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TABLE OF CONTENTS

2000-01-0303	Utilization of ADAMS to Predict Tracked Vehicle Performance	1
	Jesper Slättengren	
2000-01-0305	Self-Discharging of Lead-Acid Batteries	8
	Henry A. Catherino, Peter Shi, Andrew Rusek, and Fred Feres	
2000-01-1395	Common Occupant Crash Protection for Army Wheeled Trucks	15
	Larry A. Sicher, Gary R. Whitman, John R. Yannaccone, Louis A. D'Aulerio, and Alan Cantor	
2000-01-2543	Environmental Standards for Biodegradable Hydraulic Fluids and Correlation of Laboratory and Field Performance	20
	N. Battersby, R. T. Dixon, S. Greenall, C. W. Watson, K. J. Young, J. Ehn, and T. Marougy	
2000-01-2544	"GoldDrive"—Infinite Variable Drive Consisting of Fixed Displacement Pumps and Motors	27
	Nahum Goldenberg	
2000-01-2545	Horsepower with Brains: The Design of the CHIRON Free Piston Engine	34
	Peter A. J. Achten, Johan P. J. van den Oever, Jeroen Potma, and Georges E. M. Vael	
2000-01-2546	First Cycles of the Dual Hydraulic Free Piston Engine	51
	Seppo Tikkanen, Mika Lammila, Mika Herranen, and Matti Vilénius	
2000-01-2547	Head Injury in Fork Lift Upsets	61
	Fred H. Carlin and Anthony Sances, Jr.	
2000-01-2548	Off-Highway Noise—Diverging Demands of the Future	73
	Miles Pixley	
2000-01-2552	The SAE Clean Snowmobile Challenge 2000—Summary and Results	80
	Lori M. Fussell, Gary Bishop, and John Daily	
2000-01-2556	Performance of High Oleic Soybean Oil-Based Hydraulic Fluids in Long-Duration Pump Tests	90
	Michael Keefe, James L. Glancey, and Zhang Zong	
2000-01-2559	Switching Type Control of Hydraulic Drives—A Promising Perspective for Advanced Actuation in Agricultural Machinery	98
	R. Scheidl, M. Garstenauer, and B. Manhartsgruber	
2000-01-2561	The Innas Hydraulic Transformer, the Key to the Hydrostatic Common Pressure Rail	109
	Georges E. M. Vael, Peter A. J. Achten, and Zhao Fu	
2000-01-2562	Displacement Controlled Linear and Rotary Drives for Mobile Machines with Automatic Motion Control.....	125
	Monika Ivantysynova	
2000-01-2563	Austempered Materials and Their Applications to Drive Line and Suspension Components	133
	John R. Keough	

2000-01-2564	Evaluation of Welding Residual Stress Levels Through Shot Peening and Heat Treating	140
	Mark S. Molzen and Doug Hornbach	
2000-01-2566	Steel Quality Requirements for Heavy-Duty Off-Highway Gearing	147
	John T. Sonzilli, Gary E. Remus, Theodore M. Clarke, and Edward J. Sawdo	
2000-01-2568	Systems Engineering in the Off-Highway Market	153
	Jonathan L. Tolstedt	
2000-01-2571	A Picture is Worth a Thousand Lines of Code	161
	Lee M. Brooks	
2000-01-2577	Numerical and Experimental Methods to Investigate Cooling Air Flow in the Construction Machinery's Engine Compartment	169
	Toshikazu Nakanishi, Sanshirou Shimoda, Nobuhiko Yamasaki, Yuzo Inokuchi, Tsuyoshi Takemoto, Hisashi Okazawa, and Masanobu Namba	
2000-01-2581	Analysis of Common Failure Modes of Axial Piston Pumps	178
	Charles G. Fey, George E. Totten, Roland J. Bishop, Jr., and A. Ashraf	
2000-01-2585	Design and Analysis of CAN Networks for Vehicles	192
	Ronald G. Landman	
2000-01-2590	Root Cause Analysis of a Piston Pump Failure: A Case History	199
	C. E. Fey, R. Goebel, G. E. Totten, and R. J. Bishop, Jr.	
2000-01-2591	Utilization of Artificial Neural Networks in the Control, Identification and Condition Monitoring of Hydraulic Systems—An Overview	205
	G. J. Schoenau, J. S. Stecki, and R. T. Burton	
2000-01-2592	IT-Tool Concept for Design and Intelligent Motion Control of Hydraulic Actuators for Machines and Robots	213
	Finn Conrad, Poul Erik Hansen, Torben Sørensen, and Jianjun Zhou	
2000-01-2593	Comparison of Hydrostatic and Servovalve-Controlled Hydraulic Actuation Systems in Robotics	231
	S. R. Habibi	
2000-01-2594	Condition Monitoring of a Hydraulic Valve Through On-line Estimation of the Valve Orifice Area Profile	244
	Masoud K. Zavarehi, Farrokh Sassani, and Peter D. Lawrence	
2000-01-2596	Optimization of the Tractive Performance of Four-Wheel-Drive Tractors—Correlation Between Analytical Predictions and Experimental Data	252
	J. Y. Wong, Zhiwen Zhao, Jianqiao Li, N. B. McLaughlin, and S. Burtt	
2000-01-2601	Development of a New Life Equation for Ball and Roller Bearings.....	261
	Hiromichi Takemura, Yoichi Matsumoto, and Yasuo Murakami	
2000-01-2602	Development of Heat Resistant Long Life Through Hardening Bearing Steel (STJ2)	268
	K. Maeda, H. Tanaka, Y. Fujii, and H. Nakashima	

