seatback_ang_dsip_output"
  SIGNAL_TYPE="ANG_DISP"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="wcback_body"
    POS="0.0 0.0 0.0"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="frame_cg_body"
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      POS="0.0 0.0 0.0"
    />
  </OUTPUT_BODY>
  <OUTPUT_BODY
    ID="8"
    NAME="seatback_top_ang_dsip_output"
    SIGNAL_TYPE="ANG_DISP"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="wcback_top_body"
      POS="0.0 0.0 0.0"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="frame_cg_body"
      POS="0.0 0.0 0.0"
    />
  </OUTPUT_BODY>
  <OUTPUT_BODY
    ID="3"
    SIGNAL_TYPE="LIN_DISP"
    NAME="front_caster_excursion"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="LFront_Wheel_body"
      POS="0.0 0.0 0.0"
    />
  </OUTPUT_BODY>
  <OUTPUT_BODY
    ID="6"
    SIGNAL_TYPE="ANG_DISP"
    NAME="front_caster_ang_disp"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="LFront_Wheel_body"
      POS="0.0 0.0 0.0"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="/sled_system/sled_body"
      POS="0.0 0.0 0.0"
    />
  </OUTPUT_BODY>
  <OUTPUT_CONTACT
    EXTENDED="ON"
    FILTER="CFC60"
    SUM="ON"
    NAME="wcback_contact_SUM_output"
    BODY="wcback_body"
    ID="1"
    CONTACT_LIST="/ArmLowL_wcback /ArmLowR_wcback /ArmUpL_wcback /ArmUpR_wcback /pelvis_wcback
/torso_wcback"
  />
  <OUTPUT_CONTACT
    EXTENDED="ON"
    FILTER="CFC60"
    NAME="wcback_contact_output"
    BODY="wcback_body"
    ID="5"
    CONTACT_LIST="/ArmLowL_wcback /ArmLowR_wcback /ArmUpL_wcback /ArmUpR_wcback /pelvis_wcback
/torso_wcback"
  />
  <OUTPUT_CONTACT
    EXTENDED="ON"
    FILTER="CFC60"
    SUM="ON"
    NAME="seat_contact_output"
    BODY="wcseat_body"
    ID="4"
    CONTACT_LIST="/TibiaL_wcseat /TibiaR_wcseat /UlegL_wcseat /UlegR_wcseat /pelvis_wcseat"
  />
  <OUTPUT_CONTACT
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    EXTENDED="ON"
    FILTER="CFC60"
    SUM="ON"
    NAME="Front_caster_contact_output"
    BODY="LFront_Wheel_body"
    ID="2"
    CONTACT_LIST="/Front_wheel_contact"
  />
  <OUTPUT_CONTACT
    EXTENDED="ON"
    FILTER="CFC60"
    SUM="ON"
    NAME="Rear_caster_contact_output"
    BODY="RRear_wheel_body"
    ID="3"
    CONTACT_LIST="/Rear_wheel_contact"
  />
  <OUTPUT_JOINT_CONSTRAINT
    ID="1"
    NAME="wcseat_jnt_force_output"
    JOINT="wcseat_joint"
    SIGNAL_TYPE="FORCE"
    EXTENDED_SAMPLING="ON"
    FILTER="CFC60"
  />
  <OUTPUT_JOINT_CONSTRAINT
    ID="2"
    NAME="wcback_jnt_force_output"
    JOINT="wcback_joint"
    SIGNAL_TYPE="FORCE"
    EXTENDED_SAMPLING="ON"
    FILTER="CFC60"
  />
  <OUTPUT_JOINT_CONSTRAINT
    ID="3"
    NAME="wcback_top_jnt_force_output"
    JOINT="wcback_top_joint"
    SIGNAL_TYPE="FORCE"
    EXTENDED_SAMPLING="ON"
    FILTER="CFC60"
  />
  <OUTPUT_JOINT_CONSTRAINT
    ID="4"
    NAME="wcback_jnt_torque_output"
    JOINT="wcback_joint"
    SIGNAL_TYPE="TORQUE"
    EXTENDED_SAMPLING="ON"
    FILTER="CFC60"
  />
  <OUTPUT_JOINT_CONSTRAINT
    ID="5"
    NAME="wcback_top_jnt_torque_output"
    JOINT="wcback_top_joint"
    SIGNAL_TYPE="TORQUE"
    EXTENDED_SAMPLING="ON"
    FILTER="CFC60"
  />
  <OUTPUT_JOINT_DOF
    ID="1"
    JOINT_LIST="wcback_joint wcback_top_joint wcseat_joint"
    NAME="WC_jnts_pos_output"
    SIGNAL_TYPE="POS"
  />
  <GROUP_MB
    ID="8"
    NAME="WC_gmb"
    SURFACE_LIST="ALL"
  />
</SYSTEM.MODEL>
<SYSTEM.MODEL
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      ID="4"
      NAME="Hybrid_III_50th"
      >
      <COMMENT>
<![CDATA[
**ECM Do not edit or delete the following lines
**ECM Following lines gives the configuration table
**ECM of the current system
**ECM 1   8   7   6   5   4   3   2   9   15   14   16
**ECM 13   10   9   15   14   16
**ECM 17   16
**ECM 30   25   24   23   22   19   18   16
**ECM 31   29   28   27   26   21   20   16
**ECM 34   33   32   11   9   15   14   16
**ECM 37   36   35   12   9   15   14   16
X-axis in global X-direction
]]>
      </COMMENT>
      <ORIENTATION.VECTOR
        ID="9001"
        NAME="Zero_ori"
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        VECTOR_2="0.0 1.0 0.0"
        DESCRIPTION="No rotation"
      />
      <ORIENTATION.VECTOR
        ID="9002"
        NAME="X+90_ori"
        VECTOR_1="1.0 0.0 0.0"
        VECTOR_2="0.0 0.0 1.0"
        DESCRIPTION="X-rotation 90 degrees"
      />
      <ORIENTATION.VECTOR
        ID="9003"
        NAME="X180_ori"
        VECTOR_1="1.0 0.0 0.0"
        VECTOR_2="0.0 -1.0 0.0"
        DESCRIPTION="X-rotation 180 degrees"
      />
      <ORIENTATION.VECTOR
        ID="9004"
        NAME="X-90_ori"
        VECTOR_1="1.0 0.0 0.0"
        VECTOR_2="0.0 0.0 -1.0"
        DESCRIPTION="X-rotation -90 degrees"
      />
      <COMMENT>
<![CDATA[
X-axis in global Y-direction
]]>
      </COMMENT>
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        ID="9005"
        NAME="Z+90_ori"
        VECTOR_1="0.0 1.0 0.0"
        VECTOR_2="-1.0 0.0 0.0"
        DESCRIPTION="Z-rotation 90 degrees"
      />
      <ORIENTATION.VECTOR
        ID="9006"
        NAME="Z+90_X+90_ori"
        VECTOR_1="0.0 1.0 0.0"
        VECTOR_2="0.0 0.0 1.0"
        DESCRIPTION="Z-rotation 90 degrees followed by X-rotation 90 degrees"
      />
      <ORIENTATION.VECTOR
        ID="9007"
        NAME="Z+90_X180_ori"
        VECTOR_1="0.0 1.0 0.0"
        VECTOR_2="1.0 0.0 0.0"
```

```
      DESCRIPTION="Z-rotation 90 degrees followed by X-rotation 180 degrees"
    />
    <ORIENTATION.VECTOR
      ID="9008"
      NAME="Z+90_X-90_ori"
      VECTOR_1="0.0 1.0 0.0"
      VECTOR_2="0.0 0.0 -1.0"
      DESCRIPTION="Z-rotation 90 degrees followed by X-rotation -90 degrees"
    />
    <COMMENT>
<![CDATA[
X-axis in global Z-direction
]]>
    </COMMENT>
    <ORIENTATION.VECTOR
      ID="9009"
      NAME="Y-90_ori"
      VECTOR_1="0.0 0.0 1.0"
      VECTOR_2="0.0 1.0 0.0"
      DESCRIPTION="Y-rotation -90 degrees"
    />
    <ORIENTATION.VECTOR
      ID="9010"
      NAME="Y-90_X+90_ori"
      VECTOR_1="0.0 0.0 1.0"
      VECTOR_2="-1.0 0.0 0.0"
      DESCRIPTION="Y-rotation -90 degrees followed by X-rotation 90 degrees"
    />
    <ORIENTATION.VECTOR
      ID="9011"
      NAME="Y-90_X180_ori"
      VECTOR_1="0.0 0.0 1.0"
      VECTOR_2="0.0 -1.0 0.0"
      DESCRIPTION="Y-rotation -90 degrees followed by X-rotation 180 degrees"
    />
    <ORIENTATION.VECTOR
      ID="9012"
      NAME="Y-90_X-90_ori"
      VECTOR_1="0.0 0.0 1.0"
      VECTOR_2="1.0 0.0 0.0"
      DESCRIPTION="Y-rotation -90 degrees followed by X-rotation -90 degrees"
    />
    <COMMENT>
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X-axis in global negative X-direction
]]>
    </COMMENT>
    <ORIENTATION.VECTOR
      ID="9013"
      NAME="Y180_ori"
      VECTOR_1="-1.0 0.0 0.0"
      VECTOR_2="0.0 1.0 0.0"
      DESCRIPTION="Y-rotation 180 degrees"
    />
    <ORIENTATION.VECTOR
      ID="9014"
      NAME="Y180_X+90_ori"
      VECTOR_1="-1.0 0.0 0.0"
      VECTOR_2="0.0 0.0 -1.0"
      DESCRIPTION="Y-rotation 180 degrees followed by X-rotation 90 degrees"
    />
    <ORIENTATION.VECTOR
      ID="9015"
      NAME="Z180_ori"
      VECTOR_1="-1.0 0.0 0.0"
      VECTOR_2="0.0 -1.0 0.0"
      DESCRIPTION="Z-rotation 180 degrees"
    />
    <ORIENTATION.VECTOR
      ID="9016"
```

```
    NAME="Z180_X+90_ori"
    VECTOR_1="-1.0 0.0 0.0"
    VECTOR_2="0.0 0.0 1.0"
    DESCRIPTION="Z-rotation 180 degrees followed by X-rotation 90 degrees"
  />
  <COMMENT>
<![CDATA[
X-axis in global negative Y-direction
]]>
  </COMMENT>
  <ORIENTATION.VECTOR
    ID="9017"
    NAME="Z-90_ori"
    VECTOR_1="0.0 -1.0 0.0"
    VECTOR_2="1.0 0.0 0.0"
    DESCRIPTION="Z-rotation -90 degrees"
  />
  <ORIENTATION.VECTOR
    ID="9018"
    NAME="Z-90_X+90_ori"
    VECTOR_1="0.0 -1.0 0.0"
    VECTOR_2="0.0 0.0 1.0"
    DESCRIPTION="Z-rotation -90 degrees followed by X-rotation 90 degrees"
  />
  <ORIENTATION.VECTOR
    ID="9019"
    NAME="Z-90_X180_ori"
    VECTOR_1="0.0 -1.0 0.0"
    VECTOR_2="-1.0 0.0 0.0"
    DESCRIPTION="Z-rotation -90 degrees followed by X-rotation 180 degrees"
  />
  <ORIENTATION.VECTOR
    ID="9020"
    NAME="Z-90_X-90_ori"
    VECTOR_1="0.0 -1.0 0.0"
    VECTOR_2="0.0 0.0 -1.0"
    DESCRIPTION="Z-rotation -90 degrees followed by X-rotation -90 degrees"
  />
  <COMMENT>
<![CDATA[
X-axis in global negative Z-direction
]]>
  </COMMENT>
  <ORIENTATION.VECTOR
    ID="9021"
    NAME="Y+90_ori"
    VECTOR_1="0.0 0.0 -1.0"
    VECTOR_2="0.0 1.0 0.0"
    DESCRIPTION="Y-rotation 90 degrees"
  />
  <ORIENTATION.VECTOR
    ID="9022"
    NAME="Y+90_X+90_ori"
    VECTOR_1="0.0 0.0 -1.0"
    VECTOR_2="1.0 0.0 0.0"
    DESCRIPTION="Y-rotation 90 degrees followed by X-rotation 90 degrees"
  />
  <ORIENTATION.VECTOR
    ID="9023"
    NAME="Y+90_X180_ori"
    VECTOR_1="0.0 0.0 -1.0"
    VECTOR_2="0.0 -1.0 0.0"
    DESCRIPTION="Y-rotation 90 degrees followed by X-rotation 180 degrees"
  />
  <ORIENTATION.VECTOR
    ID="9024"
    NAME="Y+90_X-90_ori"
    VECTOR_1="0.0 0.0 -1.0"
    VECTOR_2="-1.0 0.0 0.0"
    DESCRIPTION="Y-rotation 90 degrees followed by X-rotation -90 degrees"
```

```
/>
<BODY.RIGID
  ID="1014"
  NAME="Head_bod"
  CENTRE_OF_GRAVITY="0.0203 0.0 0.0292"
  MASS="4.4"
  INERTIA="0.0204 0.0211 0.0143 0.0 0.0 0.0"
  ORIENT_INERTIA="HeadBod_ori"
/>
<ORIENTATION.MATRIX
  ID="1001"
  NAME="HeadBod_ori"
  MATRIX="0.62472 0 0.78084 0 1 0 -0.78084 0 0.62472"
/>
<SURFACE.ELLIPSOID
  ID="1025"
  NAME="Head_ell"
  CHAR="HeadEll_chr"
  SEMI_AXIS="0.105 0.073 0.105"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Head_bod"
    POS="0.0136 0.0 0.0326"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="1026"
  NAME="Face_ell"
  CHAR="HeadEll_chr"
  SEMI_AXIS="0.046 0.06 0.1"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Head_bod"
    POS="0.072 0.0 0.0112"
    ORIENT="FaceEll_ori"
  />
</SURFACE.ELLIPSOID>
<ORIENTATION.SUCCESSIVE_ROT
  ID="1002"
  NAME="FaceEll_ori"
  AXIS_1="Y"
  R1="-0.08727"
/>
<CHARACTERISTIC.CONTACT
  ID="1001"
  NAME="HeadEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="HeadEllL_fun"
  UNLOAD_FUNC="HeadEllU_fun"
  HYS_MODEL="2"
  HYS_SLOPE="8.000000E+005"
  ELAS_LIMIT="0.0"
  DAMP_COEF="200.0"
  DAMP_AMP_FUNC="HeadEllA_fun"
  DAMP_VEL_FUNC="HeadEllD_fun"
  >
  <FUNC_USAGE.2D
    FUNC="HeadEllL_fun"
    INTERPOLATION="SPLINE"
  />
  <FUNC_USAGE.2D
    FUNC="HeadEllU_fun"
    INTERPOLATION="SPLINE"
  />
  <FUNC_USAGE.2D
    FUNC="HeadEllD_fun"
    INTERPOLATION="SPLINE"
  />
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        <FUNC_USAGE.2D
          FUNC="HeadEllA_fun"
          INTERPOLATION="SPLINE"
        />
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      <FUNCTION.XY
        ID="1001"
        NAME="HeadEllL_fun"
        >
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          TYPE="XY_PAIR"
          >
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|      XI                YI      |
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     1.60000000E-003      1.00000000E+002
     2.40000000E-003      4.25000000E+002
     3.20000000E-003      1.40000000E+003
     4.00000000E-003      3.70000000E+003
     4.80000000E-003      9.00000000E+003
     8.00000000E-003      4.00000000E+004
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
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        NAME="HeadEllU_fun"
        >
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          TYPE="XY_PAIR"
          >
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|      XI                YI      |
     0.00000000E+000      0.00000000E+000
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     4.00000000E-003      4.00000000E+001
     6.00000000E-003      1.70000000E+002
     8.00000000E-003      5.60000000E+002
     1.00000000E-002      1.36000000E+003
     1.20000000E-002      3.20000000E+003
     2.40000000E-002      1.60000000E+004
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="1003"
        NAME="HeadEllD_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
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|      XI                YI      |
     -3.00000000E+000      -4.40000000E+002
     -2.00000000E+000      -5.50000000E+002
     -1.00000000E+000      -1.10000000E+003
     -5.00000000E-001      -1.21000000E+003
     -2.00000000E-001      -8.80000000E+002
     0.00000000E+000       0.00000000E+000
     2.00000000E-001       1.10000000E+003
     7.00000000E-001       2.09000000E+003
     1.10000000E+000       2.47500000E+003
     2.00000000E+000       2.64000000E+003
     3.00000000E+000       2.75000000E+003
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="1004"
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        NAME="HeadEllA_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
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|      XI                YI      |
    0.00000000E+000     0.00000000E+000
    4.00000000E+002     6.00000000E-001
    1.50000000E+003     1.10000000E+000
    3.00000000E+003     1.40000000E+000
    5.00000000E+003     1.40000000E+000
    7.00000000E+003     1.20000000E+000
    1.00000000E+004     1.10000000E+000
]]>
        </TABLE>
      </FUNCTION.XY>
      <JOINT.BRAC
        ID="2014"
        NAME="NeckUpLC_jnt"
        >
        <CRDSYS_OBJECT_1.MB
          BODY="NeckNoddingPlate_bod"
          POS="0.0 0.0 0.0178"
          ORIENT="NeckUpLCJnt_ori"
        />
        <CRDSYS_OBJECT_2.MB
          BODY="Head_bod"
          POS="0.0 0.0 0.0"
          ORIENT="X180_ori"
        />
      </JOINT.BRAC>
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        SIGNAL_TYPE="LIN_ACC"
        FILTER="CFC1000"
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        />
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        SIGNAL_TYPE="ANG_ACC"
        FILTER="NONE"
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    ORIENT="X180_ori"
  />
</OUTPUT_BODY>
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  JOINT="NeckUpLC_jnt"
  SIGNAL_TYPE="TORQUE"
  FILTER="CFC600"
/>
<OUTPUT_JOINT_CONSTRAINT
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  NAME="NeckUp_lce_F_CFC1000"
  JOINT="NeckUpLC_jnt"
  SIGNAL_TYPE="FORCE"
  FILTER="CFC1000"
/>
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  JOINT="NeckUpLC_jnt"
  SIGNAL_TYPE="FORCE"
  FILTER="CFC600"
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  NAME="HIC15_inj"
  OUTPUT_ACC="HeadCG_acc"
  TIME_WINDOW="0.015"
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  NAME="HIC36_inj"
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/>
<INJURY.NIC_FORWARD
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  COMP="TENSION"
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<INJURY.NIC_FORWARD
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<INJURY.NIC_FORWARD
  ID="2007"
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  OUTPUT_MOMENT="NeckUp_lce_T"
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/>
<INJURY.NIJ
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  OUTPUT_MOMENT="NeckUp_lce_T"
  NIJ_TYPE="NTE"
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/>
<INJURY.NIJ
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  OUTPUT_MOMENT="NeckUp_lce_T"
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<INJURY.LOAD_CELL
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  OUTPUT_LOAD="NeckUp_lce_F_CFC1000"
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  COMP="X"
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  SELECT_OBJECT="CHILD"
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<INJURY.LOAD_CELL
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  SELECT_OBJECT="CHILD"
  COMP="Z"
/>
<INJURY.LOAD_CELL
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  SELECT_OBJECT="CHILD"
  COMP="R"
/>
<INJURY.LOAD_CELL
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  SELECT_OBJECT="CHILD"
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  SELECT_OBJECT="CHILD"
  COMP="Y"
/>
<INJURY.LOAD_CELL
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  SELECT_OBJECT="CHILD"
  COMP="Z"
/>
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  MASS="0.01"
  INERTIA="1.000000E-003 1.000000E-003 1.000000E-003 0.0 0.0 0.0"
/>
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  MASS="0.1"
  INERTIA="1.000000E-003 1.000000E-003 1.000000E-003 0.0 0.0 0.0"
/>
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  MASS="0.19"
  INERTIA="1.000000E-003 1.000000E-003 1.000000E-003 0.0 0.0 0.0"
/>
<BODY.RIGID
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  MASS="0.19"
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/>
<BODY.RIGID
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  MASS="0.19"
  INERTIA="1.000000E-003 1.000000E-003 1.000000E-003 0.0 0.0 0.0"
/>
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  ID="2012"
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  MASS="0.36"
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  MASS="0.01"
  INERTIA="1.000000E-003 1.000000E-003 1.000000E-003 0.0 0.0 0.0"
/>
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  DEGREE="2"
  CHAR="NeckEll_chr"
  >
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  ID="2024"
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  SEMI_AXIS="0.04 0.025 0.005"
  DEGREE="8"
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  ID="2064"
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  SEMI_AXIS="0.043 0.043 0.03"
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  ID="2065"
  NAME="NeckPart3_ell"
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    BODY="NeckPart3_bod"
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  />
</SURFACE.ELLIPSOID>
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  CHAR="NeckEll_chr"
  ID="2066"
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  SEMI_AXIS="0.043 0.043 0.03"
  DEGREE="2"
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    POS="0.0 0.0 0.0141"
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  ID="2067"
  NAME="NeckPart5_ell"
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  >
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    POS="0.0 0.0 0.0141"
  />
</SURFACE.ELLIPSOID>
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  CONTACT_MODEL="FORCE"
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        NAME="NeckEll_fun"
        >
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      </FUNCTION.XY>
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          ORIENT="X180_ori"
        />
        <CRDSYS_OBJECT_2.MB
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          POS="0.0 0.0 0.0"
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        />
      </JOINT.BRAC>
      <JOINT.REVO
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        NAME="NeckBracket_jnt"
        STATUS="LOCK"
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          ORIENT="NeckBracketJnt_ori"
        />
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        />
      </JOINT.REVO>
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        NAME="NeckOC_jnt"
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          POS="0.0 0.0 0.0404"
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        />
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          POS="0.0 0.0 0.0"
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    BODY="NeckPart3_bod"
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  <CRDSYS_OBJECT_2.MB
    BODY="NeckPart4_bod"
    POS="0.0 0.0 0.0"
  />
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    POS="0.0 0.0 0.0282"
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  <CRDSYS_OBJECT_2.MB
    BODY="NeckPart5_bod"
    POS="0.0 0.0 0.0"
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  AXIS_2="Z"
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  />
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  NAME="NeckPivot4_six"
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  >
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      FRIC_LOAD="0.0"
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      CHAR="Neck2_chr"
      FRIC_LOAD="0.0"
    />
    <COMP_SIX_DOF
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      CHAR="Neck3_chr"
      FRIC_LOAD="0.0"
    />
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    />
    <COMP_SIX_DOF
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      CHAR="Neck2_chr"
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      DOF_TYPE="R3"
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          FRIC_LOAD="0.0"
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    ORIENT="ThoracicEll_ori"
  />
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  NAME="Collar_ell"
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  CHAR="ArmEll_chr"
  >
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  />
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<SURFACE.ELLIPSOID
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  NAME="hunchback_ell"
  SEMI_AXIS="0.08 0.075 0.04"
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  CHAR="ThoracicBackPlateEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
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  />
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<SURFACE.ELLIPSOID
  ID="4009"
  NAME="ChestUpL_ell"
  SEMI_AXIS="0.1 0.11 0.09"
  DEGREE="2"
  CHAR="ChestUpEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.071 0.044 0.09"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
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  NAME="ChestUpR_ell"
  SEMI_AXIS="0.1 0.11 0.09"
  DEGREE="2"
  CHAR="ChestUpEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.071 -0.044 0.09"
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  />
</SURFACE.ELLIPSOID>
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  SEMI_AXIS="0.0812 0.0712 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
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    POS="-0.047 0.0558 0.0711"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
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  NAME="RibPart2L_ell"
  SEMI_AXIS="0.0939 0.0839 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0594 0.0558 0.0427"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="4013"
  NAME="RibPart3L_ell"
  SEMI_AXIS="0.099 0.089 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0642 0.0545 0.0142"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="4014"
  NAME="RibPart4L_ell"
  SEMI_AXIS="0.1003 0.0903 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0651 0.0545 -0.0142"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="4015"
  NAME="RibPart5L_ell"
  SEMI_AXIS="0.0969 0.0869 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0614 0.0553 -0.0427"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="4016"
  NAME="RibPart6L_ell"
  SEMI_AXIS="0.0914 0.0814 0.06"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
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    BODY="Ribs_bod"
    POS="-0.0556 0.0558 -0.0711"
  />
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  NAME="RibPart1R_ell"
  SEMI_AXIS="0.0812 0.0712 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.047 -0.0558 0.0711"
  />
</SURFACE.ELLIPSOID>
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  ID="4018"
  NAME="RibPart2R_ell"
  SEMI_AXIS="0.0939 0.0839 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0594 -0.0558 0.0427"
  />
</SURFACE.ELLIPSOID>
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  ID="4019"
  NAME="RibPart3R_ell"
  SEMI_AXIS="0.099 0.089 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0642 -0.0545 0.0142"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="4020"
  NAME="RibPart4R_ell"
  SEMI_AXIS="0.1003 0.0903 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0651 -0.0545 -0.0142"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="4021"
  NAME="RibPart5R_ell"
  SEMI_AXIS="0.0969 0.0869 0.05"
  DEGREE="2"
  CHAR="RibEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0614 -0.0553 -0.0427"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="4022"
  NAME="RibPart6R_ell"
  SEMI_AXIS="0.0914 0.0814 0.06"
  DEGREE="2"
  CHAR="RibEll_chr"
```

```
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Ribs_bod"
    POS="-0.0556 -0.0558 -0.0711"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="4051"
  NAME="Sternum_ell"
  SEMI_AXIS="0.02 0.06 0.098"
  DEGREE="2"
  CHAR="SternumEll_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Sternum_bod"
    POS="0.015 0.0 0.0"
  />
</SURFACE.ELLIPSOID>
<ORIENTATION.SUCCESSIVE_ROT
  ID="4003"
  NAME="ThoracicEll_ori"
  AXIS_1="Y"
  R1="-0.31416"
/>
<CHARACTERISTIC.CONTACT
  ID="3002"
  NAME="ArmEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="ArmEll_fun"
  HYS_MODEL="NONE"
  ELAS_LIMIT="0.0"
/>
<CHARACTERISTIC.CONTACT
  ID="4004"
  NAME="ThoracicBackPlateEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="ThoracicEllL_fun"
  UNLOAD_FUNC="ThoracicEllU_fun"
  HYS_MODEL="1"
  HYS_SLOPE="2.000000E+006"
  ELAS_LIMIT="0.0"
/>
<CHARACTERISTIC.CONTACT
  ID="4005"
  NAME="ChestUpEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="ChestUpEll_fun"
  HYS_MODEL="1"
  HYS_SLOPE="4.000000E+005"
  ELAS_LIMIT="0.0"
/>
<CHARACTERISTIC.CONTACT
  ID="4007"
  NAME="RibEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="RibEll_fun"
  HYS_MODEL="NONE"
  ELAS_LIMIT="0.0"
/>
<CHARACTERISTIC.CONTACT
  ID="4034"
  NAME="SternumEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="SternumEll_fun"
  HYS_MODEL="NONE"
  ELAS_LIMIT="0.0"
/>
<FUNCTION.XY
  ID="3038"
  NAME="ArmEll_fun"
```

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        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI               YI      |
     0.00000000E+000     0.00000000E+000
     3.10000000E-003     3.22600000E+002
     6.50000000E-003     9.03200000E+002
     8.50000000E-003     1.99000000E+003
     1.00000000E-002     3.20000000E+003
     1.15000000E-002     5.11000000E+003
     1.30000000E-002     1.00880000E+004
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="4022"
        NAME="ThoracicEllL_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI               YI      |
     0.00000000E+000     0.00000000E+000
     6.20000000E-003     3.22600000E+002
     1.31000000E-002     9.03200000E+002
     2.08000000E-002     2.06450000E+003
     2.85000000E-002     3.41940000E+003
     3.20000000E-002     4.61620000E+003
     3.50000000E-002     6.23180000E+003
     3.70000000E-002     8.41300000E+003
     3.90000000E-002     1.13576000E+004
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="4023"
        NAME="ThoracicEllU_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI               YI      |
     0.00000000E+000     0.00000000E+000
     1.23000000E-002     0.00000000E+000
     1.92000000E-002     2.25800000E+002
     2.85000000E-002     7.74200000E+002
     3.20000000E-002     1.12260000E+003
     3.50000000E-002     1.62780000E+003
     3.70000000E-002     2.36020000E+003
     3.90000000E-002     3.54040000E+003
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="4025"
        NAME="ChestUpEll_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI               YI      |
     0.00000000E+000     0.00000000E+000
     1.45000000E-002     7.65000000E+001
     3.05000000E-002     3.44100000E+002
     5.12000000E-002     9.10000000E+002
```

```
    7.26000000E-002      1.62120000E+003
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="4026"
      NAME="RibEll_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                YI      |
    0.00000000E+000      0.00000000E+000
    1.30000000E-002      2.72100000E+002
    2.00000000E-002      5.67900000E+002
    2.40000000E-002      1.12530000E+003
    2.80000000E-002      3.15710000E+003
    3.10000000E-002      6.82580000E+003
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="4027"
      NAME="SternumEll_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                YI      |
    0.00000000E+000      0.00000000E+000
    1.30000000E-002      8.16000000E+002
    2.00000000E-002      1.70400000E+003
    2.40000000E-002      3.37600000E+003
    2.80000000E-002      9.47100000E+003
    3.10000000E-002      2.07770000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <JOINT.FREE
      ID="4006"
      NAME="Ribs_jnt"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="ThoracicSpine_bod"
        POS="0.1517 0.0 0.0762"
        ORIENT="RibsJnt_ori"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="Ribs_bod"
        POS="0.0 0.0 0.0"
      />
    </JOINT.FREE>
    <JOINT.TRAN
      ID="4035"
      NAME="Sternum_jnt"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="Ribs_bod"
        POS="0.0 0.0 0.0"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="Sternum_bod"
        POS="0.0 0.0 0.0"
      />
    </JOINT.TRAN>
    <JOINT.BRAC
      ID="5005"
      NAME="LumbarSpineUpLC_jnt"
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  >
  <CRDSYS_OBJECT_1.MB
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    POS="0.0028 0.0 0.1327"
    ORIENT="LumbarSpineUpLCJnt_1_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ThoracicSpine_bod"
    POS="0.0 0.0 0.0"
    ORIENT="LumbarSpineUpLCJnt_2_ori"
  />
</JOINT.BRAC>
<JOINT.UNIV
  ID="4015"
  NAME="ClavicleL_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ThoracicSpine_bod"
    POS="0.0125 0.0156 0.1848"
    ORIENT="ClavicleLJnt_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ClavicleL_bod"
    POS="0.0 0.0 0.0"
    ORIENT="X+90_ori"
  />
</JOINT.UNIV>
<JOINT.UNIV
  ID="4016"
  NAME="ClavicleR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ThoracicSpine_bod"
    POS="0.0125 -0.0156 0.1848"
    ORIENT="ClavicleRJnt_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ClavicleR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="X+90_ori"
  />
</JOINT.UNIV>
<ORIENTATION.SUCCESSIVE_ROT
  ID="4035"
  NAME="RibsJnt_ori"
  AXIS_1="Y"
  R1="-0.27053"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="4045"
  NAME="ClavicleLJnt_ori"
  AXIS_1="Y"
  R1="-0.17453"
  AXIS_2="X"
  R2="1.41372"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="4047"
  NAME="ClavicleRJnt_ori"
  AXIS_1="Y"
  R1="-0.17453"
  AXIS_2="X"
  R2="1.72788"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="5033"
  NAME="LumbarSpineUpLCJnt_1_ori"
  AXIS_1="Y"
  R1="0.26178"
  AXIS_2="X"
```

```
      R2="3.14159"
    />
    <ORIENTATION.SUCCESSIVE_ROT
      ID="5034"
      NAME="LumbarSpineUpLCJnt_2_ori"
      AXIS_1="Y"
      R1="-0.1571"
      AXIS_2="X"
      R2="3.14159"
    />
    <RESTRAINT.JOINT
      ID="4021"
      NAME="ClavicleL_joi"
      JOINT="ClavicleL_jnt"
      Q1_FRIC_LOAD="0.0"
      Q1_CHAR="Clavicle1Joi_chr"
      Q2_FRIC_LOAD="0.0"
      Q2_CHAR="Clavicle2Joi_chr"
    />
    <RESTRAINT.JOINT
      ID="4022"
      NAME="ClavicleR_joi"
      JOINT="ClavicleR_jnt"
      Q1_FRIC_LOAD="0.0"
      Q1_CHAR="Clavicle1Joi_chr"
      Q2_FRIC_LOAD="0.0"
      Q2_CHAR="Clavicle2Joi_chr"
    />
    <RESTRAINT.JOINT
      ID="4031"
      NAME="Sternum_joi"
      JOINT="Sternum_jnt"
      Q1_FRIC_LOAD="0.0"
      Q1_CHAR="SternumJoi_chr"
    />
    <CHARACTERISTIC.LOAD
      ID="4095"
      NAME="Clavicle1Joi_chr"
      LOAD_FUNC="Clavicle1Joi_fun"
      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
      DAMP_COEF="2.5"
    />
    <CHARACTERISTIC.LOAD
      ID="4096"
      NAME="Clavicle2Joi_chr"
      LOAD_FUNC="Clavicle2Joi_fun"
      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
      DAMP_COEF="2.5"
    />
    <CHARACTERISTIC.LOAD
      ID="4111"
      NAME="SternumJoi_chr"
      LOAD_FUNC="SternumJoi_fun"
      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
      DAMP_COEF="800.0"
    />
    <FUNCTION.XY
      ID="4002"
      NAME="Clavicle1Joi_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                YI      |
    -8.70000000E-002     -3.46500000E+002
    -4.40000000E-002     -8.66000000E+001
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```
      0.00000000E+000       0.00000000E+000
      4.40000000E-002       8.66000000E+001
      8.70000000E-002       3.46500000E+002
      1.30000000E-001       6.06400000E+002
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="4003"
        NAME="Clavicle2Joi_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|       XI                 YI       |
      -1.63000000E-001      -5.44800000E+002
      -1.09000000E-001      -3.11300000E+002
      -5.50000000E-002      -7.78000000E+001
      0.00000000E+000       0.00000000E+000
      5.50000000E-002       7.78000000E+001
      1.09000000E-001       3.11300000E+002
      1.63000000E-001       5.44800000E+002
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="4012"
        NAME="SternumJoi_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|       XI                 YI       |
      -1.00000000E+000      -1.00000000E+005
      0.00000000E+000       0.00000000E+000
      1.00000000E+000       1.00000000E+005
]]>
        </TABLE>
      </FUNCTION.XY>
      <RESTRAINT.POINT
        ID="4012"
        NAME="Ribs_poi"
        D1_CHAR="Ribs1Poi_chr"
        D2_CHAR="Ribs2Poi_chr"
        D3_CHAR="Ribs3Poi_chr"
        >
        <CRDSYS_OBJECT_1.MB
          BODY="ThoracicSpine_bod"
          POS="0.1517 0.0 0.0762"
          ORIENT="RibsPoi_ori"
        />
        <POINT_OBJECT_2.MB
          BODY="Ribs_bod"
          POS="0.0 0.0 0.0"
        />
      </RESTRAINT.POINT>
      <ORIENTATION.SUCCESSIVE_ROT
        ID="4104"
        NAME="RibsPoi_ori"
        AXIS_1="Y"
        R1="-0.27053"
      />
      <CHARACTERISTIC.LOAD
        ID="4078"
        NAME="Ribs1Poi_chr"
        LOAD_FUNC="Ribs1PoiL_fun"
        UNLOAD_FUNC="Ribs1PoiU_fun"
        HYS_MODEL="1"
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    HYS_SLOPE="2.000000E+005"
    ELAS_LIMIT="0.0"
    DAMP_COEF="600.0"
  />
  <CHARACTERISTIC.LOAD
    ID="4079"
    NAME="Ribs2Poi_chr"
    LOAD_FUNC="Ribs2Poi_fun"
    HYS_MODEL="NONE"
    ELAS_LIMIT="0.0"
    DAMP_COEF="9.600000E+003"
  />
  <CHARACTERISTIC.LOAD
    ID="4080"
    NAME="Ribs3Poi_chr"
    LOAD_FUNC="Ribs3Poi_fun"
    HYS_MODEL="NONE"
    ELAS_LIMIT="0.0"
    DAMP_COEF="1.200000E+003"
  />
  <FUNCTION.XY
    ID="4038"
    NAME="Ribs1PoiL_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|     XI              YI     |
  -5.58000000E-002    -8.00000000E+003
  -4.37000000E-002    -6.00000000E+003
  -3.06000000E-002    -4.00000000E+003
  -1.65000000E-002    -2.00000000E+003
  0.00000000E+000     0.00000000E+000
  1.65000000E-002     2.00000000E+003
]]>
    </TABLE>
  </FUNCTION.XY>
  <FUNCTION.XY
    ID="4039"
    NAME="Ribs1PoiU_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|     XI              YI     |
  -6.31000000E-002    -8.00000000E+003
  -5.10000000E-002    -6.00000000E+003
  -3.79000000E-002    -4.00000000E+003
  -2.32000000E-002    -2.00000000E+003
  -8.50000000E-003    -3.00000000E+002
  0.00000000E+000     0.00000000E+000
  8.50000000E-003     3.00000000E+002
]]>
    </TABLE>
  </FUNCTION.XY>
  <FUNCTION.XY
    ID="4040"
    NAME="Ribs2Poi_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|     XI              YI     |
  -1.00000000E+000    -9.60000000E+005
  0.00000000E+000     0.00000000E+000
  1.00000000E+000     9.60000000E+005
]]>
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      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="4041"
      NAME="Ribs3Poi_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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|      XI                YI      |
    -2.00000000E-002     -5.00000000E+003
    -1.00000000E-002     -1.20000000E+003
    0.00000000E+000      0.00000000E+000
    1.00000000E+000      1.20000000E+005
]]>
      </TABLE>
    </FUNCTION.XY>
    <RESTRAINT.CARDAN
      ID="4036"
      NAME="Ribs_crd"
      R1_CHAR="Ribs1Crd_chr"
      R2_CHAR="Ribs2Crd_chr"
      R3_CHAR="Ribs3Crd_chr"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="ThoracicSpine_bod"
        ORIENT="Ribs1Crd_ori"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="Ribs_bod"
        ORIENT="Ribs2Crd_ori"
      />
    </RESTRAINT.CARDAN>
    <ORIENTATION.SUCCESSIVE_ROT
      ID="4108"
      NAME="Ribs1Crd_ori"
      AXIS_1="Y"
      R1="-0.27053"
    />
    <ORIENTATION.SUCCESSIVE_ROT
      ID="4109"
      NAME="Ribs2Crd_ori"
      AXIS_1="Y"
      R1="0.0"
    />
    <CHARACTERISTIC.LOAD
      ID="4112"
      NAME="Ribs1Crd_chr"
      LOAD_FUNC="Ribs1Crd_fun"
      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
      DAMP_COEF="29.1"
    />
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                RibPart3L_ell RibPart4L_ell RibPart5L_ell RibPart6L_ell
                RibPart1R_ell RibPart2R_ell RibPart3R_ell RibPart4R_ell
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    <OUTPUT_BODY_REL
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      SIGNAL_TYPE="REL_POS"
      FILTER="CFC600"
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        POS="0.0 0.0 0.0"
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  AXIS_2="Y"
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  SIGNAL_TYPE="FORCE"
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  SIGNAL_TYPE="TORQUE"
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  <COMP_SIX_DOF
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    FRIC_LOAD="0.0"
  />
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       NAME="LumbarSpineLow_Fres_lce"
       OUTPUT_LOAD="LumbarSpineLow_lce_F"
       SELECT_OBJECT="CHILD"
       COMP="R"