2000-01-2603	Comparison of Plain Bushing Technologies for Reduced Grease Consumption in Construction Equipment	274
	Jean-Marc Lacambre, Eric Chaduiron, and Kenneth L. Metzgar	
2000-01-2605	"Zero Defects", Statistically Considered	281
	Stephen N. Luko	
2000-01-2611	Keeping Your Sanity When Using SAE J-1113	291
	Edward T. Heck	
2000-01-2612	Applicability of Pneumatic Cylinders in Low-Pressure Water Hydraulics.....	300
	M. Lakkonen, M. Linjama, K. T. Koskinen, and M. Vilenius	
2000-01-2613	Towards Large Eddy Simulation of Cavitation in Hydraulic Valves	306
	X Tao, S. H. Frankel, and S. Ramadhyani	
2000-01-2614	Design of Low-Pressure and High-Pressure Tap Water Hydraulic Systems for Various Industrial Applications	316
	Finn Conrad, Bjarne Hilbrecht, and Hardy Jepsen	
2000-01-2616	Application of Simulation and Knowledge Processing in Contamination Control.....	331
	Jacek S. Stecki and Greg Schoenau	
2000-01-2617	Experimental Determining and Theoretical Predicting of Source Flow Ripple Generated by Fluid Power Piston Pumps	348
	Eiichi Kojima, Jinghong Yu, and Takayoshi Ichianagi	
2000-01-2618	Methods for Measuring the Speed of Sound in the Fluid in Fluid Transmission Pipes	358
	Jinghong Yu and Eiichi Kojima	
2000-01-2619	Model Identification and Analysis of a High Performance Hydrostatic Actuation System	367
	S. R. Habibi, V. Pastrakuljic, and A. A. Goldenberg	
2000-01-2621	Fuzzy Quality Evaluation for Agricultural Applications	377
	Eric R. Benson, Qin Zhang, John F. Reid, and Monte Dickson	
2000-01-2626	An Evaluation of Friction Effects on Hypoid Gear Life and Bearing Load	385
	Shan Shih, Scott Kuan, Christopher Keeney, and Silvio Yamada	
2000-01-2627	Torque Spike Analysis of an AC Haul Truck Traction System	395
	Robert J. Ciszak, Ekkehard Pittius, and Jarek Rosinski	
2000-01-2629	Some Aspects on Modeling of the Moving Forest Machines	402
	Tommi Hammarberg and Heikki Handroos	
2000-01-2630	Effects of Timing and Odd/Even Number of Teeth on Noise Generation of Gerotor Lubricating Pumps for IC Engines	407
	S. Mancò, N. Nervegna, and M. Rundo	
2000-01-2631	Pump Pressure Control in Hydraulic Systems—Modeling and Simulation of dynamic Behavior	417
	Marcus Röst, Andreas Renberg, and Lawrence D. Blackman	