     />
     <INJURY.LOAD_CELL
       ID="5024"
       NAME="LumbarSpineLow_Fx_lce"
       OUTPUT_LOAD="LumbarSpineLow_lce_F"
       SELECT_OBJECT="CHILD"
       COMP="X"
     />
     <INJURY.LOAD_CELL
       ID="5025"
       NAME="LumbarSpineLow_Fy_lce"
       OUTPUT_LOAD="LumbarSpineLow_lce_F"
       SELECT_OBJECT="CHILD"
       COMP="Y"
     />
     <INJURY.LOAD_CELL
       ID="5026"
       NAME="LumbarSpineLow_Fz_lce"
       OUTPUT_LOAD="LumbarSpineLow_lce_F"
       SELECT_OBJECT="CHILD"
       COMP="Z"
     />
     <INJURY.LOAD_CELL
       ID="5027"
       NAME="LumbarSpineLow_Mres_lce"
       OUTPUT_LOAD="LumbarSpineLow_lce_T"
       SELECT_OBJECT="CHILD"
       COMP="R"
     />
     <INJURY.LOAD_CELL
       ID="5028"
       NAME="LumbarSpineLow_Mx_lce"
       OUTPUT_LOAD="LumbarSpineLow_lce_T"
       SELECT_OBJECT="CHILD"
       COMP="X"
     />
     <INJURY.LOAD_CELL
       ID="5029"
       NAME="LumbarSpineLow_My_lce"
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  OUTPUT_LOAD="LumbarSpineLow_lce_T"
  SELECT_OBJECT="CHILD"
  COMP="Y"
/>
<INJURY.LOAD_CELL
  ID="5030"
  NAME="LumbarSpineLow_Mz_lce"
  OUTPUT_LOAD="LumbarSpineLow_lce_T"
  SELECT_OBJECT="CHILD"
  COMP="Z"
/>
<BODY.RIGID
  ID="6001"
  NAME="Pelvis_bod"
  CENTRE_OF_GRAVITY="-0.0178 0.0 0.0328"
  MASS="16.6107"
  INERTIA="0.13 0.0887 0.1297 0.0 0.0 0.0087"
/>
<BODY.RIGID
  ID="6002"
  NAME="AbdomenInsert_bod"
  CENTRE_OF_GRAVITY="0.0 0.0 0.0"
  MASS="0.64"
  INERTIA="0.01 0.01 0.01 0.0 0.0 0.0"
/>
<SURFACE.ELLIPSOID
  ID="6001"
  NAME="Pelvis_ell"
  CHAR="PelvisEll_chr"
  SEMI_AXIS="0.118 0.183 0.09"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="Pelvis_bod"
    POS="-0.012 0.0 -0.015"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="6002"
  NAME="AbdomenLow_ell"
  CHAR="AbdomenEll_chr"
  SEMI_AXIS="0.07 0.155 0.11"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="AbdomenInsert_bod"
    POS="0.0 0.0 -0.03"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="6003"
  NAME="AbdomenMid_ell"
  CHAR="AbdomenEll_chr"
  SEMI_AXIS="0.07 0.14 0.17"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="AbdomenInsert_bod"
    POS="0.0 0.0 0.03"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="6004"
  NAME="AbdomenUp_ell"
  CHAR="AbdomenEll_chr"
  SEMI_AXIS="0.07 0.14 0.11"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="AbdomenInsert_bod"
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        POS="0.0 0.0 0.09"
      />
    </SURFACE.ELLIPSOID>
    <SURFACE.ELLIPSOID
      ID="6068"
      NAME="PelvisButtockL_ell"
      CHAR="PelvisButtockEll_chr"
      SEMI_AXIS="0.015 0.015 0.015"
      DEGREE="2"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="Pelvis_bod"
        POS="-0.012 0.053 -0.06"
      />
    </SURFACE.ELLIPSOID>
    <SURFACE.ELLIPSOID
      ID="6069"
      NAME="PelvisButtockR_ell"
      CHAR="PelvisButtockEll_chr"
      SEMI_AXIS="0.015 0.015 0.015"
      DEGREE="2"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="Pelvis_bod"
        POS="-0.012 -0.053 -0.06"
      />
    </SURFACE.ELLIPSOID>
    <CHARACTERISTIC.CONTACT
      ID="6129"
      NAME="PelvisButtockEll_chr"
      CONTACT_MODEL="FORCE"
      LOAD_FUNC="ThoracicEllL_fun"
      UNLOAD_FUNC="ThoracicEllU_fun"
      HYS_MODEL="1"
      HYS_SLOPE="1.000000E+006"
      ELAS_LIMIT="0.0"
    />
    <CHARACTERISTIC.CONTACT
      ID="6006"
      NAME="AbdomenEll_chr"
      CONTACT_MODEL="FORCE"
      LOAD_FUNC="AbdomenEll_fun"
    />
    <FUNCTION.XY
      ID="6007"
      NAME="AbdomenEll_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|     XI              YI     |
    0.00000000E+000     0.00000000E+000
    1.00000000E+000     1.00000000E+006
]]>
      </TABLE>
    </FUNCTION.XY>
    <JOINT.FREE
      ID="1"
      NAME="Dummy_jnt"
      >
      <CRDSYS_OBJECT_1.REF
        CRDSYS_REF="Dummy_Attachment"
      />
      <CRDSYS_OBJECT_2.MB
        BODY="Pelvis_bod"
        POS="0.0 0.0 0.0"
      />
    </JOINT.FREE>
    <JOINT.TRAN
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    ID="6002"
    NAME="AbdomenInsert_jnt"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="Pelvis_bod"
      POS="0.05 0.0 0.0846"
      ORIENT="AbdomenInsertJnt_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="AbdomenInsert_bod"
      POS="0.0 0.0 0.0"
      ORIENT="AbdomenInsertJnt_ori"
    />
  </JOINT.TRAN>
  <ORIENTATION.SUCCESSIVE_ROT
    ID="6027"
    NAME="AbdomenInsertJnt_ori"
    AXIS_1="Y"
    R1="2.8798"
  />
  <RESTRAINT.JOINT
    ID="6020"
    NAME="AbdomenInsert_joi"
    JOINT="AbdomenInsert_jnt"
    Q1_CHAR="AbdomenInsertJoi_chr"
    Q1_FRIC_LOAD="0.0"
  />
  <CHARACTERISTIC.LOAD
    ID="6094"
    NAME="AbdomenInsertJoi_chr"
    LOAD_FUNC="AbdomenInsert1Joi_fun"
    UNLOAD_FUNC="AbdomenInsert2Joi_fun"
    DAMP_COEF="250.0"
    HYS_MODEL="1"
    HYS_SLOPE="5.000000E+006"
    ELAS_LIMIT="0.0"
    >
    <FUNC_USAGE.2D
      FUNC="AbdomenInsert1Joi_fun"
      INTERPOLATION="SPLINE"
    />
    <FUNC_USAGE.2D
      FUNC="AbdomenInsert2Joi_fun"
      INTERPOLATION="SPLINE"
    />
  </CHARACTERISTIC.LOAD>
  <FUNCTION.XY
    ID="6011"
    NAME="AbdomenInsert1Joi_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|     XI              YI      |
  -2.00000000E-002    -2.08000000E+003
  0.00000000E+000      0.00000000E+000
  2.00000000E-002     2.08000000E+003
  3.00000000E-002     3.85000000E+003
  4.00000000E-002     6.24000000E+003
  5.00000000E-002     1.00000000E+004
  6.00000000E-002     1.49400000E+004
  7.00000000E-002     2.21400000E+004
]]>
    </TABLE>
  </FUNCTION.XY>
  <FUNCTION.XY
    ID="6101"
    NAME="AbdomenInsert2Joi_fun"
    >
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        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI                YI      |
     0.00000000E+000      0.00000000E+000
     2.00000000E-002      0.00000000E+000
     3.00000000E-002      7.00000000E+002
     4.00000000E-002      2.00000000E+003
     5.00000000E-002      4.50000000E+003
     6.00000000E-002      7.50000000E+003
     7.00000000E-002      1.20000000E+004
]]>
        </TABLE>
      </FUNCTION.XY>
      <RESTRAINT.POINT
        ID="6013"
        NAME="AbdomenVertL_poi"
        D3_CHAR="AbdomenVertPoi_chr"
        >
        <CRDSYS_OBJECT_1.MB
          BODY="ThoracicSpine_bod"
          POS="0.1988 0.1 -0.07828"
          ORIENT="Abdomen1Poi_ori"
        />
        <POINT_OBJECT_2.MB
          BODY="Pelvis_bod"
          POS="0.07 0.1 0.12"
        />
      </RESTRAINT.POINT>
      <RESTRAINT.POINT
        ID="6014"
        NAME="AbdomenVertR_poi"
        D3_CHAR="AbdomenVertPoi_chr"
        >
        <CRDSYS_OBJECT_1.MB
          BODY="ThoracicSpine_bod"
          POS="0.1988 -0.1 -0.07828"
          ORIENT="Abdomen1Poi_ori"
        />
        <POINT_OBJECT_2.MB
          BODY="Pelvis_bod"
          POS="0.07 -0.1 0.12"
        />
      </RESTRAINT.POINT>
      <RESTRAINT.POINT
        ID="6015"
        NAME="AbdomenVertM_poi"
        D3_CHAR="AbdomenVertPoi_chr"
        >
        <CRDSYS_OBJECT_1.MB
          BODY="LumbarSpineUp_bod"
          POS="0.14829 0.0 1.000000E-004"
          ORIENT="Abdomen2Poi_ori"
        />
        <POINT_OBJECT_2.MB
          BODY="Pelvis_bod"
          POS="0.067 0.0 0.14"
        />
      </RESTRAINT.POINT>
      <ORIENTATION.SUCCESSIVE_ROT
        ID="6105"
        NAME="Abdomen1Poi_ori"
        AXIS_1="Y"
        R1="-0.25"
      />
      <ORIENTATION.SUCCESSIVE_ROT
        ID="6107"
        NAME="Abdomen2Poi_ori"
        AXIS_1="Y"
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    R1="-1.0"
  />
  <CHARACTERISTIC.LOAD
    ID="6081"
    NAME="AbdomenVertPoi_chr"
    LOAD_FUNC="AbdomenVertPoiL_fun"
    UNLOAD_FUNC="AbdomenVertPoiU_fun"
    DAMP_COEF="0.0"
    HYS_MODEL="1"
    HYS_SLOPE="1.000000E+005"
    ELAS_LIMIT="0.0"
  />
  <FUNCTION.XY
    ID="6042"
    NAME="AbdomenVertPoiL_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|      XI               YI      |
  -1.00000000E+000     0.00000000E+000
  0.00000000E+000      0.00000000E+000
  5.00000000E-002      3.00000000E+002
  7.50000000E-002      9.70000000E+002
  1.50000000E-001      4.10000000E+003
]]>
    </TABLE>
  </FUNCTION.XY>
  <FUNCTION.XY
    ID="6043"
    NAME="AbdomenVertPoiU_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|      XI               YI      |
  -1.00000000E+000     0.00000000E+000
  0.00000000E+000      0.00000000E+000
  5.00000000E-002      0.00000000E+000
  1.50000000E-001      2.05000000E+003
]]>
    </TABLE>
  </FUNCTION.XY>
  <OUTPUT_BODY
    ID="6004"
    NAME="Pelvis_acc"
    SIGNAL_TYPE="LIN_ACC"
    FILTER="CFC1000"
    CRDSYS="OBJECT_1"
    CORRECT_AX="ON"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="Pelvis_bod"
      POS="-0.044 0.0 0.005"
      ORIENT="X180_ori"
    />
  </OUTPUT_BODY>
  <BODY.RIGID
    ID="7023"
    NAME="FemurL_bod"
    CENTRE_OF_GRAVITY="0.1611 0.0047 -0.0036"
    MASS="5.69"
    INERTIA="0.0117 0.048 0.0477 0.0 0.0 0.0"
  />
  <BODY.RIGID
    ID="7025"
    NAME="KneeL_bod"
    CENTRE_OF_GRAVITY="0.0523 0.0047 -0.0036"
```

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    MASS="1.71"
    INERTIA="0.01 0.0144 0.0143 0.0 0.0 0.0"
  />
  <SURFACE.ELLIPSOID
    ID="6036"
    NAME="HipL_ell"
    CHAR="PelvisEll_chr"
    SEMI_AXIS="0.15 0.088 0.085"
    DEGREE="2"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="FemurL_bod"
      POS="0.07 -0.002 -0.0189"
      ORIENT="HipLEll_ori"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    ID="7035"
    NAME="FemurL_ell"
    CHAR="PelvisEll_chr"
    SEMI_AXIS="0.234 0.088 0.083"
    DEGREE="2"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="FemurL_bod"
      POS="0.225 0.005 0.0"
      ORIENT="HipLEll_ori"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    ID="7039"
    NAME="KneeL_ell"
    CHAR="KneeEll_chr"
    SEMI_AXIS="0.068 0.065 0.068"
    DEGREE="2"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="KneeL_bod"
      POS="0.1046 0.0 0.0"
    />
  </SURFACE.ELLIPSOID>
  <ORIENTATION.SUCCESSIVE_ROT
    ID="7005"
    NAME="HipLEll_ori"
    AXIS_1="Y"
    R1="-0.12217"
    AXIS_2="Z"
    R2="-0.02862"
  />
  <JOINT.BRAC
    ID="7025"
    NAME="FemurLCL_jnt"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="FemurL_bod"
      POS="0.2965 0.0 0.0"
      ORIENT="FemurLCLJnt_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="KneeL_bod"
      POS="0.0 0.0 0.0"
      ORIENT="FemurLCLJnt_ori"
    />
  </JOINT.BRAC>
  <JOINT.SPHE
    ID="7023"
    NAME="HipL_jnt"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="Pelvis_bod"
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    POS="0.0 0.085 0.0"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="FemurL_bod"
    POS="0.0 0.0 0.0"
    ORIENT="HipLJnt_ori"
  />
</JOINT.SPHE>
<ORIENTATION.SUCCESSIVE_ROT
  ID="7062"
  NAME="HipLJnt_ori"
  AXIS_1="Z"
  R1="-0.02862"
  AXIS_2="Y"
  R2="-0.12217"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="7065"
  NAME="FemurLCLJnt_ori"
  AXIS_1="Y"
  R1="-1.69297"
  AXIS_2="X"
  R2="3.11297"
/>
<RESTRAINT.SIX_DOF
  ID="6001"
  NAME="HipL_six"
  JOINT="HipL_jnt"
  >
  <COMP_SIX_DOF
    DOF_TYPE="R1"
    LOAD_TYPE="R1"
    CHAR="Hip1_chr"
    FRIC_LOAD="0.0"
  />
  <COMP_SIX_DOF
    DOF_TYPE="R23"
    LOAD_TYPE="R23"
    CHAR="Hip2_chr"
    FRIC_LOAD="0.0"
  />
</RESTRAINT.SIX_DOF>
<GROUP_MB
  ID="7012"
  NAME="FemurKneeL_gmb"
  SURFACE_LIST="FemurL_ell KneeL_ell"
/>
<GROUP_MB
  ID="7021"
  NAME="FemurL_gmb"
  SURFACE_LIST="FemurL_ell"
/>
<GROUP_MB
  ID="7023"
  NAME="KneeL_gmb"
  SURFACE_LIST="KneeL_ell"
/>
<OUTPUT_JOINT_CONSTRAINT
  ID="7019"
  NAME="FemurL_lce_F"
  JOINT="FemurLCL_jnt"
  SIGNAL_TYPE="FORCE"
  FILTER="CFC600"
/>
<OUTPUT_JOINT_CONSTRAINT
  ID="7020"
  NAME="FemurL_lce_T"
  JOINT="FemurLCL_jnt"
  SIGNAL_TYPE="TORQUE"
  FILTER="CFC600"
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/>
<INJURY.FFC
  ID="7013"
  NAME="FFCL_inj"
  OUTPUT_FORCE="FemurL_lce_F"
/>
<INJURY.LOAD_CELL
  ID="7054"
  NAME="FemurL_Fres_lce"
  OUTPUT_LOAD="FemurL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="R"
/>
<INJURY.LOAD_CELL
  ID="7055"
  NAME="FemurL_Fx_lce"
  OUTPUT_LOAD="FemurL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="X"
/>
<INJURY.LOAD_CELL
  ID="7056"
  NAME="FemurL_Fy_lce"
  OUTPUT_LOAD="FemurL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="Y"
/>
<INJURY.LOAD_CELL
  ID="7057"
  NAME="FemurL_Fz_lce"
  OUTPUT_LOAD="FemurL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="Z"
/>
<INJURY.LOAD_CELL
  ID="7058"
  NAME="FemurL_Mres_lce"
  OUTPUT_LOAD="FemurL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="R"
/>
<INJURY.LOAD_CELL
  ID="7059"
  NAME="FemurL_Mx_lce"
  OUTPUT_LOAD="FemurL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="X"
/>
<INJURY.LOAD_CELL
  ID="7060"
  NAME="FemurL_My_lce"
  OUTPUT_LOAD="FemurL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="Y"
/>
<INJURY.LOAD_CELL
  ID="7061"
  NAME="FemurL_Mz_lce"
  OUTPUT_LOAD="FemurL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="Z"
/>
<BODY.RIGID
  ID="7024"
  NAME="FemurR_bod"
  CENTRE_OF_GRAVITY="0.1611 -0.0047 -0.0036"
  MASS="5.69"
  INERTIA="0.0117 0.048 0.0477 0.0 0.0 0.0"
/>
<BODY.RIGID
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  ID="7026"
  NAME="KneeR_bod"
  CENTRE_OF_GRAVITY="0.0523 -0.0047 -0.0036"
  MASS="1.71"
  INERTIA="0.01 0.0144 0.0143 0.0 0.0 0.0"
/>
<SURFACE.ELLIPSOID
  ID="6038"
  NAME="HipR_ell"
  CHAR="PelvisEll_chr"
  SEMI_AXIS="0.15 0.088 0.085"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FemurR_bod"
    POS="0.07 0.002 -0.0189"
    ORIENT="HipREll_ori"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7037"
  NAME="FemurR_ell"
  CHAR="PelvisEll_chr"
  SEMI_AXIS="0.234 0.088 0.083"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FemurR_bod"
    POS="0.225 -0.005 0.0"
    ORIENT="HipREll_ori"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7040"
  NAME="KneeR_ell"
  CHAR="KneeEll_chr"
  SEMI_AXIS="0.068 0.065 0.068"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="KneeR_bod"
    POS="0.1046 0.0 0.0"
  />
</SURFACE.ELLIPSOID>
<ORIENTATION.SUCCESSIVE_ROT
  ID="7007"
  NAME="HipREll_ori"
  AXIS_1="Y"
  R1="-0.12217"
  AXIS_2="Z"
  R2="0.02862"
/>
<JOINT.BRAC
  ID="7026"
  NAME="FemurLCR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FemurR_bod"
    POS="0.2965 0.0 0.0"
    ORIENT="FemurLCRJnt_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="KneeR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="FemurLCRJnt_ori"
  />
</JOINT.BRAC>
<JOINT.SPHE
  ID="7024"
  NAME="HipR_jnt"
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    >
    <CRDSYS_OBJECT_1.MB
      BODY="Pelvis_bod"
      POS="0.0 -0.085 0.0"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="FemurR_bod"
      POS="0.0 0.0 0.0"
      ORIENT="HipRJnt_ori"
    />
  </JOINT.SPHE>
  <ORIENTATION.SUCCESSIVE_ROT
    ID="7064"
    NAME="HipRJnt_ori"
    AXIS_1="Z"
    R1="0.02862"
    AXIS_2="Y"
    R2="-0.12217"
  />
  <ORIENTATION.SUCCESSIVE_ROT
    ID="7067"
    NAME="FemurLCRJnt_ori"
    AXIS_1="Y"
    R1="-1.69297"
    AXIS_2="X"
    R2="-3.11297"
  />
  <RESTRAINT.SIX_DOF
    ID="6002"
    NAME="HipR_six"
    JOINT="HipR_jnt"
    >
    <COMP_SIX_DOF
      DOF_TYPE="R1"
      LOAD_TYPE="R1"
      CHAR="Hip3_chr"
      FRIC_LOAD="0.0"
    />
    <COMP_SIX_DOF
      DOF_TYPE="R23"
      LOAD_TYPE="R23"
      CHAR="Hip2_chr"
      FRIC_LOAD="0.0"
    />
  </RESTRAINT.SIX_DOF>
  <GROUP_MB
    ID="7013"
    NAME="FemurKneeR_gmb"
    SURFACE_LIST="FemurR_ell KneeR_ell"
  />
  <GROUP_MB
    ID="7022"
    NAME="FemurR_gmb"
    SURFACE_LIST="FemurR_ell"
  />
  <GROUP_MB
    ID="7024"
    NAME="KneeR_gmb"
    SURFACE_LIST="KneeR_ell"
  />
  <OUTPUT_JOINT_CONSTRAINT
    ID="7021"
    NAME="FemurR_lce_F"
    JOINT="FemurLCR_jnt"
    SIGNAL_TYPE="FORCE"
    FILTER="CFC600"
  />
  <OUTPUT_JOINT_CONSTRAINT
    ID="7022"
    NAME="FemurR_lce_T"
```

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      INERTIA="0.01 0.009 0.01 0.0 0.0 0.0"
    />
    <BODY.RIGID
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      MASS="2.12"
      INERTIA="0.03 0.0271 0.01 0.0 0.0 0.0"
    />
    <BODY.RIGID
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      NAME="TibiaLowL_bod"
      CENTRE_OF_GRAVITY="0.0112 3.000000E-004 -0.0347"
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      INERTIA="0.01 0.006 0.01 0.0 0.0 0.0"
    />
    <BODY.RIGID
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      CENTRE_OF_GRAVITY="0.0518 0.0 -0.0302"
      MASS="1.48"
      INERTIA="0.002 0.0064 0.0064 0.0 0.0 0.0"
    />
    <SURFACE.ELLIPSOID
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      >
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        POS="-0.015 0.0 -0.12"
        ORIENT="Tibia3Ell_ori"
      />
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    <SURFACE.ELLIPSOID
      ID="7043"
      NAME="FootL_ell"
      CHAR="FootEll_chr"
      SEMI_AXIS="0.12 0.044 0.032"
      DEGREE="2"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="FootL_bod"
        POS="0.06 0.0 -0.047"
        ORIENT="FootEll_ori"
      />
    </SURFACE.ELLIPSOID>
    <SURFACE.ELLIPSOID
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      NAME="HeelL_ell"
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CHAR="HeelEll_chr"
SEMI_AXIS="0.045 0.04 0.02"
DEGREE="2"
>
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BODY="FootL_bod"
POS="-0.02 0.0 -0.062"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
ID="7052"
NAME="TibiaPart5L_ell"
CHAR="TibiaEll_chr"
SEMI_AXIS="0.055 0.06 0.07"
DEGREE="2"
>
<CRDSYS_OBJECT_1.MB
BODY="TibiaUpL_bod"
POS="0.02 0.0 -0.05"
ORIENT="Tibia5Ell_ori"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
ID="7054"
NAME="TibiaPart4L_ell"
CHAR="TibiaEll_chr"
SEMI_AXIS="0.065 0.055 0.075"
DEGREE="2"
>
<CRDSYS_OBJECT_1.MB
BODY="TibiaMidL_bod"
POS="-0.025 0.0 -0.05"
ORIENT="Tibia4Ell_ori"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
ID="7056"
NAME="TibiaPart2L_ell"
CHAR="TibiaEll_chr"
SEMI_AXIS="0.055 0.045 0.05"
DEGREE="2"
>
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BODY="TibiaMidL_bod"
POS="0.0 0.0 -0.21"
ORIENT="Tibia3Ell_ori"
/>
</SURFACE.ELLIPSOID>
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ID="7058"
NAME="TibiaPart1L_ell"
CHAR="TibiaEll_chr"
SEMI_AXIS="0.055 0.045 0.07"
DEGREE="2"
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BODY="TibiaLowL_bod"
POS="0.0122 0.0 -0.035"
/>
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
ID="7060"
NAME="ToesL_ell"
CHAR="ToesEll_chr"
SEMI_AXIS="0.085 0.049 0.02"
DEGREE="2"
>
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BODY="FootL_bod"
POS="0.12 -0.004 -0.059"

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      ORIENT="ToesLEll_ori"
    />
  </SURFACE.ELLIPSOID>
  <ORIENTATION.SUCCESSIVE_ROT
    ID="7023"