2000-01-2632	Prediction of Pump Dynamics Utilizing Computer Simulation Model—With Special Reference to Noise Reduction	426
	Andreas Johansson and Lawrence D. Blackman	
2000-01-2641	Simulation Modeling Guided Transmission Design—A Case Study	433
	Shan Shih	
2000-01-2643	Profiles of the Wave Generators of the Chain-Wave Transmission.....	446
	Ara K. Amiryan and Karapet A. Amiryan	
2000-01-2650	Theoretical Basis for the Calculation of Press Fit Connections in Track Links of Undercarriages for Construction Machinery	935
	Michael Ketting and Wolfgang Kunkel	
2000-01-2651	Rethinking the Design Paradigm: A Customer-Focused Approach to Designing a Mini-Baja Vehicle	454
	Brent Zollinger and Robert H. Todd	
2000-01-3402	Ergonomics Program at Freightliner	462
	Josef Loczi	
2000-01-3404	Human Body Size for Truck Cab Design	470
	Bruce Bradtmiller and Mary E. Gross	
2000-01-3405	Methods for Laboratory Investigation of Truck and Bus Driver Postures	476
	Matthew P. Reed, Michelle M. Lehto, and Lawrence W. Schneider	
2000-01-3406	Biomechanical Design and Evaluation of Truck Seats	486
	Tamara Reid Bush and Robert P. Hubbard	
2000-01-3408	Vibration and Shock Isolation Performance of a Commercial Semi-Active Vehicle Seat Damper	493
	Steven J. McManus and Kenneth A. St. Clair	
2000-01-3409	Human Factors Evaluation of the Truck Productivity Computer's™ Electroluminescent Display	500
	Steven S. Wreggit, Jared Powell, Chris Kirn, and Elizabeth Hayes	
2000-01-3410	The Creation of Symbols for Road Vehicles, Especially for Heavy Trucks	505
	Douglas Sjöqvist	
2000-01-3412	Kansei Engineering Application on Commercial Truck Interior Design Harmony.....	514
	Lijian Zhang and Alicia Vértiz	
2000-01-3413	On the Distribution of Braking Forces in Road Braking	521
	Mauri Haataja and Tatu Leinonen	
2000-01-3414	Pneumatic Brake System Modeling for Systems Analysis.....	533
	Tankut Acarman, Umit Ozguner, Cem Hatipoglu, and Anne-Marie Igusky	
2000-01-3415	A Simulation Program for the Braking Characteristics of Tractor-Semitrailer Vehicle	540
	Myung-Won Suh, Yoon-Ki Park, Seong-Jin Kwon, Seung-Hwan Yang, and Byung-Chul Park	

2000-01-3418	Developing an Artificial Neural Network for Modeling Heavy Vehicle Rollover	551
	David R. Woerner, Raman Ranganathan, and Alley C. Butler	
2000-01-3421	Dual-Use Hybrid Electric Technology for 21st Century Truck Program.....	562
	Robert Crow and Stephen P. Cortese	
2000-01-3422	Alternative Fuels: Gas to Liquids as Potential 21st Century Truck Fuels	567
	Leo L. Stavinoha, Emilio S. Alfaro, Herbert H. Dobbs, Jr., Luis A. Villahermosa, and John B. Heywood	
2000-01-3423	Parasitic Loss Reduction for 21st Century Trucks	583
	Wsewołod Hnatczuk, Michael P. Lasecki, John Bishop, and Jarrett Goodell	
2000-01-3424	Advanced Material Technologies for 21st Century Trucks	592
	Richard Patton, Ellen Brebop, Matthew State, Vickie Furman, Paul Geck, and Michael Cummins	
2000-01-3427	Multimedia Occupant Crash Protection Development Guide	605
	Gary Whitman, Tim Joganich, James Dayman, Bruce Holmberg, Michael Gedeon, and Jack Reed	
2000-01-3428	Alternative Fuels: Development of a Biodiesel B20 Purchase Description	611
	Leo L. Stavinoha, Emilio S. Alfaro, Herbert H. Dobbs, Jr., and Luis A. Villahermosa	
2000-01-3431	Truck Tire Force and Moment in Cornering—Braking—Driving on Ice, Snow, and Dry Surfaces	629
	Marion G. Pottinger, James E. McIntyre, Alan J. Kempainen, and Wolfgang Pelz	
2000-01-3432	On Vehicle Testing of Michelin New Wide-Base Tire	637
	Matt Markstaller, Al Pearson, and Ibrahim Janajreh	
2000-01-3436	Design and Development of Bus Operator Seat as an Integral Part of the Bus Operator Workstation Redesign	643
	Christian U. Hammarskjold, Harry Saporta, and Steve Russell	
2000-01-3437	Vehicle Dynamics Simulation for Handling Optimization of Heavy Trucks	656
	Mark Sherman and George Myers	
2000-01-3441	The Development of the Diagnosis Fault System in Electronic Architectures for Commercial Vehicles	662
	Cirilo de Paula Silva, Carlos Alberto Favero, Stefan Specht, and Helcio Onusic	
2000-01-3447	New Suspension Design for Heavy Duty Trucks: Dynamic Considerations	669
	M. O. A. Mokhtar, I. M. Ibrahim, and A. M. El-Butch	
2000-01-3448	Uniform Suspension Response for Commercial Vehicles	678
	P. Dennis McNeely	

2000-01-3452	Composite Compression C Springs and Light Independent Suspension for Trucks, Buses, Cars and Trains	683
	Max A. Sardou and Patricia Djomseu	
2000-01-3456	CuproBraze Mobile Heat Exchanger Technology	696
	Johan Scheel and Bengt Gustafsson	
2000-01-3458	Strategic Analysis of Technologies for Future Truck Engines	701
	S. P. Edwards, G. R. Fränkle, K. Binder, and F. Wirbeleit	
2000-01-3459	Plasma Treatment of Diesel Particulate for a Minibus.....	718
	Fuming Xiao, Shenghua Liu, J.W. Hwang, C. U. Son, J. Y. Jeong, J. H. Han, H. J. Hwang, U. H. Kim, and Jae-Ou Chae	
2000-01-3461	Prediction of Driveshaft Critical Speed Using the Transfer Matrix Method	724
	Thomas M. Essi	
2000-01-3471	An Analysis of Start-Up for an Operational Fuel Cell Transit Bus	729
	Paul A. Erickson, Daniel A. Betts, Timothy C. Simmons, and Vernon P. Roan	
2000-01-3473	Comparison of In-Use Emissions from Diesel and Natural Gas Trucks and Buses	733
	Christopher S. Weaver, Sean H. Turner, Marco V. Balam-Almanza, and Rajeana Gable	
2000-01-3474	Enhanced All-Composite NGV Fuel Container Design and Qualification	739
	Norman L. Newhouse and Chad A. Cederberg	
2000-01-3475	Commercial Drivers' Subjective Rating of Stopping Capability of Air-Braked Vehicles	749
	Daniel D. Filiatrault, Peter J. Cooper, and Yvonne Y. Zheng	
2000-01-3476	Fluid Load Analysis Within the Static Roll Model	759
	Ericka Southcombe, Roland L. Ruhl, and Edward Kuznetsov	
2000-01-3477	Directional Dynamics of a Partly-Filled Tank Vehicle Under Braking and Steering	765
	X. Kang, S. Rakheja, and I. Stiharu	
2000-01-3481	Heavy Vehicle Stability Notification and Assistance	776
	Falk Hecker, Herbert Schramm, Claus Beyer, Gusztav Holler, and Mark Bennett	
2000-01-3488	Demonstration of a Proton Exchange Membrane Fuel Cell as an Auxiliary Power Source for Heavy Trucks	783
	C. J. Brodrick, M. Farshchi, H. A. Dwyer, S. W. Gouse, J. Martin, and M. Von Mayenburg	
2000-01-3492	A Method Determining the Dynamic Rollover Threshold of Commercial Vehicles	789
	Erik Dahlberg	
2000-01-3495	Electrochemical Capacitors and Their Potential Application to Heavy-Duty Vehicles	802
	Wee Ong and Ralph H. Johnston	