    NAME="ToesLEll_ori"
    AXIS_1="Y"
    R1="-0.09"
    AXIS_2="Z"
    R2="-0.18"
  />
  <JOINT.BRAC
    ID="7029"
    NAME="TibiaUpLCL_jnt"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="TibiaUpL_bod"
      POS="0.0424 0.0 -0.0963"
      ORIENT="X180_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="TibiaMidL_bod"
      POS="0.0 0.0 0.0"
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  </JOINT.BRAC>
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    ID="7031"
    NAME="TibiaLowLCL_jnt"
    >
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      BODY="TibiaMidL_bod"
      POS="0.0 0.0 -0.2375"
      ORIENT="X180_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="TibiaLowL_bod"
      POS="0.0 0.0 0.0"
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  </JOINT.BRAC>
  <JOINT.SPHE
    ID="7033"
    NAME="AnkleL_jnt"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="TibiaLowL_bod"
      POS="0.0175 0.0 -0.076"
      ORIENT="AnkleJnt_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="FootL_bod"
      POS="0.0 0.0 0.0"
      ORIENT="Y-90_X-90_ori"
    />
  </JOINT.SPHE>
  <JOINT.REVO_TRAN
    ID="7027"
    NAME="KneeL_jnt"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="KneeL_bod"
      POS="0.1046 0.0 0.0"
      ORIENT="KneeJnt_1_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="TibiaUpL_bod"
      POS="0.0 0.0 0.0"
      ORIENT="KneeJnt_2_ori"
    />
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<RESTRAINT.SIX_DOF
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  NAME="AnkleL_six"
  JOINT="AnkleL_jnt"
  >
  <COMP_SIX_DOF
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    LOAD_TYPE="R1"
    CHAR="Ankle1_chr"
    FRIC_LOAD="0.0"
  />
  <COMP_SIX_DOF
    DOF_TYPE="R2"
    LOAD_TYPE="R2"
    CHAR="Ankle2_chr"
    FRIC_LOAD="0.0"
  />
  <COMP_SIX_DOF
    DOF_TYPE="R3"
    LOAD_TYPE="R3"
    CHAR="Ankle3_chr"
    FRIC_LOAD="0.0"
  />
</RESTRAINT.SIX_DOF>
<RESTRAINT.JOINT
  ID="7029"
  NAME="KneeL_joi"
  JOINT="KneeL_jnt"
  Q1_CHAR="Knee1Joi_chr"
  Q2_CHAR="Knee2Joi_chr"
  Q1_FRIC_LOAD="21.3"
  Q2_FRIC_LOAD="500.0"
/>
<GROUP_MB
  ID="7014"
  NAME="TibiaL_gmb"
  SURFACE_LIST="TibiaPart1L_ell TibiaPart2L_ell TibiaPart3L_ell
            TibiaPart4L_ell TibiaPart5L_ell"
/>
<GROUP_MB
  ID="7018"
  NAME="FootL_gmb"
  SURFACE_LIST="FootL_ell HeelL_ell ToesL_ell"
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<GROUP_MB
  ID="7052"
  NAME="HeelL_gmb"
  SURFACE_LIST="HeelL_ell"
/>
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  ID="7053"
  NAME="ToesL_gmb"
  SURFACE_LIST="ToesL_ell"
/>
<OUTPUT_JOINT_CONSTRAINT
  ID="7023"
  NAME="TibiaUpL_lce_F"
  JOINT="TibiaUpLCL_jnt"
  SIGNAL_TYPE="FORCE"
  FILTER="CFC600"
/>
<OUTPUT_JOINT_CONSTRAINT
  ID="7024"
  NAME="TibiaUpL_lce_T"
  JOINT="TibiaUpLCL_jnt"
  SIGNAL_TYPE="TORQUE"
  FILTER="CFC600"
/>
<OUTPUT_JOINT_CONSTRAINT
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  ID="7027"
  NAME="TibiaLowL_lce_F"
  JOINT="TibiaLowLCL_jnt"
  SIGNAL_TYPE="FORCE"
  FILTER="CFC600"
/>
<OUTPUT_JOINT_CONSTRAINT
  ID="7028"
  NAME="TibiaLowL_lce_T"
  JOINT="TibiaLowLCL_jnt"
  SIGNAL_TYPE="TORQUE"
  FILTER="CFC600"
/>
<OUTPUT_JOINT_DOF
  ID="7031"
  NAME="KneeL_pos"
  JOINT_LIST="KneeL_jnt"
  SIGNAL_TYPE="POS"
/>
<INJURY.TI
  ID="7015"
  NAME="TIUpL_inj"
  OUTPUT_FORCE="TibiaUpL_lce_F"
  OUTPUT_MOMENT="TibiaUpL_lce_T"
  COMPRESSIVE_FORCE="3.590000E+004"
  BENDING_TORQUE="225.0"
/>
<INJURY.TI
  ID="7017"
  NAME="TILowL_inj"
  OUTPUT_FORCE="TibiaLowL_lce_F"
  OUTPUT_MOMENT="TibiaLowL_lce_T"
  COMPRESSIVE_FORCE="3.590000E+004"
  BENDING_TORQUE="225.0"
/>
<INJURY.TCFC
  ID="7019"
  NAME="TCFCUpL_inj"
  OUTPUT_FORCE="TibiaUpL_lce_F"
/>
<INJURY.TCFC
  ID="7021"
  NAME="TCFCLowL_inj"
  OUTPUT_FORCE="TibiaLowL_lce_F"
/>
<INJURY.LOAD_CELL
  ID="7070"
  NAME="TibiaUpL_Fres_lce"
  OUTPUT_LOAD="TibiaUpL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="R"
/>
<INJURY.LOAD_CELL
  ID="7071"
  NAME="TibiaUpL_Fx_lce"
  OUTPUT_LOAD="TibiaUpL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="X"
/>
<INJURY.LOAD_CELL
  ID="7072"
  NAME="TibiaUpL_Fy_lce"
  OUTPUT_LOAD="TibiaUpL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="Y"
/>
<INJURY.LOAD_CELL
  ID="7073"
  NAME="TibiaUpL_Fz_lce"
  OUTPUT_LOAD="TibiaUpL_lce_F"
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  SELECT_OBJECT="PARENT"
  COMP="Z"
/>
<INJURY.LOAD_CELL
  ID="7074"
  NAME="TibiaUpL_Mres_lce"
  OUTPUT_LOAD="TibiaUpL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="R"
/>
<INJURY.LOAD_CELL
  ID="7075"
  NAME="TibiaUpL_Mx_lce"
  OUTPUT_LOAD="TibiaUpL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="X"
/>
<INJURY.LOAD_CELL
  ID="7076"
  NAME="TibiaUpL_My_lce"
  OUTPUT_LOAD="TibiaUpL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="Y"
/>
<INJURY.LOAD_CELL
  ID="7077"
  NAME="TibiaUpL_Mz_lce"
  OUTPUT_LOAD="TibiaUpL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="Z"
/>
<INJURY.LOAD_CELL
  ID="7086"
  NAME="TibiaLowL_Fres_lce"
  OUTPUT_LOAD="TibiaLowL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="R"
/>
<INJURY.LOAD_CELL
  ID="7087"
  NAME="TibiaLowL_Fx_lce"
  OUTPUT_LOAD="TibiaLowL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="X"
/>
<INJURY.LOAD_CELL
  ID="7088"
  NAME="TibiaLowL_Fy_lce"
  OUTPUT_LOAD="TibiaLowL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="Y"
/>
<INJURY.LOAD_CELL
  ID="7089"
  NAME="TibiaLowL_Fz_lce"
  OUTPUT_LOAD="TibiaLowL_lce_F"
  SELECT_OBJECT="PARENT"
  COMP="Z"
/>
<INJURY.LOAD_CELL
  ID="7090"
  NAME="TibiaLowL_Mres_lce"
  OUTPUT_LOAD="TibiaLowL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="R"
/>
<INJURY.LOAD_CELL
  ID="7091"
  NAME="TibiaLowL_Mx_lce"
  OUTPUT_LOAD="TibiaLowL_lce_T"
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  SELECT_OBJECT="PARENT"
  COMP="X"
/>
<INJURY.LOAD_CELL
  ID="7092"
  NAME="TibiaLowL_My_lce"
  OUTPUT_LOAD="TibiaLowL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="Y"
/>
<INJURY.LOAD_CELL
  ID="7093"
  NAME="TibiaLowL_Mz_lce"
  OUTPUT_LOAD="TibiaLowL_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="Z"
/>
<BODY.RIGID
  ID="7028"
  NAME="TibiaUpR_bod"
  CENTRE_OF_GRAVITY="-0.0029 0.0 -0.0201"
  MASS="1.31"
  INERTIA="0.01 0.009 0.01 0.0 0.0 0.0"
/>
<BODY.RIGID
  ID="7030"
  NAME="TibiaMidR_bod"
  CENTRE_OF_GRAVITY="0.0 -3.000000E-004 -0.11"
  MASS="2.12"
  INERTIA="0.03 0.0271 0.01 0.0 0.0 0.0"
/>
<BODY.RIGID
  ID="7032"
  NAME="TibiaLowR_bod"
  CENTRE_OF_GRAVITY="0.0112 -3.000000E-004 -0.0347"
  MASS="0.71"
  INERTIA="0.01 0.006 0.01 0.0 0.0 0.0"
/>
<BODY.RIGID
  ID="7034"
  NAME="FootR_bod"
  CENTRE_OF_GRAVITY="0.0518 0.0 -0.0302"
  MASS="1.48"
  INERTIA="0.002 0.0064 0.0064 0.0 0.0 0.0"
/>
<SURFACE.ELLIPSOID
  ID="7042"
  NAME="TibiaPart3R_ell"
  CHAR="TibiaEll_chr"
  SEMI_AXIS="0.06 0.055 0.13"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="TibiaMidR_bod"
    POS="-0.015 0.0 -0.12"
    ORIENT="Tibia3Ell_ori"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7047"
  NAME="FootR_ell"
  CHAR="FootEll_chr"
  SEMI_AXIS="0.12 0.044 0.032"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FootR_bod"
    POS="0.06 0.0 -0.047"
    ORIENT="FootEll_ori"
  />
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</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7048"
  NAME="HeelR_ell"
  CHAR="HeelEll_chr"
  SEMI_AXIS="0.045 0.04 0.02"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FootR_bod"
    POS="-0.02 0.0 -0.062"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7053"
  NAME="TibiaPart5R_ell"
  CHAR="TibiaEll_chr"
  SEMI_AXIS="0.055 0.06 0.07"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="TibiaUpR_bod"
    POS="0.02 0.0 -0.05"
    ORIENT="Tibia5Ell_ori"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7055"
  NAME="TibiaPart4R_ell"
  CHAR="TibiaEll_chr"
  SEMI_AXIS="0.065 0.055 0.075"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="TibiaMidR_bod"
    POS="-0.025 0.0 -0.05"
    ORIENT="Tibia4Ell_ori"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7057"
  NAME="TibiaPart2R_ell"
  CHAR="TibiaEll_chr"
  SEMI_AXIS="0.055 0.045 0.05"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="TibiaMidR_bod"
    POS="0.0 0.0 -0.21"
    ORIENT="Tibia3Ell_ori"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7059"
  NAME="TibiaPart1R_ell"
  CHAR="TibiaEll_chr"
  SEMI_AXIS="0.055 0.045 0.07"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="TibiaLowR_bod"
    POS="0.0122 0.0 -0.035"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7061"
  NAME="ToesR_ell"
  CHAR="ToesEll_chr"
  SEMI_AXIS="0.085 0.049 0.02"
  DEGREE="2"
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    BODY="FootR_bod"
    POS="0.12 0.004 -0.059"
    ORIENT="ToesREll_ori"
  />
</SURFACE.ELLIPSOID>
<ORIENTATION.SUCCESSIVE_ROT
  ID="7024"
  NAME="ToesREll_ori"
  AXIS_1="Y"
  R1="-0.09"
  AXIS_2="Z"
  R2="0.18"
/>
<JOINT.BRAC
  ID="7030"
  NAME="TibiaUpLCR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="TibiaUpR_bod"
    POS="0.0424 0.0 -0.0963"
    ORIENT="X180_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="TibiaMidR_bod"
    POS="0.0 0.0 0.0"
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  />
</JOINT.BRAC>
<JOINT.BRAC
  ID="7032"
  NAME="TibiaLowLCR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="TibiaMidR_bod"
    POS="0.0 0.0 -0.2375"
    ORIENT="X180_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="TibiaLowR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="X180_ori"
  />
</JOINT.BRAC>
<JOINT.SPHE
  ID="7034"
  NAME="AnkleR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="TibiaLowR_bod"
    POS="0.0175 0.0 -0.076"
    ORIENT="AnkleJnt_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="FootR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="Y-90_X-90_ori"
  />
</JOINT.SPHE>
<JOINT.REVO_TRAN
  ID="7028"
  NAME="KneeR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="KneeR_bod"
    POS="0.1046 0.0 0.0"
    ORIENT="KneeJnt_1_ori"
  />
  <CRDSYS_OBJECT_2.MB
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    BODY="TibiaUpR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="KneeJnt_2_ori"
  />
</JOINT.REVO_TRAN>
<RESTRAINT.SIX_DOF
  ID="7002"
  NAME="AnkleR_six"
  JOINT="AnkleR_jnt"
  >
  <COMP_SIX_DOF
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    LOAD_TYPE="R1"
    CHAR="Ankle1_chr"
    FRIC_LOAD="0.0"
  />
  <COMP_SIX_DOF
    DOF_TYPE="R2"
    LOAD_TYPE="R2"
    CHAR="Ankle2_chr"
    FRIC_LOAD="0.0"
  />
  <COMP_SIX_DOF
    DOF_TYPE="R3"
    LOAD_TYPE="R3"
    CHAR="Ankle3_chr"
    FRIC_LOAD="0.0"
  />
</RESTRAINT.SIX_DOF>
<RESTRAINT.JOINT
  ID="7030"
  NAME="KneeR_joi"
  JOINT="KneeR_jnt"
  Q1_CHAR="Knee1Joi_chr"
  Q2_CHAR="Knee2Joi_chr"
  Q1_FRIC_LOAD="21.3"
  Q2_FRIC_LOAD="500.0"
/>
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          TibiaPart4R_ell TibiaPart5R_ell"
/>
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  SURFACE_LIST="FootR_ell HeelR_ell ToesR_ell"
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<GROUP_MB
  ID="7055"
  NAME="HeelR_gmb"
  SURFACE_LIST="HeelR_ell"
/>
<GROUP_MB
  ID="7056"
  NAME="ToesR_gmb"
  SURFACE_LIST="ToesR_ell"
/>
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  JOINT="TibiaUpLCR_jnt"
  SIGNAL_TYPE="FORCE"
  FILTER="CFC600"
/>
<OUTPUT_JOINT_CONSTRAINT
  ID="7026"
  NAME="TibiaUpR_lce_T"
  JOINT="TibiaUpLCR_jnt"
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  FILTER="CFC600"
/>
<OUTPUT_JOINT_CONSTRAINT
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  NAME="TibiaLowR_lce_F"
  JOINT="TibiaLowLCR_jnt"
  SIGNAL_TYPE="FORCE"
  FILTER="CFC600"
/>
<OUTPUT_JOINT_CONSTRAINT
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  JOINT="TibiaLowLCR_jnt"
  SIGNAL_TYPE="TORQUE"
  FILTER="CFC600"
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  NAME="KneeR_pos"
  JOINT_LIST="KneeR_jnt"
  SIGNAL_TYPE="POS"
/>
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  NAME="TIUpR_inj"
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  OUTPUT_MOMENT="TibiaUpR_lce_T"
  COMPRESSIVE_FORCE="3.590000E+004"
  BENDING_TORQUE="225.0"
/>
<INJURY.TI
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  NAME="TILowR_inj"
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  OUTPUT_MOMENT="TibiaLowR_lce_T"
  COMPRESSIVE_FORCE="3.590000E+004"
  BENDING_TORQUE="225.0"
/>
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  NAME="TCFCUpR_inj"
  OUTPUT_FORCE="TibiaUpR_lce_F"
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  NAME="TCFCLowR_inj"
  OUTPUT_FORCE="TibiaLowR_lce_F"
/>
<INJURY.LOAD_CELL
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  SELECT_OBJECT="PARENT"
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<INJURY.LOAD_CELL
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  OUTPUT_LOAD="TibiaUpR_lce_F"
  SELECT_OBJECT="PARENT"
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<INJURY.LOAD_CELL
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  OUTPUT_LOAD="TibiaUpR_lce_F"
  SELECT_OBJECT="PARENT"
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  SELECT_OBJECT="PARENT"
  COMP="Z"
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<INJURY.LOAD_CELL
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  SELECT_OBJECT="PARENT"
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  OUTPUT_LOAD="TibiaUpR_lce_T"
  SELECT_OBJECT="PARENT"
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<INJURY.LOAD_CELL
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  NAME="TibiaUpR_My_lce"
  OUTPUT_LOAD="TibiaUpR_lce_T"
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  COMP="Y"
/>
<INJURY.LOAD_CELL
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  NAME="TibiaUpR_Mz_lce"
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/>
<INJURY.LOAD_CELL
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  SELECT_OBJECT="PARENT"
  COMP="R"
/>
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<INJURY.LOAD_CELL
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  SELECT_OBJECT="PARENT"
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<INJURY.LOAD_CELL
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  OUTPUT_LOAD="TibiaLowR_lce_T"
  SELECT_OBJECT="PARENT"
  COMP="R"
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  NAME="TibiaLowR_My_lce"
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  NAME="TibiaLowR_Mz_lce"
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  SELECT_OBJECT="PARENT"
  COMP="Z"
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  R1="-0.17"
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  ID="7011"
  NAME="FootEll_ori"
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  R1="0.11"
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<ORIENTATION.SUCCESSIVE_ROT
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  NAME="Tibia5Ell_ori"
  AXIS_1="Y"
  R1="-0.18"
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  NAME="Tibia4Ell_ori"
  AXIS_1="Y"
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/>
<CHARACTERISTIC.CONTACT
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  CONTACT_MODEL="FORCE"
  LOAD_FUNC="FootEll_fun"
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  ELAS_LIMIT="0.0"
/>
<CHARACTERISTIC.CONTACT
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  NAME="HeelEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="HeelEllL_fun"
  UNLOAD_FUNC="HeelEllU_fun"
  HYS_MODEL="2"
  HYS_SLOPE="6.000000E+006"
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  />
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    CONTACT_MODEL="FORCE"
    LOAD_FUNC="FootEll_fun"
    HYS_MODEL="1"
    HYS_SLOPE="2.000000E+006"
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  />
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    NAME="TibiaEll_fun"
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  2.10000000E-002    1.30000000E+003
  2.40000000E-002    4.00000000E+003
  2.70000000E-002    1.00000000E+004
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    </TABLE>
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  <FUNCTION.XY
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    NAME="HeelEllL_fun"
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  6.04579000E-003    8.90000000E+002
  7.49426000E-003    1.51024000E+003
  9.00571000E-003    2.58890000E+003
  1.05801000E-002    4.58500000E+003
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     2.07000000E-002      8.57049000E+003
]]>
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       NAME="KneeJnt_2_ori"
       AXIS_1="Y"
       R1="2.86234"
     />
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1eSi0FXzqIX0WBGfFZSurdkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7P
]]>
</FUNCTION.ENCRYPTED>
<FUNCTION.ENCRYPTED
ID="7005"
NAME="Hyb350elAnkle05_fun"
>
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v4sPgl(45edMY9svp6dx7lrHZdCbkEIhlJPBbmWsLq8DYbefjB)C5dHkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7P
kbl2axvrl7P0WBGfFZSurdkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7P
)t6HzpxuttlMY9svp6dx7lEMUGbZGDEXpJPBbmWsLq8DYbefjB)C5dHkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7P
1eSi0FXzqIX0WBGfFZSurdkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7Pkbl2axvrl7P
]]>
</FUNCTION.ENCRYPTED>
<CHARACTERISTIC.LOAD
ID="7107"
NAME="Knee1Joi_chr"
LOAD_FUNC="Knee1Joi_fun"
DAMP_COEF="0.0"
HYS_MODEL="NONE"
ELAS_LIMIT="0.0"
/>
<CHARACTERISTIC.LOAD
ID="7108"
NAME="Knee2Joi_chr"
LOAD_FUNC="Knee2Joi_fun"
DAMP_COEF="0.0"
HYS_MODEL="NONE"

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    ELAS_LIMIT="0.0"
  />
  <FUNCTION.XY
    ID="7010"
    NAME="Knee1Joi_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|     XI              YI      |
  -1.71600000E+000     -1.28400000E+002
  -1.60500000E+000     -1.20000000E+001
  -1.55300000E+000     -6.00000000E+000
  -5.21000000E-001     0.00000000E+000
  0.00000000E+000      0.00000000E+000
  5.70000000E-001      0.00000000E+000
  6.88000000E-001      5.40000000E+000
  9.00000000E-001      1.86000000E+001
  9.97000000E-001      4.08000000E+001
  1.07700000E+000      9.00000000E+001
  1.16000000E+000      1.98000000E+002
  1.32000000E+000      5.29800000E+002
]]>
    </TABLE>
  </FUNCTION.XY>
  <FUNCTION.XY
    ID="7011"
    NAME="Knee2Joi_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|     XI              YI      |
  -1.00000000E+000     -6.00000000E+006
  0.00000000E+000      0.00000000E+000
  2.10000000E-002      3.00000000E+003
  1.00000000E+000      6.00000000E+006
]]>
    </TABLE>
  </FUNCTION.XY>
  <BODY.RIGID
    ID="7036"
    NAME="ShoeL_bod"
    CENTRE_OF_GRAVITY="0.0518 0.0 0.0"
    MASS="0.643"
    INERTIA="0.002 0.007 0.007 0.0 0.0 0.0"
  />
  <SURFACE.ELLIPSOID
    ID="7045"
    NAME="ShoeSoleL_ell"
    CHAR="ShoeEll_chr"
    SEMI_AXIS="0.09 0.06 0.015"
    DEGREE="2"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="ShoeL_bod"