2000-01-3500	External Flow Analysis of a Truck for Drag Reduction	808
	Subrata Roy and Pradeep Srinivasan	
2000-01-3501	Computational Simulations for the External Aerodynamics of Heavy Trucks.....	813
	Oktay Baysal and Ilhan Bayraktar	
2000-01-3503	Internet-Based Vehicle Communication Network.....	820
	John Skibinski, Jim Trainor, and Chad Reed	
2000-01-3506	Vehicle Intelligence and Remote Wireless OBD.....	826
	Martin Nathanson	
2000-01-3507	Freightliner/MeritorWABCO Roll Advisory and Control System	838
	Jim Ehlbeck, Chris Kirn, Joerg Moellenhoff, Alan Korn, Hartmut Rosendahl, and Gerhard Ruhnau	
2000-01-3509	New Approaches to Modal Transient Fatigue Analysis.....	845
	Senthivel Vellaichamy and Hamid Keshtkar	
2000-01-3513	Emission Control for the Duramax6600 V8 Diesel Engine	851
	Teruo Nakada, Taiji Uekusa, Koichi Hamaguchi, and Masanori Sanada	
2000-01-3515	A New Generation of Vibration Isolation for the Conventional Truck Cab	860
	Thomas A. McKenzie, William J. Hicks, and Richard L. Conaway	
2000-01-3517	Comfort and Vibration Study of a Tractor and Trailer Combination Using Simulation and Experimental Approaches: The Jumping Ride Behavior	866
	Odilon T. Perseguiim, Costa Neto, Marcos A. Argentino, C. F. Nogueira, P. Federico Neto, M. A. Fogaça, A. Dybal, and M. D. Torre Garcia	
2000-01-3518	Rubber Isolators—Measurements and Modeling Using Fractional Derivatives and Friction	873
	Mattias Sjöberg	
2000-01-3519	Low Energy Consumption and Low Noise Fans for Cooling System of Trucks, Bus, Cars and Trains	885
	Max A. Sardou and Patricia Djomseu	
2000-01-3520	Rollover Crashworthiness of a New Coach Structure	905
	James C. Anderson	
2000-01-3521	Underride in Fatal Rear-End Truck Crashes	910
	Daniel Blower and Kenneth L. Campbell	
2000-01-3522	Trailer Underride Protection—A Canadian Perspective.....	918
	Denis Boucher and Daniel B.T. Davis	
2000-01-3526	A Unique Approach to All-Wheel-Drive Vehicle Dynamics Model Simulation and Correlation	930
	Venu Subramanyam, Vince Monkaba, and Todd Alexander	
	Index	942

Ergonomics Program at Freightliner

Josef Loczi

Freightliner Corporation

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ABSTRACT

This paper describes the ergonomics program at Freightliner and how it is integrated in the engineering and design process. It will also describe how we use advanced technologies such as 3-D Digital Human Modeling with RAMSIS and how these are applied to the design process to ensure optimized ergonomics in our trucks.

INTRODUCTION

Sound ergonomics is an important differentiator among all vehicles but especially among trucks, because professional truck drivers spend many hours at a time on the road in their trucks. It is not unusual for a truck driver to spend up to 10 hours each day behind the wheel and to log more than 100,000 miles per year. With today's changed anthropometrics, demographics and shortage of qualified truck drivers, good ergonomics in trucks has become even more important to attract and retain drivers. Due to secular growth (younger generations are taller than older generations) and an increase in overweight people (40% of the adult populations is overweight or obese) cab and seat design has to accommodate taller and bigger drivers. In addition, during the last decade the number of female truck drivers, including those of class 8 trucks, has nearly doubled from 100,000 to 175,000 (1). This also has important implications for the design and layout of the driver cab and seats. Today this anthropometrically more versatile driver population must be accommodated by addressing the spatial and comfort needs of shorter and smaller female drivers as well as taller and heavier male drivers.

Traditionally, general ergonomic guidelines provided in textbooks, published papers and SAE procedures have been used. However, these guidelines are often not specific enough for the truck environment, are out-dated, and frequently fail to address any interactions that different items would have with each other. For example, the location of a dash-mounted shifter may be optimized for reach and reduced effort to actuate, but at the same time obscure vision to important controls. Therefore a truck OEM has to build bucks or prototypes, select appropriate test subjects that reflect their domestic and

international truck buying populations and then test for ergonomic, safety and comfort concerns. This is always time consuming and expensive to develop and build the hardware, find test subjects and administer tests. Also to build bucks, you have to have the design completed to a certain point to produce parts. This becomes especially difficult early on in the truck development cycle. It is very important to incorporate good ergonomics early on in the concept phase, when changes are still easily and economically made. With today's shorter product development cycles, the use of virtual mock-ups and virtual people in a CAD environment is one solution that can provide quality information early on in the design process. In addition, the 3-D CAD environment is easily changed when new design proposals or different iterations need to be evaluated. This is much faster and less costly than modifying existing hardware or building new bucks.

ORGANIZATIONAL OVERVIEW

To address ergonomic and comfort issues Freightliner has a dedicated ergonomics and human factors group that is part of the Engineering Body Center. The Ergonomics group works closely with styling, interior and exterior body groups, chassis and safety departments to implement ergonomic design in our vehicles. We provide support to all truck platforms within Freightliner, which allows for uniform ergonomic guidelines, criteria and tool applications.

Ergonomic support is provided during all phases of the truck and feature development cycle. However, the main emphasis for us is to provide input early on in the concept phase when design concepts are developed. This allows Freightliner to implement optimized ergonomic design and changes relatively easily and economically.

In order to evaluate many ergonomic issues early on in the concept phase we employ RAMSIS, a 3-D Human Model for ergonomic evaluations. This allows us to perform necessary ergonomic investigations in the CATIA CAD environment even with little geometry defined. In addition, we use SAE and ISO guidelines and perform subject testing in either concept bucks or trucks.

3D- HUMAN ERGONOMIC MODELING

RAMSIS is a 3-D human model for ergonomic evaluations and was specifically developed for use in the automotive and trucking industry (2). We use RAMSIS to define and develop the driver and passenger workspace and to develop design criteria to meet our ergonomic objectives. Issues such as reach to dash, controls, pedals, and outside and instrument visibility are addressed. In addition we use RAMSIS to address spatial accommodation for the sleeper cab and entry and exit issues.

RAMSIS allows us to generate and simulate any truck driver population. This enables us to evaluate design issues for drivers of different sizes and proportions. Figure 1 shows a family of manikins representing a range of body heights, nationalities and body proportions. For example we can evaluate a particular design proposal and how it would impact a 5th percentile female vs. a 95th percentile male, or the impact on a driver with the same stature but different body proportions such as leg length and weight.

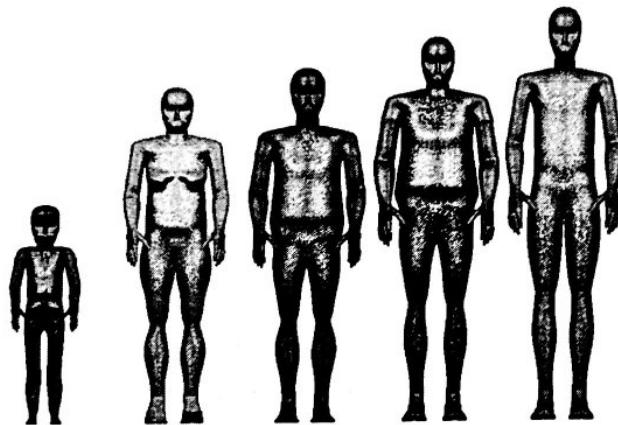


Figure 1. Family of Manikins, 4-year old Child, 5% US Female, 50% Mexican Male, 5% US Male and 95% US Male (from left to right)

One of the most important features of RAMSIS is that it allows us to consistently and repeatedly position a manikin with a realistic posture in the seat and the vehicle CAD geometry (3-4). This gives us a high degree of confidence for any subsequent analysis such as arm reach or visibility evaluations (5). Figure 2 shows overlaid seated postures for manikins representing a 5% female, 50% male and 95% male.

Besides being able to evaluate ergonomic issues with RAMSIS early in the truck development cycle, RAMSIS also is an excellent visualization tool. Ergonomic issues are presented in a context that is easily understood by non-experts, such as high level managers. We will show 5 examples of RAMSIS applications in the truck development cycle.

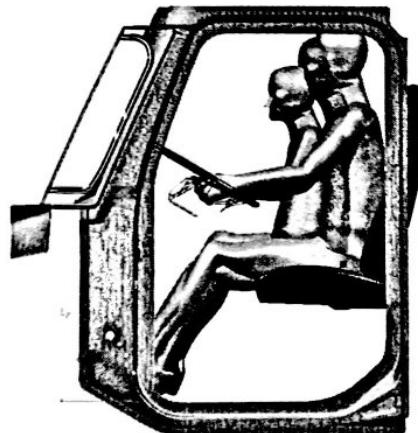


Figure 2. 5% female, 50% male and 95% male in overlaid driving position.