      POS="0.155 -0.01 0.004"
      ORIENT="ShoeSoleEll_ori"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    ID="7046"
    NAME="ShoeHeelL_ell"
    CHAR="ShoeHeelEll_chr"
    SEMI_AXIS="0.05 0.05 0.025"
    DEGREE="4"
    >
    <CRDSYS_OBJECT_1.MB
```

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      BODY="ShoeL_bod"
      POS="-0.02 0.0 -0.002"
      ORIENT="ShoeHeelEll_ori"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.ELLIPSOID
    ID="7062"
    NAME="ShoeFrontL_ell"
    CHAR="ShoeEll_chr"
    SEMI_AXIS="0.14 0.06 0.043"
    DEGREE="2"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="ShoeL_bod"
      POS="0.11 -0.01 0.03"
    />
  </SURFACE.ELLIPSOID>
  <SURFACE.PLANE
    ID="7070"
    NAME="ShoeSoleL_pla"
    BODY="ShoeL_bod"
    POINT_1="-0.03 -0.03 0.0"
    POINT_2="0.13 -0.03 0.0"
    POINT_3="0.13 0.03 0.0"
  />
  <JOINT.FREE
    ID="7036"
    NAME="ShoeL_jnt"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="FootL_bod"
      POS="0.0 0.0 -0.08"
      ORIENT="Y-90_ori"
    />
    <CRDSYS_OBJECT_2.MB
      BODY="ShoeL_bod"
      POS="0.0 0.0 0.0"
      ORIENT="Y-90_ori"
    />
  </JOINT.FREE>
  <RESTRAINT.POINT
    ID="7016"
    NAME="ShoeFrontL_poi"
    D1_CHAR="Shoe1Poi_chr"
    D2_CHAR="Shoe2Poi_chr"
    D3_CHAR="Shoe3Poi_chr"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="FootL_bod"
      POS="0.08 0.0 -0.06"
    />
    <POINT_OBJECT_2.MB
      BODY="ShoeL_bod"
      POS="0.08 0.0 0.02"
    />
  </RESTRAINT.POINT>
  <RESTRAINT.POINT
    ID="7017"
    NAME="ShoeRearL_poi"
    D1_CHAR="Shoe1Poi_chr"
    D2_CHAR="Shoe2Poi_chr"
    >
    <CRDSYS_OBJECT_1.MB
      BODY="FootL_bod"
      POS="-0.02 0.0 -0.06"
    />
    <POINT_OBJECT_2.MB
      BODY="ShoeL_bod"
      POS="-0.02 0.0 0.02"
    />
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</RESTRAINT.POINT>
<RESTRAINT.CARDAN
  ID="7037"
  NAME="ShoeL_crd"
  R1_CHAR="Shoe1Crd_chr"
  R2_CHAR="Shoe2Crd_chr"
  R3_CHAR="Shoe3Crd_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FootL_bod"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ShoeL_bod"
  />
</RESTRAINT.CARDAN>
<GROUP_MB
  ID="7016"
  NAME="ShoeL_gmb"
  SURFACE_LIST="ShoeSoleL_ell ShoeHeelL_ell ShoeFrontL_ell"
/>
<GROUP_MB
  ID="7051"
  NAME="ShoeSoleL_gmb"
  SURFACE_LIST="ShoeSoleL_pla"
/>
<CONTACT.MB_MB
  ID="8007"
  NAME="ShoeSoleLHeelL_con"
  MASTER_SURFACE="ShoeSoleL_gmb"
  SLAVE_SURFACE="HeelL_gmb"
  BOUNDARY_WIDTH="INF"
  INITIAL_TYPE="CORRECT"
  FRIC_COEF="0.9"
  DAMP_COEF="870.0"
  DAMP_AMP_FUNC="ShoeConD_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="USER_MID_POINT"
    USER_CHAR="ShoeHeelCon_chr"
  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  ID="8008"
  NAME="ShoeSoleLToesL_con"
  MASTER_SURFACE="ShoeSoleL_gmb"
  SLAVE_SURFACE="ToesL_gmb"
  BOUNDARY_WIDTH="INF"
  INITIAL_TYPE="CORRECT"
  FRIC_COEF="0.9"
  DAMP_COEF="400.0"
  DAMP_AMP_FUNC="ShoeConD_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="USER_MID_POINT"
    USER_CHAR="ShoeToesCon_chr"
  />
</CONTACT.MB_MB>
<BODY.RIGID
  ID="7037"
  NAME="ShoeR_bod"
  CENTRE_OF_GRAVITY="0.0518 0.0 0.0"
  MASS="0.643"
  INERTIA="0.002 0.007 0.007 0.0 0.0 0.0"
/>
<SURFACE.ELLIPSOID
  ID="7049"
  NAME="ShoeSoleR_ell"
  CHAR="ShoeEll_chr"
  SEMI_AXIS="0.09 0.06 0.015"
  DEGREE="2"
```

```
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ShoeR_bod"
    POS="0.155 0.01 0.004"
    ORIENT="ShoeSoleEll_ori"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7050"
  NAME="ShoeHeelR_ell"
  CHAR="ShoeHeelEll_chr"
  SEMI_AXIS="0.05 0.05 0.025"
  DEGREE="4"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ShoeR_bod"
    POS="-0.02 0.0 -0.002"
    ORIENT="ShoeHeelEll_ori"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="7063"
  NAME="ShoeFrontR_ell"
  CHAR="ShoeEll_chr"
  SEMI_AXIS="0.14 0.06 0.043"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ShoeR_bod"
    POS="0.11 0.01 0.03"
  />
</SURFACE.ELLIPSOID>
<SURFACE.PLANE
  ID="7071"
  NAME="ShoeSoleR_pla"
  BODY="ShoeR_bod"
  POINT_1="-0.03 -0.03 0.0"
  POINT_2="0.13 -0.03 0.0"
  POINT_3="0.13 0.03 0.0"
/>
<JOINT.FREE
  ID="7037"
  NAME="ShoeR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FootR_bod"
    POS="0.0 0.0 -0.08"
    ORIENT="Y-90_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ShoeR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="Y-90_ori"
  />
</JOINT.FREE>
<RESTRAINT.POINT
  ID="7018"
  NAME="ShoeFrontR_poi"
  D1_CHAR="Shoe1Poi_chr"
  D2_CHAR="Shoe2Poi_chr"
  D3_CHAR="Shoe3Poi_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FootR_bod"
    POS="0.08 0.0 -0.06"
  />
  <POINT_OBJECT_2.MB
    BODY="ShoeR_bod"
    POS="0.08 0.0 0.02"
  />
```

```
</RESTRAINT.POINT>
<RESTRAINT.POINT
  ID="7019"
  NAME="ShoeRearR_poi"
  D1_CHAR="Shoe1Poi_chr"
  D2_CHAR="Shoe2Poi_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FootR_bod"
    POS="-0.02 0.0 -0.06"
  />
  <POINT_OBJECT_2.MB
    BODY="ShoeR_bod"
    POS="-0.02 0.0 0.02"
  />
</RESTRAINT.POINT>
<RESTRAINT.CARDAN
  ID="7038"
  NAME="ShoeR_crd"
  R1_CHAR="Shoe1Crd_chr"
  R2_CHAR="Shoe2Crd_chr"
  R3_CHAR="Shoe3Crd_chr"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="FootR_bod"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ShoeR_bod"
  />
</RESTRAINT.CARDAN>
<GROUP_MB
  ID="7017"
  NAME="ShoeR_gmb"
  SURFACE_LIST="ShoeSoleR_ell ShoeHeelR_ell ShoeFrontR_ell"
/>
<GROUP_MB
  ID="7054"
  NAME="ShoeSoleR_gmb"
  SURFACE_LIST="ShoeSoleR_pla"
/>
<CONTACT.MB_MB
  ID="8009"
  NAME="ShoeSoleRHeelR_con"
  MASTER_SURFACE="ShoeSoleR_gmb"
  SLAVE_SURFACE="HeelR_gmb"
  BOUNDARY_WIDTH="INF"
  INITIAL_TYPE="CORRECT"
  FRIC_COEF="0.9"
  DAMP_COEF="870.0"
  DAMP_AMP_FUNC="ShoeConD_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="USER_MID_POINT"
    USER_CHAR="ShoeHeelCon_chr"
  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  ID="8010"
  NAME="ShoeSoleRToesR_con"
  MASTER_SURFACE="ShoeSoleR_gmb"
  SLAVE_SURFACE="ToesR_gmb"
  BOUNDARY_WIDTH="INF"
  INITIAL_TYPE="CORRECT"
  FRIC_COEF="0.9"
  DAMP_COEF="400.0"
  DAMP_AMP_FUNC="ShoeConD_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="USER_MID_POINT"
    USER_CHAR="ShoeToesCon_chr"
```

```
  />
</CONTACT.MB_MB>
<ORIENTATION.SUCCESSIVE_ROT
  ID="7012"
  NAME="ShoeSoleEll_ori"
  AXIS_1="Y"
  R1="-0.172"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="7013"
  NAME="ShoeHeelEll_ori"
  AXIS_1="Y"
  R1="-0.07"
/>
<CHARACTERISTIC.CONTACT
  ID="7028"
  NAME="ShoeEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="ShoeEll_fun"
  HYS_MODEL="NONE"
  ELAS_LIMIT="0.0"
/>
<CHARACTERISTIC.CONTACT
  ID="7029"
  NAME="ShoeHeelEll_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="ShoeHeelEll_fun"
  HYS_MODEL="NONE"
  ELAS_LIMIT="0.0"
/>
<FUNCTION.XY
  ID="7034"
  NAME="ShoeHeelEll_fun"
  >
  <TABLE
    TYPE="XY_PAIR"
    >
<![CDATA[
|      XI                YI      |
    0.00000000E+000     0.00000000E+000
    3.00000000E-003     1.00000000E+003
    6.00000000E-003     4.00000000E+003
]]>
  </TABLE>
</FUNCTION.XY>
<FUNCTION.XY
  ID="7035"
  NAME="ShoeEll_fun"
  >
  <TABLE
    TYPE="XY_PAIR"
    >
<![CDATA[
|      XI                YI      |
    0.00000000E+000     0.00000000E+000
    3.00000000E-003     1.00000000E+003
    5.00000000E-003     3.00000000E+003
    6.00000000E-003     5.00000000E+003
]]>
  </TABLE>
</FUNCTION.XY>
<CHARACTERISTIC.LOAD
  ID="7084"
  NAME="Shoe1Poi_chr"
  LOAD_FUNC="Shoe1PoiL_fun"
  UNLOAD_FUNC="Shoe1PoiU_fun"
  DAMP_COEF="0.0"
  HYS_MODEL="1"
  HYS_SLOPE="3.000000E+005"
  ELAS_LIMIT="0.0"
```

```
    />
    <CHARACTERISTIC.LOAD
      ID="7085"
      NAME="Shoe2Poi_chr"
      LOAD_FUNC="Shoe2PoiL_fun"
      UNLOAD_FUNC="Shoe2PoiU_fun"
      DAMP_COEF="0.0"
      HYS_MODEL="1"
      HYS_SLOPE="2.000000E+005"
      ELAS_LIMIT="0.0"
    />
    <CHARACTERISTIC.LOAD
      ID="7086"
      NAME="Shoe3Poi_chr"
      LOAD_FUNC="Shoe3PoiL_fun"
      UNLOAD_FUNC="Shoe3PoiU_fun"
      DAMP_COEF="0.0"
      HYS_MODEL="1"
      HYS_SLOPE="2.000000E+005"
      ELAS_LIMIT="0.0"
    />
    <FUNCTION.XY
      ID="7044"
      NAME="Shoe1PoiL_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI               YI      |
    -2.00000000E-002     -1.00000000E+003
    -1.00000000E-002     -2.00000000E+002
    0.00000000E+000      0.00000000E+000
    3.00000000E-003      2.00000000E+002
    1.00000000E-002      2.00000000E+003
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="7045"
      NAME="Shoe1PoiU_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI               YI      |
    -2.00000000E-002     -5.00000000E+001
    0.00000000E+000      0.00000000E+000
    1.00000000E-002      5.00000000E+001
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="7046"
      NAME="Shoe2PoiL_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI               YI      |
    -1.00000000E-002     -5.00000000E+002
    -3.00000000E-003     -1.00000000E+002
    0.00000000E+000      0.00000000E+000
    3.00000000E-003      1.00000000E+002
    1.00000000E-002      5.00000000E+002
]]>
      </TABLE>
    </FUNCTION.XY>
```

```
    <FUNCTION.XY
      ID="7047"
      NAME="Shoe2PoiU_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI              YI      |
    -1.00000000E-002    -5.00000000E+001
    0.00000000E+000      0.00000000E+000
    1.00000000E-002      5.00000000E+001
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="7048"
      NAME="Shoe3PoiL_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI              YI      |
    -1.50000000E-002    -1.00000000E+003
    -5.00000000E-003    -1.00000000E+002
    0.00000000E+000      0.00000000E+000
    2.00000000E-002      1.00000000E+002
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="7049"
      NAME="Shoe3PoiU_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI              YI      |
    -1.50000000E-002    -1.00000000E+002
    0.00000000E+000      0.00000000E+000
    2.00000000E-002      1.00000000E+001
]]>
      </TABLE>
    </FUNCTION.XY>
    <CHARACTERISTIC.LOAD
      ID="7115"
      NAME="Shoe1Crd_chr"
      LOAD_FUNC="Shoe1CrdL_fun"
      UNLOAD_FUNC="Shoe1CrdU_fun"
      DAMP_COEF="2.0"
      HYS_MODEL="2"
      HYS_SLOPE="2.000000E+003"
      ELAS_LIMIT="0.0"
    />
    <CHARACTERISTIC.LOAD
      ID="7116"
      NAME="Shoe2Crd_chr"
      LOAD_FUNC="Shoe2CrdL_fun"
      UNLOAD_FUNC="Shoe1CrdU_fun"
      DAMP_COEF="1.0"
      HYS_MODEL="2"
      HYS_SLOPE="2.000000E+003"
      ELAS_LIMIT="0.0"
    />
    <CHARACTERISTIC.LOAD
      ID="7117"
      NAME="Shoe3Crd_chr"
      LOAD_FUNC="Shoe2CrdL_fun"
```

```
        UNLOAD_FUNC="Shoe1CrdU_fun"
        DAMP_COEF="2.0"
        HYS_MODEL="2"
        HYS_SLOPE="2.000000E+003"
        ELAS_LIMIT="0.0"
      />
      <FUNCTION.XY
        ID="7017"
        NAME="Shoe1CrdL_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI                YI      |
      -1.00000000E+000      -2.00000000E+002
      -2.00000000E-001      -2.50000000E+001
      0.00000000E+000       0.00000000E+000
      2.00000000E-001       2.50000000E+001
      1.00000000E+000       2.00000000E+002
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="7018"
        NAME="Shoe2CrdL_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI                YI      |
      -1.00000000E+000      -3.00000000E+002
      -2.00000000E-001      -2.50000000E+001
      0.00000000E+000       0.00000000E+000
      2.00000000E-001       2.50000000E+001
      1.00000000E+000       3.00000000E+002
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="7020"
        NAME="Shoe1CrdU_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI                YI      |
      -1.00000000E+000      -5.00000000E+001
      -2.00000000E-001      -8.00000000E+000
      0.00000000E+000       0.00000000E+000
      2.00000000E-001       8.00000000E+000
      1.00000000E+000       5.00000000E+001
]]>
        </TABLE>
      </FUNCTION.XY>
      <CHARACTERISTIC.CONTACT
        ID="8125"
        NAME="ShoeHeelCon_chr"
        CONTACT_MODEL="FORCE"
        LOAD_FUNC="ShoeHeelCon_fun"
        HYS_MODEL="NONE"
        HYS_SLOPE="0.0"
        ELAS_LIMIT="0.0"
      />
      <CHARACTERISTIC.CONTACT
        ID="8126"
        NAME="ShoeToesCon_chr"
        CONTACT_MODEL="FORCE"
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    LOAD_FUNC="ShoeToesCon_fun"
    HYS_MODEL="NONE"
    HYS_SLOPE="0.0"
    ELAS_LIMIT="0.0"
  />
  <FUNCTION.XY
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    NAME="ShoeHeelCon_fun"
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    <TABLE
      TYPE="XY_PAIR"
      >
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|      XI                YI      |
  0.00000000E+000    0.00000000E+000
  2.00000000E-003    1.60420000E+002
  3.35000000E-003    6.41670000E+002
  4.80000000E-003    1.60420000E+003
  5.95000000E-003    2.72210000E+003
  7.15000000E-003    4.66630000E+003
  8.40000000E-003    8.26420000E+003
  1.01500000E-002    1.60410000E+004
]]>
    </TABLE>
  </FUNCTION.XY>
  <FUNCTION.XY
    ID="8054"
    NAME="ShoeConD_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|      XI                YI      |
  0.00000000E+000    0.00000000E+000
  1.00000000E+003    1.00000000E+000
  1.00000000E+004    2.00000000E+000
]]>
    </TABLE>
  </FUNCTION.XY>
  <FUNCTION.XY
    ID="8055"
    NAME="ShoeToesCon_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
      >
<![CDATA[
|      XI                YI      |
  0.00000000E+000    0.00000000E+000
  7.10000000E-003    2.49319000E+003
  1.28000000E-002    4.41549000E+003
  2.07000000E-002    8.57049000E+003
]]>
    </TABLE>
  </FUNCTION.XY>
  <CHARACTERISTIC.CONTACT
    ID="6010"
    NAME="PelvisEll_chr"
    CONTACT_MODEL="FORCE"
    LOAD_FUNC="PelvisEll_fun"
    HYS_MODEL="NONE"
    ELAS_LIMIT="0.0"
  />
  <FUNCTION.XY
    ID="6028"
    NAME="PelvisEll_fun"
    >
    <TABLE
      TYPE="XY_PAIR"
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        >
<![CDATA[
|      XI                YI      |
    0.00000000E+000      0.00000000E+000
    6.20000000E-003      3.22600000E+002
    1.31000000E-002      9.03200000E+002
    1.70000000E-002      1.99000000E+003
    2.00000000E-002      3.20000000E+003
    2.30000000E-002      5.11000000E+003
    2.60000000E-002      1.00880000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <BODY.RIGID
      ID="3017"
      NAME="ArmUpL_bod"
      CENTRE_OF_GRAVITY="9.000000E-004 -0.0025 -0.1323"
      MASS="2.06"
      INERTIA="0.0122 0.0125 0.01 0.0 0.0 0.0"
    />
    <BODY.RIGID
      ID="3019"
      NAME="ArmLowL_bod"
      CENTRE_OF_GRAVITY="-0.0013 -0.0017 -0.0885"
      MASS="1.71"
      INERTIA="0.0133 0.0153 0.01 0.0 0.0 0.0"
    />
    <BODY.RIGID
      ID="3021"
      NAME="HandL_bod"
      CENTRE_OF_GRAVITY="0.0035 0.0017 -0.0547"
      MASS="0.6"
      INERTIA="0.01 0.01 0.01 0.0 0.0 0.0"
    />
    <SURFACE.ELLIPSOID
      ID="3029"
      NAME="ArmUpL_ell"
      CHAR="ArmEll_chr"
      SEMI_AXIS="0.048 0.044 0.153"
      DEGREE="2"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="ArmUpL_bod"
        POS="0.0 0.0 -0.113"
      />
    </SURFACE.ELLIPSOID>
    <SURFACE.ELLIPSOID
      ID="3031"
      NAME="ArmLowL_ell"
      CHAR="ArmEll_chr"
      SEMI_AXIS="0.044 0.044 0.146"
      DEGREE="2"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="ArmLowL_bod"
        POS="0.0 0.0 -0.1"
      />
    </SURFACE.ELLIPSOID>
    <SURFACE.ELLIPSOID
      ID="3033"
      NAME="HandL_ell"
      CHAR="ArmEll_chr"
      SEMI_AXIS="0.048 0.025 0.084"
      DEGREE="2"
      >
      <CRDSYS_OBJECT_1.MB
        BODY="HandL_bod"
        POS="0.0 0.0 -0.069"
      />
    </SURFACE.ELLIPSOID>
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<JOINT.UNIV
  ID="3017"
  NAME="ShoulderL_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ClavicleL_bod"
    POS="-0.0257 0.1724 -3.000000E-004"
    ORIENT="ShoulderJnt_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ArmUpL_bod"
    POS="0.0 0.0 0.0"
    ORIENT="Z+90_X180_ori"
  />
</JOINT.UNIV>
<JOINT.UNIV
  ID="3019"
  NAME="ElbowL_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ArmUpL_bod"
    POS="0.0 0.0 -0.2646"
    ORIENT="Y-90_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ArmLowL_bod"
    POS="0.0 0.0 0.0"
    ORIENT="Y-90_ori"
  />
</JOINT.UNIV>
<JOINT.UNIV
  ID="3021"
  NAME="WristL_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ArmLowL_bod"
    POS="0.0 0.0 -0.2512"
    ORIENT="Y-90_X-90_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="HandL_bod"
    POS="0.0 0.0 0.0"
    ORIENT="Y-90_X-90_ori"
  />
</JOINT.UNIV>
<RESTRAINT.JOINT
  ID="3023"
  NAME="ShoulderL_joi"
  JOINT="ShoulderL_jnt"
  Q1_CHAR="Shoulder1Joi_chr"
  Q2_CHAR="Shoulder2Joi_chr"
  Q1_FRIC_LOAD="20.1"
  Q2_FRIC_LOAD="20.1"
/>
<RESTRAINT.JOINT
  ID="3025"
  NAME="ElbowL_joi"
  JOINT="ElbowL_jnt"
  Q2_CHAR="ElbowJoi_chr"
  Q1_FRIC_LOAD="0.1"
  Q2_FRIC_LOAD="4.0"
/>
<RESTRAINT.JOINT
  ID="3027"
  NAME="WristL_joi"
  JOINT="WristL_jnt"
  Q2_CHAR="WristJoi_chr"
  Q1_FRIC_LOAD="0.1"
  Q2_FRIC_LOAD="0.4"
/>
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<BODY.RIGID
  ID="3018"
  NAME="ArmUpR_bod"
  CENTRE_OF_GRAVITY="9.000000E-004 0.0025 -0.1323"
  MASS="2.06"
  INERTIA="0.0122 0.0125 0.01 0.0 0.0 0.0"
/>
<BODY.RIGID
  ID="3020"
  NAME="ArmLowR_bod"
  CENTRE_OF_GRAVITY="-0.0013 0.0017 -0.0885"
  MASS="1.71"
  INERTIA="0.0133 0.0153 0.01 0.0 0.0 0.0"
/>
<BODY.RIGID
  ID="3022"
  NAME="HandR_bod"
  CENTRE_OF_GRAVITY="0.0035 -0.0017 -0.0547"
  MASS="0.6"
  INERTIA="0.01 0.01 0.01 0.0 0.0 0.0"
/>
<SURFACE.ELLIPSOID
  ID="3030"
  NAME="ArmUpR_ell"
  CHAR="ArmEll_chr"
  SEMI_AXIS="0.048 0.044 0.153"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ArmUpR_bod"
    POS="0.0 0.0 -0.113"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="3032"
  NAME="ArmLowR_ell"
  CHAR="ArmEll_chr"
  SEMI_AXIS="0.044 0.044 0.146"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ArmLowR_bod"
    POS="0.0 0.0 -0.1"
  />
</SURFACE.ELLIPSOID>
<SURFACE.ELLIPSOID
  ID="3034"
  NAME="HandR_ell"
  CHAR="ArmEll_chr"
  SEMI_AXIS="0.048 0.025 0.084"
  DEGREE="2"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="HandR_bod"
    POS="0.0 0.0 -0.069"
  />
</SURFACE.ELLIPSOID>
<JOINT.UNIV
  ID="3018"
  NAME="ShoulderR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ClavicleR_bod"
    POS="-0.0257 -0.1724 -3.000000E-004"
    ORIENT="ShoulderJnt_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ArmUpR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="Z+90_X180_ori"
```

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  />
</JOINT.UNIV>
<JOINT.UNIV
  ID="3020"
  NAME="ElbowR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ArmUpR_bod"
    POS="0.0 0.0 -0.2646"
    ORIENT="Y-90_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="ArmLowR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="Y-90_ori"
  />
</JOINT.UNIV>
<JOINT.UNIV
  ID="3022"
  NAME="WristR_jnt"
  >
  <CRDSYS_OBJECT_1.MB
    BODY="ArmLowR_bod"
    POS="0.0 0.0 -0.2512"
    ORIENT="Y-90_X-90_ori"
  />
  <CRDSYS_OBJECT_2.MB
    BODY="HandR_bod"
    POS="0.0 0.0 0.0"
    ORIENT="Y-90_X-90_ori"
  />
</JOINT.UNIV>
<RESTRAINT.JOINT
  ID="3024"
  NAME="ShoulderR_joi"
  JOINT="ShoulderR_jnt"
  Q1_CHAR="Shoulder1Joi_chr"
  Q2_CHAR="Shoulder3Joi_chr"
  Q1_FRIC_LOAD="20.1"
  Q2_FRIC_LOAD="20.1"
/>
<RESTRAINT.JOINT
  ID="3026"
  NAME="ElbowR_joi"
  JOINT="ElbowR_jnt"
  Q2_CHAR="ElbowJoi_chr"
  Q1_FRIC_LOAD="0.1"
  Q2_FRIC_LOAD="4.0"
/>
<RESTRAINT.JOINT
  ID="3028"
  NAME="WristR_joi"
  JOINT="WristR_jnt"
  Q2_CHAR="WristJoi_chr"
  Q1_FRIC_LOAD="0.1"
  Q2_FRIC_LOAD="0.4"
/>
<ORIENTATION.SUCCESSIVE_ROT
  ID="3049"
  NAME="ShoulderJnt_ori"
  AXIS_1="Y"
  R1="2.93215"
  AXIS_2="Z"
  R2="1.5708"
/>
<CHARACTERISTIC.LOAD
  ID="3099"
  NAME="Shoulder1Joi_chr"
  LOAD_FUNC="Shoulder1Joi_fun"
  DAMP_COEF="0.0"
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      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
    />
    <CHARACTERISTIC.LOAD
      ID="3100"
      NAME="Shoulder2Joi_chr"
      LOAD_FUNC="Shoulder2Joi_fun"
      DAMP_COEF="0.0"
      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
    />
    <CHARACTERISTIC.LOAD
      ID="3102"
      NAME="Shoulder3Joi_chr"
      LOAD_FUNC="Shoulder3Joi_fun"
      DAMP_COEF="0.0"
      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
    />
    <CHARACTERISTIC.LOAD
      ID="3103"
      NAME="ElbowJoi_chr"
      LOAD_FUNC="ElbowJoi_fun"
      DAMP_COEF="1.0"
      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
    />
    <CHARACTERISTIC.LOAD
      ID="3105"
      NAME="WristJoi_chr"
      LOAD_FUNC="WristJoi_fun"
      DAMP_COEF="0.0"
      HYS_MODEL="NONE"
      ELAS_LIMIT="0.0"
    />
    <FUNCTION.XY
      ID="3004"
      NAME="Shoulder1Joi_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI              YI       |
    -4.29400000E+000     -5.55000000E+002
    -4.21800000E+000     -7.08000000E+001
    -4.10700000E+000     -3.48000000E+001
    -3.99500000E+000     -1.50000000E+001
    -3.86300000E+000     -6.60000000E+000
    -3.47400000E+000     0.00000000E+000
    4.88000000E-001      0.00000000E+000
    6.12000000E-001      5.40000000E+001
    7.61000000E-001      3.25200000E+002
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="3005"
      NAME="Shoulder2Joi_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI              YI       |
    -3.72000000E-001     -6.28800000E+002
    -1.86000000E-001     -3.14400000E+002
    0.00000000E+000      0.00000000E+000
    2.67200000E+000      0.00000000E+000
    3.04000000E+000      1.92000000E+001
```

```
    3.18600000E+000       5.82000000E+001
    3.26900000E+000       1.05000000E+002
    3.34200000E+000       1.90800000E+002
    3.51600000E+000       5.38800000E+002
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="3006"
      NAME="Shoulder3Joi_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                YI      |
    -3.51600000E+000      -5.38800000E+002
    -3.34200000E+000      -1.90800000E+002
    -3.26900000E+000      -1.05000000E+002
    -3.18600000E+000      -5.82000000E+001
    -3.04000000E+000      -1.92000000E+001
    -2.67200000E+000      0.00000000E+000
    0.00000000E+000       0.00000000E+000
    1.86000000E-001       3.14400000E+002
    3.72000000E-001       6.28800000E+002
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="3007"
      NAME="ElbowJoi_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                YI      |
    -3.03200000E+000      -5.29700000E+002
    -2.03200000E+000      -2.97000000E+001
    -1.98000000E+000      -1.81000000E+001
    -1.83400000E+000      -6.40000000E+000
    -1.65000000E+000      0.00000000E+000
    0.00000000E+000       0.00000000E+000
    1.39000000E-001       1.97000000E+001
    2.60000000E-001       6.23000000E+001
    3.13000000E-001       1.53600000E+002
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      ID="3008"
      NAME="WristJoi_fun"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|      XI                YI      |
    -2.37900000E+000      -5.00000000E+002
    -1.37900000E+000      0.00000000E+000
    0.00000000E+000       0.00000000E+000
    1.37900000E+000       0.00000000E+000
    2.37900000E+000       5.00000000E+002
]]>
      </TABLE>
    </FUNCTION.XY>
    <GROUP_MB
      ID="8001"
      NAME="Dummy_gmb"
      SURFACE_LIST="Head_ell Face_ell NeckNoddingPlate_ell NeckPart1_ell
```

```
            NeckPart2_ell NeckPart3_ell NeckPart4_ell NeckPart5_ell
            ArmUpL_ell ArmUpR_ell ArmLowL_ell HandL_ell ArmLowR_ell
            HandR_ell Collar_ell ChestUpL_ell ChestUpR_ell
            ShoulderL_ell ShoulderR_ell RibPart1L_ell RibPart2L_ell
            RibPart3L_ell RibPart4L_ell RibPart5L_ell RibPart6L_ell
            RibPart1R_ell RibPart2R_ell RibPart3R_ell RibPart4R_ell
            RibPart5R_ell RibPart6R_ell Sternum_ell
            ThoracicBackPlate_ell LumbarSpineLow_ell
            LumbarSpineUp_ell AbdomenLow_ell AbdomenMid_ell
            AbdomenUp_ell Pelvis_ell HipL_ell HipR_ell FemurL_ell
            KneeL_ell FemurR_ell KneeR_ell TibiaPart1L_ell
            TibiaPart2L_ell TibiaPart3L_ell TibiaPart4L_ell
            TibiaPart5L_ell TibiaPart1R_ell TibiaPart2R_ell
            TibiaPart3R_ell TibiaPart4R_ell TibiaPart5R_ell
            ShoeSoleL_ell ShoeHeelL_ell ShoeFrontL_ell ShoeSoleR_ell
            ShoeHeelR_ell ShoeFrontR_ell"
/>
<GROUP_MB
  ID="4009"
  NAME="Thorax_gmb"
  SURFACE_LIST="ChestUpL_ell ChestUpR_ell RibPart1L_ell RibPart2L_ell
            RibPart3L_ell RibPart4L_ell RibPart5L_ell RibPart6L_ell
            RibPart1R_ell RibPart2R_ell RibPart3R_ell RibPart4R_ell
            RibPart5R_ell RibPart6R_ell Sternum_ell
            ThoracicBackPlate_ell LumbarSpineLow_ell
            LumbarSpineUp_ell hunchback_ell"
/>
<GROUP_MB
  ID="3004"
  NAME="ArmUpL_gmb"
  SURFACE_LIST="ArmUpL_ell"
/>
<GROUP_MB
  ID="3005"
  NAME="ArmUpR_gmb"
  SURFACE_LIST="ArmUpR_ell"
/>
<GROUP_MB
  ID="3006"
  NAME="ArmLowL_gmb"
  SURFACE_LIST="ArmLowL_ell HandL_ell"
/>
<GROUP_MB
  ID="3007"
  NAME="ArmLowR_gmb"
  SURFACE_LIST="ArmLowR_ell HandR_ell"
/>
<GROUP_MB
  ID="6010"
  NAME="Abdomen_gmb"
  SURFACE_LIST="AbdomenLow_ell AbdomenMid_ell AbdomenUp_ell"
/>
<GROUP_MB
  ID="6011"
  NAME="Pelvis_gmb"
  SURFACE_LIST="Pelvis_ell HipL_ell HipR_ell PelvisButtockL_ell
            PelvisButtockR_ell"
/>
<CONTACT.MB_MB
  ID="8001"
  NAME="HeadThorax_con"
  MASTER_SURFACE="Head_gmb"
  SLAVE_SURFACE="Ribcage_gmb"
  FRIC_COEF="0.5"
  DAMP_COEF="200.0"
  DAMP_VEL_FUNC="HeadEllD_fun"
  DAMP_AMP_FUNC="HeadEllA_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="COMBINED"
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  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  ID="8002"
  NAME="ThoraxPelvis_con"
  MASTER_SURFACE="Ribcage_gmb"
  SLAVE_SURFACE="Pelvis_gmb"
  FRIC_COEF="0.5"
  DAMP_COEF="25.0"
  DAMP_AMP_FUNC="ThoraxConD_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="USER_MID_POINT"
    USER_CHAR="ThoraxCon_chr"
  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  ID="8003"
  NAME="ThoraxFemurL_con"
  MASTER_SURFACE="Ribcage_gmb"
  SLAVE_SURFACE="FemurKneeL_gmb"
  FRIC_COEF="0.5"
  DAMP_COEF="25.0"
  DAMP_AMP_FUNC="ThoraxConD_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="USER_MID_POINT"
    USER_CHAR="ThoraxCon_chr"
  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  ID="8004"
  NAME="ThoraxFemurR_con"
  MASTER_SURFACE="Ribcage_gmb"
  SLAVE_SURFACE="FemurKneeR_gmb"
  FRIC_COEF="0.5"
  DAMP_COEF="25.0"
  DAMP_AMP_FUNC="ThoraxConD_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="USER_MID_POINT"
    USER_CHAR="ThoraxCon_chr"
  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  ID="8006"
  NAME="KneeLKneeR_con"
  MASTER_SURFACE="FemurKneeL_gmb"
  SLAVE_SURFACE="FemurKneeR_gmb"
  FRIC_COEF="0.5"
  DAMP_COEF="25.0"
  DAMP_AMP_FUNC="ThoraxConD_fun"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="USER_MID_POINT"
    USER_CHAR="ThoraxCon_chr"
  />
</CONTACT.MB_MB>
<CHARACTERISTIC.CONTACT
  ID="8121"
  NAME="ThoraxCon_chr"
  CONTACT_MODEL="FORCE"
  LOAD_FUNC="ThoraxConL_fun"
  HYS_MODEL="NONE"
  HYS_SLOPE="0.0"
  ELAS_LIMIT="0.0"
/>
<FUNCTION.XY
  ID="8051"
  NAME="ThoraxConL_fun"
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```
        >
        <TABLE
          TYPE="XY_PAIR"
          >
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|      XI                YI      |
     0.00000000E+000      0.00000000E+000
     2.00000000E-002      2.00000000E+002
     4.00000000E-002      5.00000000E+002
     1.00000000E-001      1.40000000E+003
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        ID="8052"
        NAME="ThoraxConD_fun"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|      XI                YI      |
     0.00000000E+000      0.00000000E+000
     1.00000000E+004      1.00000000E+004
]]>
        </TABLE>
      </FUNCTION.XY>
      <CRDSYS_OBJECT.MB
        ID="1"
        NAME="Dummy_Attachment"
        ORIENT="Dummy_Attachment_ori"
        POS="5.22 0.94 0.43"
      />
      <ORIENTATION.SUCCESSIVE_ROT
        AXIS_1="X"
        AXIS_2="Y"
        AXIS_3="Z"
        ID="25"
        NAME="Dummy_Attachment_ori"
        R1="0.0"
        R2="0.0"
        R3="3.1416"
      />
      <RESTRAINT.JOINT
        DYNAMIC_FRIC_COEF="0.0044"
        DYNAMIC_FRIC_LOAD="12.8"
        ID="32"
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        NAME="HipL_joi"
        STATIC_FRIC_COEF="0.0044"
        STATIC_FRIC_LOAD="12.8"
      />
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        DYNAMIC_FRIC_LOAD="12.8"
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        NAME="HipR_joi"
        STATIC_FRIC_COEF="0.0044"
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      />
      <RESTRAINT.JOINT
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        DYNAMIC_FRIC_LOAD="2.0"
        ID="34"
        JOINT="AnkleL_jnt"
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        STATIC_FRIC_COEF="0.0048"
        STATIC_FRIC_LOAD="4.0"
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  DYNAMIC_FRIC_LOAD="2.0"
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  NAME="AnkleR_joi"
  STATIC_FRIC_COEF="0.0048"
  STATIC_FRIC_LOAD="4.0"
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  ORIENT="Dummy_ori"
  Q5="4.075"
  Q7="0.10"
/>
<INITIAL.JOINT_POS
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/>
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  JOINT="NeckPivot2_jnt"
  ORIENT="NeckPivot2_ori"
/>
<INITIAL.JOINT_POS
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  ORIENT="NeckPivot3_ori"
/>
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  JOINT="NeckPivot4_jnt"
  ORIENT="NeckPivot4_ori"
/>
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  JOINT="ShoulderL_jnt"
  Q2="0.15708"
  Q1="-.25"
/>
<INITIAL.JOINT_POS
  JOINT="ShoulderR_jnt"
  Q2="-0.15708"
  Q1="-.25"
/>
<INITIAL.JOINT_POS
  JOINT="ElbowL_jnt"
  Q2="-1.3963"
/>
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  JOINT="ElbowR_jnt"
  Q2="-1.3963"
/>
<INITIAL.JOINT_POS
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/>
<INITIAL.JOINT_POS
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/>
<INITIAL.JOINT_POS
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  ORIENT="LumbarSpine_ori"
/>
<INITIAL.JOINT_POS
  JOINT="HipL_jnt"
  ORIENT="HipL_ori"
/>
<INITIAL.JOINT_POS
  JOINT="HipR_jnt"
  ORIENT="HipR_ori"
/>
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  Q1="-0.34907"
/>
<INITIAL.JOINT_POS
  JOINT="KneeR_jnt"
  Q1="-0.34907"
/>
<INITIAL.JOINT_POS
  JOINT="AnkleL_jnt"
  ORIENT="AnkleL_ori"
/>
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  JOINT="AnkleR_jnt"
  ORIENT="AnkleR_ori"
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  R1="-0.25"
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  ID="92"
  NAME="LumbarSpine_ori"
  R1="0.1"
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  AXIS_1="X"
  ID="94"
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  R1="0.0"
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  AXIS_1="X"
  ID="95"
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  R1="0.0"
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  ID="96"
  NAME="NeckPivot3_ori"
  R1="0.0"
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  AXIS_1="X"
  ID="97"
  NAME="NeckPivot4_ori"
  R1="0.0"
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  AXIS_1="Y"
  ID="98"
  NAME="HipL_ori"
  R1="0.17453"
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  ID="99"
  NAME="HipR_ori"
  R1="0.17453"
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  ID="100"
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  R1="-0.06"
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  V1="-4.208333"
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/>
<INITIAL.JOINT_VEL
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/>
<INITIAL.JOINT_VEL
  JOINT="NeckPivot2_jnt"
/>
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  JOINT="NeckPivot3_jnt"
/>
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  JOINT="NeckPivot4_jnt"
/>
<INITIAL.JOINT_VEL
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/>
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/>
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/>
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  JOINT="NeckOC_jnt"
/>
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/>
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JOINT="WristR_jnt"
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JOINT="Ribs_jnt"
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JOINT="Sternum_jnt"
/>
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JOINT="AbdomenInsert_jnt"
/>
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JOINT="LumbarSpine_jnt"
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JOINT="HipL_jnt"
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JOINT="HipR_jnt"
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    />
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      POS="0.033 -0.073 0.041"
    />
    <POINT_OBJECT.MB
      BODY="ClavicleL_bod"
      ID="3"
      NAME="ClavicleLHS_pnt"
      POS="0.033 0.073 0.041"
    />
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      BODY="Ribs_bod"
      ID="4"
      NAME="RibsUpRHS_pnt"
      POS="0.03 0.01 0.07"
    />
    <POINT_OBJECT.MB
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      ID="5"
      NAME="RibsUpLHS_pnt"
      POS="0.03 -0.01 0.07"
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    <POINT_OBJECT.MB
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      ID="6"
      NAME="RibsLowRHS_pnt"
      POS="0.03 0.095 -0.07"
    />
    <POINT_OBJECT.MB
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      ID="7"
      NAME="RibsLowLHS_pnt"
      POS="0.03 -0.095 -0.07"
    />
    <POINT_OBJECT.MB
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      ID="10"
      NAME="AbdomenInsertR_pnt"
      POS="-0.0362 -0.163 -0.0546"
    />
    <POINT_OBJECT.MB
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      ID="11"
      NAME="AbdomenInsertL_pnt"
      POS="-0.0362 0.163 -0.0546"
    />
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  <SYSTEM.MODEL
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    NAME="Lap_Belt_sys"
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      POINT_REF_1="PointObj_2"
      >
      <COMMENT>
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    **BLTSGNSHP     72
    **BLTSGSLST1     /Hybrid_III_50th/Head_ell /Hybrid_III_50th/Face_ell /Hybrid_III_50th/NeckPart1_ell
/Hybrid_III_50th/NeckNoddingPlate_ell /Hybrid_III_50th/NeckPart2_ell /Hybrid_III_50th/NeckPart3_ell
/Hybrid_III_50th/NeckPart4_ell /Hybrid_III_50th/NeckPart5_ell /Hybrid_III_50th/ShoulderL_ell
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**BLTSGSLST2 /Hybrid_III_50th/ShoulderR_ell /Hybrid_III_50th/ThoracicBackPlate_ell /Hybrid_III_50th/Collar_ell /Hybrid_III_50th/ChestUpL_ell /Hybrid_III_50th/ChestUpR_ell /Hybrid_III_50th/RibPart1L_ell /Hybrid_III_50th/RibPart2L_ell /Hybrid_III_50th/RibPart3L_ell /Hybrid_III_50th/RibPart4L_ell
**BLTSGSLST3 /Hybrid_III_50th/RibPart5L_ell /Hybrid_III_50th/RibPart6L_ell /Hybrid_III_50th/RibPart1R_ell /Hybrid_III_50th/RibPart2R_ell /Hybrid_III_50th/RibPart3R_ell /Hybrid_III_50th/RibPart4R_ell /Hybrid_III_50th/RibPart5R_ell /Hybrid_III_50th/RibPart6R_ell /Hybrid_III_50th/Sternum_ell
**BLTSGSLST4 /Hybrid_III_50th/LumbarSpineLow_ell /Hybrid_III_50th/LumbarSpineUp_ell /Hybrid_III_50th/Pelvis_ell /Hybrid_III_50th/AbdomenLow_ell /Hybrid_III_50th/AbdomenMid_ell /Hybrid_III_50th/AbdomenUp_ell /Hybrid_III_50th/PelvisButtockL_ell /Hybrid_III_50th/PelvisButtockR_ell
**BLTSGSLST5 /Hybrid_III_50th/HipL_ell /Hybrid_III_50th/FemurL_ell /Hybrid_III_50th/KneeL_ell /Hybrid_III_50th/HipR_ell /Hybrid_III_50th/FemurR_ell /Hybrid_III_50th/KneeR_ell /Hybrid_III_50th/TibiaPart3L_ell /Hybrid_III_50th/FootL_ell /Hybrid_III_50th/HeelL_ell /Hybrid_III_50th/TibiaPart5L_ell
**BLTSGSLST6 /Hybrid_III_50th/TibiaPart4L_ell /Hybrid_III_50th/TibiaPart2L_ell /Hybrid_III_50th/TibiaPart1L_ell /Hybrid_III_50th/ToesL_ell /Hybrid_III_50th/TibiaPart3R_ell /Hybrid_III_50th/FootR_ell /Hybrid_III_50th/HeelR_ell /Hybrid_III_50th/TibiaPart5R_ell /Hybrid_III_50th/TibiaPart4R_ell
**BLTSGSLST7 /Hybrid_III_50th/TibiaPart2R_ell /Hybrid_III_50th/TibiaPart1R_ell /Hybrid_III_50th/ToesR_ell /Hybrid_III_50th/ShoeSoleL_ell /Hybrid_III_50th/ShoeHeelL_ell /Hybrid_III_50th/ShoeFrontL_ell /Hybrid_III_50th/ShoeSoleL_pla /Hybrid_III_50th/ShoeSoleR_ell /Hybrid_III_50th/ShoeHeelR_ell
**BLTSGSLST8 /Hybrid_III_50th/ShoeFrontR_ell /Hybrid_III_50th/ShoeSoleR_pla /wheelchair_system/wcseat_surface /wheelchair_system/l_hor2 /wheelchair_system/l_ver4 /wheelchair_system/r_hor2 /wheelchair_system/r_ver2 /wheelchair_system/r_ver4 /wheelchair_system/l_ver2
**BPFN /Lap_Belt_sys/FeModel_3 160
**BPSB /sled_track 1.303252756 1.1690419757 0.42877280566
**BPSB /sled_track 1.3023933169 1.1689809807 0.42946842822
**BPSB /sled_track 1.2766353543 1.1665996698 0.45031669879
**BPSB /sled_track 1.2758276468 1.1664839384 0.4509704502
**BPSB /sled_track 1.275660943 1.1664413737 0.4511053788
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**BPSB /sled_track 1.133466836 1.1195230144 0.56619605069
**BPSB /sled_track 1.1330620887 1.1193405742 0.5665236496
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    **BPSB    /sled_track    1.073582306    0.79877543539    0.61466606773
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    **BPSB    /sled_track    1.087848618    0.7879829706    0.60311903901
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    **BPSB    /sled_track    1.2758276468    0.7135189791    0.4509704502
    **BPSB    /sled_track    1.2766353543    0.71340325947    0.45031669879
    **BPSB    /sled_track    1.3023966813    0.71102245686    0.42946570506
    **BPSB    /sled_track    1.3032561214    0.71096147447    0.42877008178
    **BPSB    /sled_track    1.3045527997    0.71092516423    0.42772056161
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    **REF_POINT    0.979484 0.938147 0.690828
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        CHAR="/Lap_Belt_sys/belt_loading"
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    <BELT
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      NAME="Seat_Belt-&gt;2"
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        NAME="SeatBelt6_Seg1"
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        POINT_REF_2="/Lap_Belt_sys/PointObj_59"
        CHAR="/Lap_Belt_sys/belt_loading"
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      HYS_SLOPE="3.000000E+005"
      ELAS_LIMIT="0.0"
    />
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      NAME="belt_load"
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2.10E-02  3.00E+02
3.00E-02  8.85E+02
4.00E-02  1.20E+03
5.00E-02  1.41E+03
6.00E-02  1.60E+03
7.00E-02  1.80E+03
8.00E-02  1.98E+03
```

```
9.00E-02   2.18E+03
1.00E-01   2.40E+03
1.10E-01   2.60E+03
1.20E-01   2.85E+03
1.26E-01   3.00E+03
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      </FUNCTION.XY>
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        NAME="belt_unload"
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             2     1.3479623E+000     1.1712264E+000     4.1831216E-001
             3     1.3357026E+000     1.1709280E+000     4.0246983E-001
             4     1.3514026E+000     1.1718492E+000     3.8978075E-001
             5     1.3320036E+000     1.1724505E+000     4.3114965E-001
             6     1.3200041E+000     1.1700128E+000     4.1516104E-001
             7     1.3160777E+000     1.1716673E+000     4.4413293E-001
             8     1.3041610E+000     1.1710999E+000     4.2789239E-001
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            10     1.2884195E+000     1.1697103E+000     4.4064635E-001
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      NAME="BeltContact_chr"
      CONTACT_MODEL="FORCE"
      LOAD_FUNC="BeltContact_fun"
    />
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      NAME="BeltContact_fun"
      >
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        TYPE="XY_PAIR"
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    1.00000000E-003     1.00000000E+003
]]>
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    </FUNCTION.XY>
    <OUTPUT_BELT
      ID="1"
      INPUT_CLASS="BELT_SEGMENT"
      INPUT_REF="/Lap_Belt_sys/Seat_Belt-&gt;1/SeatBelt5_Seg5"
      FILTER="CFC60"
    />
  </SYSTEM.MODEL>
  <SYSTEM.MODEL
    ID="6"
    NAME="Shoulder_Belt_sys"
    >
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      NAME="Seat_Belt-&gt;1"
      POINT_REF_1="PointObj_2"
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      >
      <COMMENT>
<![CDATA[
**WARN Followings lines in COMMENT are not to be deleted
    **BELTPOINTS    3    10    32    /Shoulder_Belt_sys/FeModel_9 1 0.040000 0.020000 1  2  0
    **BLTSGNSHP    68
    **BLTSGSLST1    /Hybrid_III_50th/Head_ell /Hybrid_III_50th/Face_ell /Hybrid_III_50th/NeckPart1_ell
/Hybrid_III_50th/NeckNoddingPlate_ell /Hybrid_III_50th/NeckPart2_ell /Hybrid_III_50th/NeckPart3_ell
/Hybrid_III_50th/NeckPart4_ell /Hybrid_III_50th/NeckPart5_ell /Hybrid_III_50th/ShoulderL_ell
    **BLTSGSLST2    /Hybrid_III_50th/ShoulderR_ell /Hybrid_III_50th/ThoracicBackPlate_ell /Hybrid_III_50th/Collar_ell
/Hybrid_III_50th/ChestUpL_ell /Hybrid_III_50th/ChestUpR_ell /Hybrid_III_50th/RibPart1L_ell /Hybrid_III_50th/RibPart2L_ell
/Hybrid_III_50th/RibPart3L_ell /Hybrid_III_50th/RibPart4L_ell
    **BLTSGSLST3    /Hybrid_III_50th/RibPart5L_ell /Hybrid_III_50th/RibPart6L_ell /Hybrid_III_50th/RibPart1R_ell
/Hybrid_III_50th/RibPart2R_ell /Hybrid_III_50th/RibPart3R_ell /Hybrid_III_50th/RibPart4R_ell /Hybrid_III_50th/RibPart5R_ell
/Hybrid_III_50th/RibPart6R_ell /Hybrid_III_50th/Sternum_ell
    **BLTSGSLST4    /Hybrid_III_50th/LumbarSpineLow_ell /Hybrid_III_50th/LumbarSpineUp_ell /Hybrid_III_50th/Pelvis_ell
/Hybrid_III_50th/AbdomenLow_ell /Hybrid_III_50th/AbdomenMid_ell /Hybrid_III_50th/AbdomenUp_ell
/Hybrid_III_50th/PelvisButtockL_ell /Hybrid_III_50th/PelvisButtockR_ell
    **BLTSGSLST5    /Hybrid_III_50th/HipL_ell /Hybrid_III_50th/FemurL_ell /Hybrid_III_50th/KneeL_ell
/Hybrid_III_50th/HipR_ell /Hybrid_III_50th/FemurR_ell /Hybrid_III_50th/KneeR_ell /Hybrid_III_50th/TibiaPart3L_ell
/Hybrid_III_50th/FootL_ell /Hybrid_III_50th/HeelL_ell /Hybrid_III_50th/TibiaPart5L_ell
    **BLTSGSLST6    /Hybrid_III_50th/TibiaPart4L_ell /Hybrid_III_50th/TibiaPart2L_ell /Hybrid_III_50th/TibiaPart1L_ell
/Hybrid_III_50th/ToesL_ell /Hybrid_III_50th/TibiaPart3R_ell /Hybrid_III_50th/FootR_ell /Hybrid_III_50th/HeelR_ell
/Hybrid_III_50th/TibiaPart5R_ell /Hybrid_III_50th/TibiaPart4R_ell
    **BLTSGSLST7    /Hybrid_III_50th/TibiaPart2R_ell /Hybrid_III_50th/TibiaPart1R_ell /Hybrid_III_50th/ToesR_ell
/Hybrid_III_50th/ShoeSoleL_ell /Hybrid_III_50th/ShoeHeelL_ell /Hybrid_III_50th/ShoeFrontL_ell /Hybrid_III_50th/ShoeSoleL_pla
/Hybrid_III_50th/ShoeSoleR_ell /Hybrid_III_50th/ShoeHeelR_ell
    **BLTSGSLST8    /Hybrid_III_50th/ShoeFrontR_ell /Hybrid_III_50th/ShoeSoleR_pla /wheelchair_system/wcseat_surface
/wheelchair_system/l_hor2 /wheelchair_system/l_ver4
    **BPFN    /Shoulder_Belt_sys/FeModel_9    151
    **BPSB    /sled_track    1.1624189474    0.99436159577    1.0584449483
    **BPSB    /sled_track    1.1587554974    0.99194373998    1.056536872
    **BPSB    /sled_track    1.1568407538    0.99055993627    1.0553086418
    **BPSB    /sled_track    1.1552015841    0.98932518105    1.0541608039
    **BPSB    /sled_track    1.1517705747    0.98645639067    1.0512114832
    **BPSB    /sled_track    1.1118979077    0.9514213541    1.0136746769
    **BPSB    /sled_track    1.089456284    0.92984263272    0.98897073817
    **BPSB    /sled_track    1.0877444989    0.92818916051    0.9870719522
    **BPSB    /sled_track    1.0835615935    0.92382341656    0.98180639666
    **BPSB    /sled_track    1.0815065984    0.92140750583    0.97869813699
    **BPSB    /sled_track    1.0790168939    0.91820235181    0.97439733812
    **BPSB    /sled_track    1.0759781591    0.91359040099    0.9678018548
    **BPSB    /sled_track    1.0755779303    0.91290887349    0.96679067218
    **BPSB    /sled_track    1.0733456984    0.90801368245    0.95904677971
    **BPSB    /sled_track    1.0675276273    0.88995284417    0.92866595057
    **BPSB    /sled_track    1.0674493373    0.8895919408    0.92803044039
    **BPSB    /sled_track    1.0672079078    0.88755579304    0.92429511359
    **BPSB    /sled_track    1.0684186691    0.873273158    0.8959196792
    **BPSB    /sled_track    1.0722502529    0.86000381651    0.86753139043
    **BPSB    /sled_track    1.0777986798    0.84748436493    0.83930028045
    **BPSB    /sled_track    1.0857146064    0.8358752357    0.81104788745
    **BPSB    /sled_track    1.107589461    0.81228452771    0.74930361455
    **BPSB    /sled_track    1.1108516086    0.80927813259    0.74107983422
    **BPSB    /sled_track    1.1185018605    0.80331864    0.7238920032
    **BPSB    /sled_track    1.2502069252    0.71224597872    0.45015494791
    **BPSB    /sled_track    1.2505687343    0.71211245921    0.44962734234
    **BPSB    /sled_track    1.2511917591    0.71201501044    0.44897359093
    **BPSB    /sled_track    1.2521843785    0.71195407137    0.44811341642
    **BPSB    /sled_track    1.3029684557    0.71020568554    0.40673907385
    **BPSB    /sled_track    1.3042649034    0.71017030709    0.4057006443
    **BPFN    /Shoulder_Belt_sys/FeModel_9    152
    **REF_POINT    0.990268 0.832473 0.875947
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      <BELT_SEGMENT
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        NAME="SeatBelt7_Seg8"
        POINT_REF_1="/Shoulder_Belt_sys/PointObj_2"
        POINT_REF_2="/Shoulder_Belt_sys/PointObj_47"
        CHAR="/Shoulder_Belt_sys/belt_loading"
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        ADD_LENGTH="0.1"
      />
    </BELT>
    <BELT
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      NAME="Seat_Belt-&gt;2"
      >
      <BELT_SEGMENT
        ID="1"
        NAME="SeatBelt8_Seg1"
        POINT_REF_1="/Shoulder_Belt_sys/PointObj_51"
        POINT_REF_2="/Shoulder_Belt_sys/PointObj_52"
        CHAR="/Shoulder_Belt_sys/belt_loading"
      />
    </BELT>
    <CHARACTERISTIC.LOAD
      ID="8127"
      NAME="belt_loading"
      LOAD_FUNC="belt_load"
      UNLOAD_FUNC="belt_unload"
      HYS_MODEL="1"
      HYS_SLOPE="3.000000E+005"
      ELAS_LIMIT="0.0"
    />
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      NAME="belt_load"
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    3.00000000E-002     2.95000000E+003
    4.00000000E-002     4.00000000E+003
    5.00000000E-002     4.70000000E+003
    6.00000000E-002     5.32000000E+003
    7.00000000E-002     6.00000000E+003
    8.00000000E-002     6.60000000E+003
    9.00000000E-002     7.25000000E+003
    1.00000000E-001     8.00000000E+003
    1.10000000E-001     8.68000000E+003
    1.20000000E-001     9.50000000E+003
    1.26000000E-001     1.00000000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
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      NAME="belt_unload"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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    1.00000000E-001     1.00000000E+003
]]>
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    </FUNCTION.XY>
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      NAME="FeModel_9"
      >
      <CONTROL_FE_MODEL
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        ALPHA_REL_BODY="/sled_system/sled_body"
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        />
        <CONTROL_FE_TIME_STEP/>
        <TABLE
          TYPE="COORDINATE.CARTESIAN"
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         3   1.2509195E+000   1.0525366E+000   1.1045863E+000
         4   1.2664578E+000   1.0628782E+000   1.1126111E+000
         5   1.2384686E+000   1.0279359E+000   1.1096952E+000
         6   1.2353763E+000   1.0422153E+000   1.0965446E+000
         7   1.2218124E+000   1.0186295E+000   1.1027922E+000
         8   1.2198261E+000   1.0319247E+000   1.0884775E+000
         9   1.2052192E+000   1.0093671E+000   1.0956806E+000
        10   1.2042669E+000   1.0216749E+000   1.0803765E+000
        11   1.1887220E+000   1.0000998E+000   1.0883555E+000
        12   1.1886965E+000   1.0114763E+000   1.0722332E+000
        13   1.1723067E+000   9.9080270E-001   1.0808862E+000
        14   1.1731130E+000   1.0013392E+000   1.0640389E+000
        15   1.1569328E+000   9.8095912E-001   1.0722640E+000
        16   1.1577860E+000   9.9118167E-001   1.0554975E+000
        17   1.1432317E+000   9.7022968E-001   1.0618304E+000
        18   1.1444733E+000   9.8035590E-001   1.0446910E+000
        19   1.1318248E+000   9.5848324E-001   1.0499370E+000
        20   1.1322094E+000   9.6922659E-001   1.0328264E+000
        21   1.1207378E+000   9.4665609E-001   1.0377116E+000
        22   1.1193115E+000   9.5851588E-001   1.0213194E+000
        23   1.1103558E+000   9.3480105E-001   1.0249350E+000
        24   1.1071867E+000   9.4726900E-001   1.0094336E+000
        25   1.1006517E+000   9.2310629E-001   1.0114686E+000
        26   1.0958303E+000   9.3616513E-001   9.9681165E-001
        27   1.0905679E+000   9.1176067E-001   9.9800400E-001
        28   1.0849785E+000   9.2507345E-001   9.8368949E-001
        29   1.0817056E+000   9.0075916E-001   9.8347611E-001
        30   1.0763804E+000   9.1417048E-001   9.6891758E-001
        31   1.0747027E+000   8.9010865E-001   9.6777811E-001
        32   1.0713453E+000   9.0361657E-001   9.5228231E-001
        33   1.0713488E+000   8.7982148E-001   9.5061762E-001
        34   1.0681005E+000   8.9356332E-001   9.3493445E-001
        35   1.0692479E+000   8.6986200E-001   9.3301914E-001
        36   1.0668413E+000   8.8384954E-001   9.1716841E-001
        37   1.0711645E+000   8.6079219E-001   9.1496068E-001
        38   1.0677932E+000   8.7472481E-001   8.9893838E-001
        39   1.0748946E+000   8.5248121E-001   8.9680348E-001
        40   1.0699866E+000   8.6603198E-001   8.8067237E-001
        41   1.0790882E+000   8.4459541E-001   8.7858972E-001
        42   1.0731416E+000   8.5775507E-001   8.6237069E-001
        43   1.0840354E+000   8.3718697E-001   8.6035945E-001
        44   1.0766867E+000   8.4966128E-001   8.4407006E-001
        45   1.0897431E+000   8.3028095E-001   8.4215609E-001
        46   1.0811772E+000   8.4193780E-001   8.2581875E-001
        47   1.0963717E+000   8.2403289E-001   8.2404033E-001
        48   1.0868046E+000   8.3472328E-001   8.0769489E-001
        49   1.1036593E+000   8.1829613E-001   8.0599795E-001
        50   1.0931166E+000   8.2787954E-001   7.8963666E-001
        51   1.1112688E+000   8.1287283E-001   7.8798752E-001
        52   1.0994998E+000   8.2096617E-001   7.7163029E-001
        53   1.1186828E+000   8.0745146E-001   7.6989490E-001
        54   1.1059801E+000   8.1397602E-001   7.5368913E-001
        55   1.1264011E+000   8.0223631E-001   7.5186953E-001
        56   1.1131663E+000   8.0746464E-001   7.3584233E-001
        57   1.1346947E+000   7.9714304E-001   7.3407073E-001
        58   1.1212329E+000   8.0139365E-001   7.1821214E-001
        59   1.1433169E+000   7.9206940E-001   7.1641825E-001
        60   1.1296465E+000   7.9559853E-001   7.0065065E-001
        61   1.1520124E+000   7.8694111E-001   6.9881742E-001
        62   1.1379319E+000   7.8978792E-001   6.8303361E-001
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65	1.1692756E+000	7.7653614E-001	6.6359640E-001
66	1.1546709E+000	7.7812220E-001	6.4789412E-001
67	1.1778629E+000	7.7127385E-001	6.4598200E-001
68	1.1630672E+000	7.7228436E-001	6.3033866E-001
69	1.1864268E+000	7.6597627E-001	6.2836675E-001
70	1.1714461E+000	7.6644628E-001	6.1277503E-001
71	1.1949700E+000	7.6064531E-001	6.1075154E-001
72	1.1798275E+000	7.6060611E-001	5.9521317E-001
73	1.2034901E+000	7.5527268E-001	5.9313781E-001
74	1.1882145E+000	7.5476450E-001	5.7765453E-001
75	1.2119964E+000	7.4987235E-001	5.7552586E-001
76	1.1966089E+000	7.4892233E-001	5.6009960E-001
77	1.2204906E+000	7.4444626E-001	5.5791596E-001
78	1.2050020E+000	7.4307973E-001	5.4254419E-001
79	1.2289740E+000	7.3899599E-001	5.4030837E-001
80	1.2132630E+000	7.3722735E-001	5.2492825E-001
81	1.2374470E+000	7.3352040E-001	5.2270362E-001
82	1.2216216E+000	7.3138043E-001	5.0735811E-001
83	1.2459107E+000	7.2801979E-001	5.0510217E-001
84	1.2304217E+000	7.2556303E-001	4.8999662E-001
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86	1.2389510E+000	7.1591924E-001	4.7379854E-001
87	1.2633136E+000	7.1336441E-001	4.7128317E-001
88	1.2484473E+000	7.1002986E-001	4.5666729E-001
89	1.2742357E+000	7.1068889E-001	4.5431997E-001
90	1.2610738E+000	7.0770853E-001	4.4049311E-001
91	1.2904603E+000	7.0846870E-001	4.4197715E-001
92	1.2770006E+000	7.0910101E-001	4.2752635E-001
93	1.3062102E+000	7.0795451E-001	4.2909349E-001
94	1.2927246E+000	7.1057704E-001	4.1457855E-001
95	1.3207633E+000	7.0315323E-001	4.1577530E-001
96	1.3082056E+000	7.0828576E-001	4.0141250E-001
97	1.3345447E+000	6.9799158E-001	4.0184013E-001
98	1.3239840E+000	7.0617458E-001	3.8939939E-001
99	1.3483380E+000	6.9408820E-001	3.8763227E-001
100	1.3402514E+000	7.0546335E-001	3.7743538E-001
101	1.2601029E+000	1.0794794E+000	1.1031979E+000
102	1.2447453E+000	1.0689396E+000	1.0945002E+000
103	1.2293919E+000	1.0583840E+000	1.0858145E+000
104	1.2140416E+000	1.0478131E+000	1.0771418E+000
105	1.1986934E+000	1.0372269E+000	1.0684839E+000
106	1.1833458E+000	1.0266236E+000	1.0598461E+000
107	1.1679973E+000	1.0160084E+000	1.0512246E+000
108	1.1526119E+000	1.0055787E+000	1.0424483E+000
109	1.1372088E+000	9.9529818E-001	1.0335267E+000
110	1.1216261E+000	9.8460888E-001	1.0252854E+000
111	1.1077648E+000	9.7338228E-001	1.0150756E+000
112	1.0961653E+000	9.6237965E-001	1.0022461E+000
113	1.0872921E+000	9.5150075E-001	9.8730025E-001
114	1.0820218E+000	9.4042441E-001	9.7069216E-001
115	1.0770113E+000	9.2881994E-001	9.5448035E-001
116	1.0733542E+000	9.1824411E-001	9.3725350E-001
117	1.0708887E+000	9.0802746E-001	9.1956347E-001
118	1.0690730E+000	8.9839087E-001	9.0149611E-001
119	1.0683327E+000	8.8930595E-001	8.8305156E-001
120	1.0682878E+000	8.8040451E-001	8.6450254E-001
121	1.0700119E+000	8.7163542E-001	8.4595678E-001
122	1.0723969E+000	8.6302981E-001	8.2745118E-001
123	1.0755949E+000	8.5453370E-001	8.0901305E-001
124	1.0794217E+000	8.4604272E-001	7.9068961E-001
125	1.0837779E+000	8.3742601E-001	7.7254114E-001
126	1.0886037E+000	8.2874726E-001	7.5454173E-001
127	1.0940894E+000	8.2006987E-001	7.3673620E-001
128	1.1005251E+000	8.1154059E-001	7.1919104E-001
129	1.1078993E+000	8.0331109E-001	7.0186177E-001
130	1.1158677E+000	7.9552666E-001	6.8458471E-001
131	1.1238559E+000	7.8832745E-001	6.6706471E-001
132	1.1321417E+000	7.8176175E-001	6.4944509E-001
133	1.1406532E+000	7.7567716E-001	6.3174981E-001

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     135   1.1576835E+000   7.6352584E-001   5.9635658E-001
     136   1.1662019E+000   7.5745892E-001   5.7865856E-001
     137   1.1747221E+000   7.5139681E-001   5.6095972E-001
     138   1.1832438E+000   7.4533936E-001   5.4326006E-001
     139   1.1917671E+000   7.3928642E-001   5.2555960E-001
     140   1.2002923E+000   7.3323921E-001   5.0785807E-001
     141   1.2088187E+000   7.2719610E-001   4.9015574E-001
     142   1.2176073E+000   7.1770568E-001   4.7360244E-001
     143   1.2273496E+000   7.1251694E-001   4.5626011E-001
     144   1.2376063E+000   7.0897698E-001   4.3843103E-001
     145   1.2512695E+000   7.0737197E-001   4.2307597E-001
     146   1.2674169E+000   7.0898763E-001   4.0991885E-001
     147   1.2833453E+000   7.0862013E-001   3.9691498E-001
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-3.00000000E-003	7.72880000E-002
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1.25600000E-001	2.22659200E+000
1.25700000E-001	2.28145700E+000
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1.25900000E-001	2.38067700E+000
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1.69500000E-001	-9.43679000E-001
1.69600000E-001	-9.84586000E-001
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1.69800000E-001	-1.06151600E+000
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1.70100000E-001	-1.17333000E+000
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1.70300000E-001	-1.24040400E+000
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1.70900000E-001	-1.32438000E+000
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1.71200000E-001	-1.28278100E+000
1.71300000E-001	-1.25377700E+000
1.71400000E-001	-1.21671200E+000
1.71500000E-001	-1.17103900E+000
1.71600000E-001	-1.11590800E+000
1.71700000E-001	-1.05058500E+000
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1.71900000E-001	-8.90310000E-001
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1.72100000E-001	-6.99154000E-001
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1.72300000E-001	-4.87967000E-001
1.72400000E-001	-3.77902000E-001
1.72500000E-001	-2.66340000E-001
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1.72800000E-001	6.91360000E-002
1.72900000E-001	1.78217000E-001
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1.73700000E-001	8.98815000E-001
1.73800000E-001	9.66202000E-001
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1.74500000E-001	1.32485200E+000
1.74600000E-001	1.36050000E+000
1.74700000E-001	1.39357900E+000
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1.74900000E-001	1.45442600E+000
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1.75200000E-001	1.53584400E+000
1.75300000E-001	1.56112400E+000

1.75400000E-001	1.58486000E+000
1.75500000E-001	1.60678400E+000
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1.75700000E-001	1.64639100E+000
1.75800000E-001	1.66420900E+000
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1.76200000E-001	1.72213600E+000
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1.76500000E-001	1.74549600E+000
1.76600000E-001	1.74909100E+000
1.76700000E-001	1.74999400E+000
1.76800000E-001	1.74763100E+000
1.76900000E-001	1.74189900E+000
1.77000000E-001	1.73301100E+000
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1.78100000E-001	1.45828700E+000
1.78200000E-001	1.42049200E+000
1.78300000E-001	1.38152000E+000
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1.78500000E-001	1.30024500E+000
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1.79400000E-001	9.42924000E-001
1.79500000E-001	9.17060000E-001
1.79600000E-001	8.93948000E-001
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1.79800000E-001	8.48227000E-001
1.79900000E-001	8.25184000E-001
1.80000000E-001	8.02188000E-001
1.80100000E-001	7.78765000E-001
1.80200000E-001	7.54856000E-001
1.80300000E-001	7.31071000E-001
1.80400000E-001	7.08069000E-001
1.80500000E-001	6.86283000E-001
1.80600000E-001	6.66348000E-001
1.80700000E-001	6.49015000E-001
1.80800000E-001	6.34005000E-001
1.80900000E-001	6.19261000E-001
1.81000000E-001	6.01945000E-001
1.81100000E-001	5.80445000E-001
1.81200000E-001	5.55505000E-001
1.81300000E-001	5.29174000E-001
1.81400000E-001	5.02676000E-001
1.81500000E-001	4.75934000E-001
1.81600000E-001	4.49063000E-001
1.81700000E-001	4.23161000E-001
1.81800000E-001	3.99740000E-001
1.81900000E-001	3.80336000E-001
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1.82200000E-001	3.50225000E-001
1.82300000E-001	3.43796000E-001

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      1.82400000E-001       3.37212000E-001
      1.82500000E-001       3.31736000E-001
      1.82600000E-001       3.27456000E-001
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      1.83000000E-001       3.07798000E-001
      1.83100000E-001       3.09213000E-001
      1.83200000E-001       3.11891000E-001
      1.83300000E-001       3.14078000E-001
      1.83400000E-001       3.15384000E-001
      1.83500000E-001       3.15450000E-001
      1.83600000E-001       3.13265000E-001
      1.83700000E-001       3.07686000E-001
      1.83800000E-001       2.98303000E-001
      1.83900000E-001       2.85978000E-001
      1.84000000E-001       2.72503000E-001
      1.84100000E-001       2.59451000E-001
      1.84200000E-001       2.47267000E-001
      1.84300000E-001       2.35225000E-001
      1.84400000E-001       2.22071000E-001
      1.84500000E-001       2.06982000E-001
      1.84600000E-001       1.90288000E-001
      1.84700000E-001       1.73421000E-001
      1.84800000E-001       1.58114000E-001
      1.84900000E-001       1.45450000E-001
      1.85000000E-001       1.35581000E-001
      1.85100000E-001       1.28366000E-001
      1.85200000E-001       1.24040000E-001
      1.85300000E-001       1.23194000E-001
      1.85400000E-001       1.26662000E-001
      1.85500000E-001       1.35414000E-001
      1.85600000E-001       1.49579000E-001
      1.85700000E-001       1.67457000E-001
      1.85800000E-001       1.86280000E-001
      1.85900000E-001       2.03793000E-001
      1.86000000E-001       2.18606000E-001
      1.86100000E-001       2.29642000E-001
      1.86200000E-001       2.35991000E-001
      1.86300000E-001       2.36922000E-001
      1.86400000E-001       2.31711000E-001
      1.86500000E-001       2.19937000E-001
      1.86600000E-001       2.01943000E-001
      1.86700000E-001       1.78443000E-001
      1.86800000E-001       1.49687000E-001
      1.86900000E-001       1.15615000E-001
      1.87000000E-001       7.68640000E-002
      1.87100000E-001       3.48850000E-002
      1.87200000E-001       -9.06000000E-003
]]>
      </TABLE>
    </FUNCTION.XY>
    <LOAD.SYSTEM_ACC
      DESCRIPTION="gravity"
      SYSTEM_LIST="Lap_Belt_sys Shoulder_Belt_sys tiedowns_sys
               wheelchair_system Hybrid_III_50th"
      AZ_FUNC="gravity"
    />
    <FUNCTION.XY
      ID="2"
      NAME="gravity"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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|       XI                  YI       |
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      2.00000000E+000       -9.81000000E+000
]]>
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  </TABLE>
</FUNCTION.XY>
<SYSTEM.MODEL
  ID="7"
  NAME="tiedowns_sys"
  >
  <BELT
    NAME="RFront_tiedown_belt"
    ID="1"
    >
    <BELT_SEGMENT
      ID="1"
      POINT_REF_1="/sled_system/RFront_sled_secure_pnt"
      POINT_REF_2="/wheelchair_system/RFront_WCsecurement_pnt"
      CHAR="/tiedowns_sys/Ftiedown_char_load"
      INITIAL_STRAIN="0.0042"
    />
  </BELT>
  <BELT
    NAME="LFront_tiedown_belt"
    ID="2"
    >
    <BELT_SEGMENT
      ID="1"
      POINT_REF_1="/sled_system/LFront_sled_secure_pnt"
      POINT_REF_2="/wheelchair_system/LFront_WCsecurement_pnt"
      CHAR="/tiedowns_sys/Ftiedown_char_load"
      INITIAL_STRAIN="0.0042"
    />
  </BELT>
  <BELT
    NAME="RRear_tiedown_belt"
    ID="3"
    >
    <BELT_SEGMENT
      ID="1"
      POINT_REF_1="/sled_system/RRear_sled_secure_pnt"
      POINT_REF_2="/wheelchair_system/RRear_WCsecurement_pnt"
      CHAR="/tiedowns_sys/Rtiedown_char_load"
      INITIAL_STRAIN="0.0046"
    />
  </BELT>
  <BELT
    NAME="LRear_tiedown_belt"
    ID="4"
    >
    <BELT_SEGMENT
      ID="1"
      POINT_REF_1="/sled_system/LRear_sled_secure_pnt"
      POINT_REF_2="/wheelchair_system/LRear_WCsecurement_pnt"
      CHAR="/tiedowns_sys/Rtiedown_char_load"
      INITIAL_STRAIN="0.0046"
    />
  </BELT>
  <OUTPUT_BELT
    ID="1"
    NAME="RFront_tiedown_output"
    INPUT_CLASS="BELT_SEGMENT"
    INPUT_REF="/7/1/1"
    FILTER="CFC60"
  />
  <OUTPUT_BELT
    ID="2"
    NAME="LFront_tiedown_output"
    INPUT_CLASS="BELT_SEGMENT"
    INPUT_REF="/7/2/1"
    FILTER="CFC60"
  />
  <OUTPUT_BELT
    ID="3"
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      NAME="RRear_tiedown_output"
      INPUT_CLASS="BELT_SEGMENT"
      INPUT_REF="/7/3/1"
      FILTER="CFC60"
    />
    <OUTPUT_BELT
      ID="4"
      NAME="LRear_tiedown_output"
      INPUT_CLASS="BELT_SEGMENT"
      INPUT_REF="/7/4/1"
      FILTER="CFC60"
    />
    <CHARACTERISTIC.LOAD
      NAME="Ftiedown_char_load"
      ELAS_LIMIT="0.025"
      LOAD_FUNC="Ftiedown_load_func"
      UNLOAD_FUNC="Ftiedown_unload_func"
      HYS_MODEL="1"
      HYS_SLOPE="3.000000E+006"
      DAMP_COEF="1.000000E+003"
      ID="10000"
    />
    <FUNCTION.XY
      NAME="Ftiedown_load_func"
      ID="10003"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
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    0.00000000E+000     0.00000000E+000
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    4.20000000E-003     4.51900000E+002
    7.60000000E-003     1.11310000E+003
    1.10000000E-002     2.32770000E+003
    1.45000000E-002     3.89680000E+003
    1.79000000E-002     5.53890000E+003
    2.12000000E-002     7.10840000E+003
    2.46000000E-002     8.53830000E+003
    2.81000000E-002     9.81160000E+003
    3.15000000E-002     1.09857000E+004
    3.48000000E-002     1.20968000E+004
    3.82000000E-002     1.31829000E+004
    4.16000000E-002     1.42877000E+004
    4.49000000E-002     1.53979000E+004
    4.82000000E-002     1.65543000E+004
    5.15000000E-002     1.77780000E+004
    5.49000000E-002     1.90255000E+004
    5.82000000E-002     2.02627000E+004
    6.14000000E-002     2.14491000E+004
    6.46000000E-002     2.26952000E+004
    6.80000000E-002     2.39195000E+004
    7.12000000E-002     2.51452000E+004
    7.45000000E-002     2.63710000E+004
    7.78000000E-002     2.75968000E+004
    8.11000000E-002     2.88226000E+004
    8.43000000E-002     3.00484000E+004
    8.76000000E-002     3.12742000E+004
]]>
      </TABLE>
    </FUNCTION.XY>
    <FUNCTION.XY
      NAME="Ftiedown_unload_func"
      ID="10004"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
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|      XI                 YI      |
     0.00000000E+000      0.00000000E+000
     2.40000000E-002      0.00000000E+000
     2.86000000E-002      2.53400000E+002
     3.20000000E-002      8.63300000E+002
     3.55000000E-002      1.68210000E+003
     3.89000000E-002      2.64580000E+003
     4.23000000E-002      3.74220000E+003
     4.55000000E-002      4.98430000E+003
     4.89000000E-002      6.42480000E+003
     5.23000000E-002      8.06620000E+003
     5.57000000E-002      9.94970000E+003
     5.91000000E-002      1.18332000E+004
     6.25000000E-002      1.37167000E+004
     6.59000000E-002      1.56002000E+004
     6.93000000E-002      1.74837000E+004
     7.27000000E-002      1.93673000E+004
     7.60000000E-002      2.12508000E+004
     7.94000000E-002      2.31343000E+004
     8.28000000E-002      2.50178000E+004
     8.62000000E-002      2.69013000E+004
]]>
       </TABLE>
     </FUNCTION.XY>
     <CHARACTERISTIC.LOAD
       ELAS_LIMIT="0.0"
       NAME="Rtiedown_char_load"
       LOAD_FUNC="Rtiedown_load_func"
       UNLOAD_FUNC="Rtiedown_unload_func"
       HYS_MODEL="1"
       HYS_SLOPE="1.990000E+005"
       DAMP_COEF="1.000000E+003"
       ID="10001"
     />
     <FUNCTION.XY
       NAME="Rtiedown_load_func"
       ID="10005"
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       <TABLE
         TYPE="XY_PAIR"
         >
<![CDATA[
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     1.00000000E-004      2.34000000E+001
     2.20000000E-003      2.80800000E+002
     4.60000000E-003      3.73200000E+002
     6.90000000E-003      4.68400000E+002
     9.10000000E-003      5.85100000E+002
     1.14000000E-002      7.13200000E+002
     1.37000000E-002      8.74700000E+002
     1.62000000E-002      1.05950000E+003
     1.85000000E-002      1.25990000E+003
     2.07000000E-002      1.48960000E+003
     2.30000000E-002      1.74550000E+003
     2.53000000E-002      2.02480000E+003
     2.76000000E-002      2.32790000E+003
     2.98000000E-002      2.63880000E+003
     3.22000000E-002      2.95150000E+003
     3.45000000E-002      3.29670000E+003
     3.69000000E-002      3.64490000E+003
     3.92000000E-002      4.00290000E+003
     4.17000000E-002      4.36890000E+003
     4.40000000E-002      4.60000000E+003
     4.64000000E-002      4.90000000E+003
     4.88000000E-002      5.20000000E+003
     5.12000000E-002      5.50000000E+003
     5.36000000E-002      5.80000000E+003
     5.60000000E-002      6.10000000E+003
     5.84000000E-002      6.40000000E+003
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      6.08000000E-002      6.70000000E+003
      6.31000000E-002      7.00000000E+003
      6.55000000E-002      7.30000000E+003
      6.79000000E-002      7.60000000E+003
      7.03000000E-002      7.90000000E+003
      7.27000000E-002      8.20000000E+003
      7.51000000E-002      8.50000000E+003
      7.75000000E-002      8.80000000E+003
      7.99000000E-002      9.10000000E+003
      8.23000000E-002      9.40000000E+003
      8.47000000E-002      9.70000000E+003
      8.71000000E-002      1.00000000E+004
]]>
        </TABLE>
      </FUNCTION.XY>
      <FUNCTION.XY
        NAME="Rtiedown_unload_func"
        ID="10006"
        >
        <TABLE
          TYPE="XY_PAIR"
          >
<![CDATA[
|       XI                 YI       |
      0.00000000E+000      0.00000000E+000
      2.40000000E-002      0.00000000E+000
      2.59000000E-002      6.58000000E+001
      2.82000000E-002      1.43500000E+002
      3.06000000E-002      2.42700000E+002
      3.29000000E-002      4.00000000E+002
      3.52000000E-002      6.91800000E+002
      3.75000000E-002      1.18570000E+003
      3.98000000E-002      1.50000000E+003
      4.22000000E-002      1.90000000E+003
      4.46000000E-002      2.30000000E+003
      4.70000000E-002      2.70000000E+003
      4.94000000E-002      3.10000000E+003
      5.18000000E-002      3.50000000E+003
      5.42000000E-002      3.90000000E+003
      5.66000000E-002      4.30000000E+003
      5.89000000E-002      4.70000000E+003
      6.13000000E-002      5.10000000E+003
      6.37000000E-002      5.50000000E+003
      6.61000000E-002      5.90000000E+003
      6.85000000E-002      6.30000000E+003
]]>
        </TABLE>
      </FUNCTION.XY>
    </SYSTEM.MODEL>
    <CHARACTERISTIC.CONTACT
      CONTACT_MODEL="FORCE"
      HYS_MODEL="2"
      HYS_SLOPE="1.000000E+010"
      ID="9999"
      LOAD_FUNC="dummy_contact_func"
      NAME="dummy_contact"
    />
    <FUNCTION.XY
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      NAME="dummy_contact_func"
      >
      <TABLE
        TYPE="XY_PAIR"
        >
<![CDATA[
|       XI                 YI       |
      0.00000000E+000      0.00000000E+000
      0.20000000E-000      2.00000000E+004
]]>
      </TABLE>
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</FUNCTION.XY>
<CONTACT.MB_MB
  EVALUATION_TYPE="CONTINUOUS"
  NAME="Front_wheel_contact"
  ID="1"
  MASTER_SURFACE="/sled_system/sled_mbg"
  SLAVE_SURFACE="/wheelchair_system/front_wh_surfaces"
  FRIC_COEF="1.3"
  DAMP_COEF="1.000000E+003"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="SLAVE"
  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  EVALUATION_TYPE="CONTINUOUS"
  NAME="Rear_wheel_contact"
  ID="2"
  MASTER_SURFACE="/sled_system/sled_mbg"
  SLAVE_SURFACE="/wheelchair_system/rear_wh_surfaces"
  FRIC_COEF="2.0"
  DAMP_COEF="1.000000E+004"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="SLAVE"
  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  EVALUATION_TYPE="CONTINUOUS"
  DAMP_COEF="800.0"
  FRIC_COEF="0.8"
  ID="3"
  INITIAL_TYPE="CORRECT"
  MASTER_SURFACE="/wheelchair_system/wcseat_contact_surface"
  NAME="pelvis_wcseat"
  SLAVE_SURFACE="/Hybrid_III_50th/Pelvis_gmb"
  >
  <CONTACT_FORCE.CHAR
    CONTACT_TYPE="COMBINED"
    MAX_FORCE_PAR="1.000000E+010"
    USER_CHAR="/wheelchair_system/wcseat_contact"
  />
</CONTACT.MB_MB>
<CONTACT.MB_MB
  EVALUATION_TYPE="CONTINUOUS"
  DAMP_COEF="800.0"
  FRIC_COEF="0.8"
  ID="4"
  INITIAL_TYPE="CORRECT"
  MASTER_SURFACE="/wheelchair_system/wcseat_contact_surface"
  NAME="UlegR_wcseat"
  SLAVE_SURFACE="/Hybrid_III_50th/FemurKneeR_gmb"
  >
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  />
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  NAME="UlegL_wcseat"
  SLAVE_SURFACE="/Hybrid_III_50th/FemurKneeL_gmb"
  >
  <CONTACT_FORCE.CHAR
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      NAME="pelvis_wcback"
      SLAVE_SURFACE="/Hybrid_III_50th/Pelvis_gmb"
      >
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      NAME="torso_wcback"
      SLAVE_SURFACE="/Hybrid_III_50th/Thorax_gmb"
      >
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      NAME="shoeL_footrest"
      SLAVE_SURFACE="/Hybrid_III_50th/ShoeL_gmb"
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  >
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  INITIAL_TYPE="CORRECT"
  MASTER_SURFACE="/Hybrid_III_50th/TibiaL_gmb"
  NAME="TibiaL_wcseat"
  SLAVE_SURFACE="/wheelchair_system/wcseat_contact_surface"
  >
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  MASTER_SURFACE="/Hybrid_III_50th/TibiaR_gmb"
  NAME="TibiaR_wcseat"
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  >
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  MASTER_SURFACE="/wheelchair_system/top-wcback_contact_surface"
  NAME="ArmUpR_wcback"
  SLAVE_SURFACE="/Hybrid_III_50th/ArmUpR_gmb"
  >
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  MASTER_SURFACE="/wheelchair_system/top-wcback_contact_surface"
  NAME="ArmUpL_wcback"
  SLAVE_SURFACE="/Hybrid_III_50th/ArmUpL_gmb"
  >
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      NAME="ArmLowR_armrest"
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      FRIC_COEF="0.8"
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      FRIC_COEF="0.8"
      INITIAL_TYPE="CORRECT"
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        USER_CHAR="/arms_wcback_contact"
      />
    </CONTACT.MB_MB>
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    ID="24"
    INITIAL_TYPE="CORRECT"
    MASTER_SURFACE="/Hybrid_III_50th/Head_gmb"
    NAME="head_back"
    SLAVE_SURFACE="/Hybrid_III_50th/Thorax_gmb"
    >
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    >
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  <CONTACT.MB_FE
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    NAME="Shoulderbelt_contact"
    MASTER_SURFACE="/Hybrid_III_50th/Dummy_gmb"
    SLAVE_SURFACE="/Shoulder_Belt_sys/Shoulder_fe_grp"
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      >
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        CONTACT_TYPE="MASTER"
        FRIC_FUNC="belt_friction_fnc"
      />
    </CONTACT.MB_FE>
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      NAME="Lapbelt_WC_contact"
      MASTER_SURFACE="/wheelchair_system/WC_gmb"
      SLAVE_SURFACE="/Lap_Belt_sys/Lap_fe_grp"
      >
      <CONTACT_FORCE.CHAR
        CONTACT_TYPE="SLAVE"
        FRIC_FUNC="belt_friction_fnc"
      />
    </CONTACT.MB_FE>
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      ID="17"
      NAME="Shoulderbelt_WC_contact"
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      SLAVE_SURFACE="/Shoulder_Belt_sys/Shoulder_fe_grp"
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        FRIC_FUNC="belt_friction_fnc"
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]]>
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