VISIBILITY EVALUATIONS – In trucks, one of the most critical ergonomic and safety issues is visibility to the outside of the truck. One of the methods to evaluate visibility is the horizontal planar projection provided in SAE J1750 (6). With this procedure we determine the ground area obstructed from the view of the center of the SAE eyellipse. The results of these evaluations are very abstract and the impact is often hard to understand, especially by non-experts such as managers. These procedures do not show visibility in the context of the driving environment, as a driver would see, nor do they provide what the negative or positive effect would be for drivers of different body sizes. This very often makes it difficult to understand the impact of proposed design changes or design differences. While there may be a numerical difference in ground visibility, is the difference large enough to be perceived by drivers? What is the impact for short vs. tall drivers?

Figure 3 shows a comparison of two different hood designs using the SAE J1750 horizontal planar projection method. Design 1 shows a lowered hood design and 2 a raised hood. The results of SAE J1750 clearly show hood design 1 has less ground obstruction.

With RAMSIS we get a realistic perspective from the driver's eyes. Figure 4 shows the RAMSIS street scene setup for our visibility evaluations. Child manikins of age 4 are placed around the truck at defined locations. Figures 5 – 6 show forward visibility for hood design 1 for a 5% percentile female and 95% male. Figures 7 – 8 show the effect of hood design 2 on visibility. This example shows that hood design 1 clearly provides superior visibility over hood design 2 and is presented in a clearly understood context from a driver's perspective.

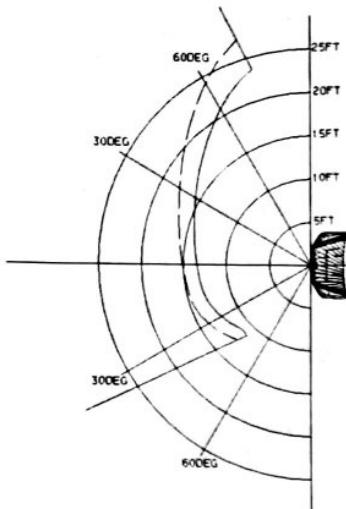


Figure 3. Horizontal Planar Projection per SAE J1750



Figure 4. Visibility Evaluation SetUp with RAMSIS

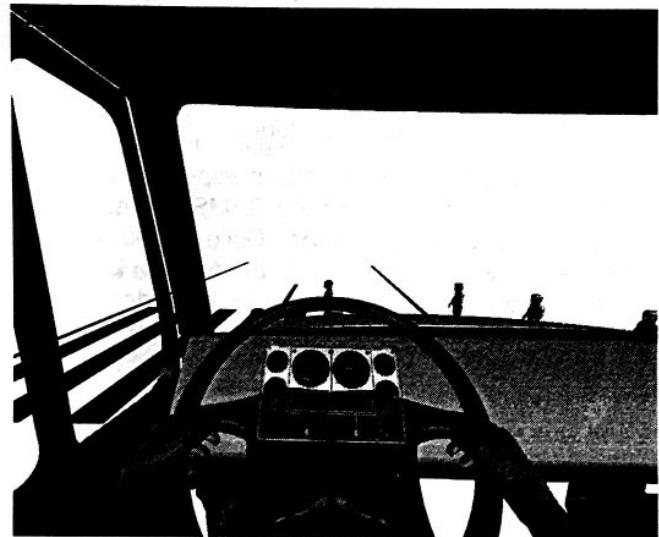


Figure 5. Visibility for a 5% US Female with Hood Design 1



Figure 6. Visibility for a 95% US Male with Hood Design 1



Figure 7. Visibility for a 5% US Female with Hood Design 2

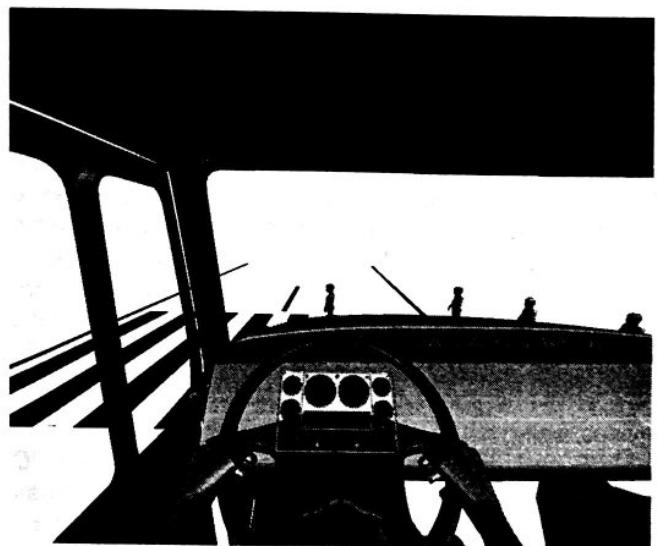


Figure 8. Visibility for a 95% US Male with Hood Design 2

MIRROR VISIBILITY – Another major ergonomic and safety factor is mirror visibility. In order to test mirror visibility, a real truck with proposed mirrors usually has to be set-up and tested with drivers. Two issues are of importance:

- a. unobstructed visibility to the mirrors
- b. indirect visibility as covered in the mirrors

For indirect mirror visibility, RAMSIS has a mirror analysis function that lets the designer simulate mirror reflections based on specific eye point locations. Any trimmed surface in CATIA can be transformed into a mirror. RAMSIS calculates and displays a view volume. Vision rays from the manikin's active eye are projected to each segment of the mirror edge curve and reflected, thus visualizing the limits of the possible mirror view. This allows us to optimize a mirror design for specific truck applications. For example, we can evaluate the effect of mirror size, shape, radius of curvature and effects of mirror location and orientation on mirror coverage.

Figure 9 shows a top view of a mirror evaluation study. The ground intercepts for the vision rays for a 95% male and 5% female are shown. Figure 10 shows a side view with the reflected vision rays and in Figure 11 a vision ray intersecting one of the child manikins. The area below the vision ray is visible to the driver.

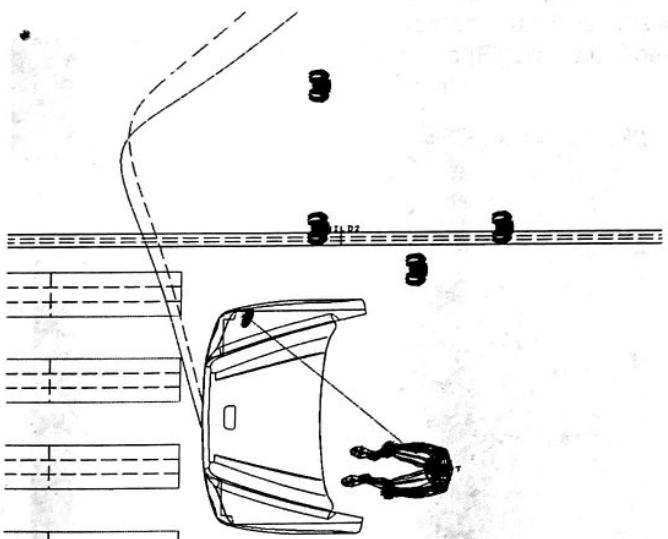


Figure 9. Top View of Mirror Reflective Ray Ground Intercepts

ARM REACH AND FORCE EVALUATION – At Freightliner we also use RAMSIS to design and evaluate the interior vehicle lay out such as dash design and control locations. Here we use RAMSIS to either evaluate proposed or existing control locations on the dash or to develop optimized locations early on in the design process. Where appropriate, we also perform maximum arm force evaluations that are posture dependent in addition to the reach evaluations.

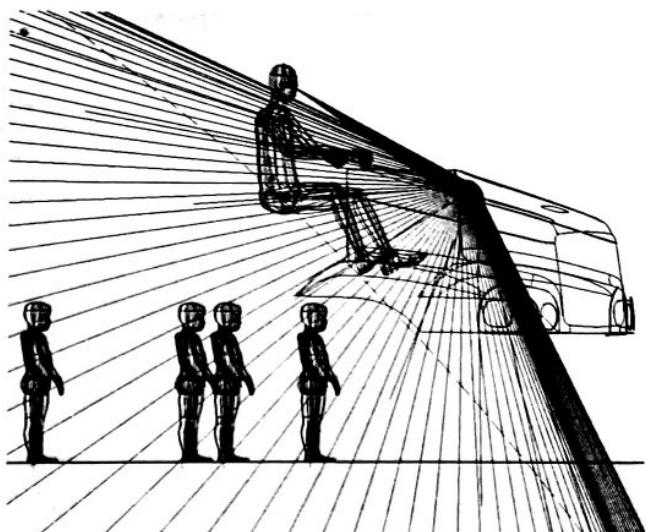


Figure 10. Side View of Mirror Reflective Rays

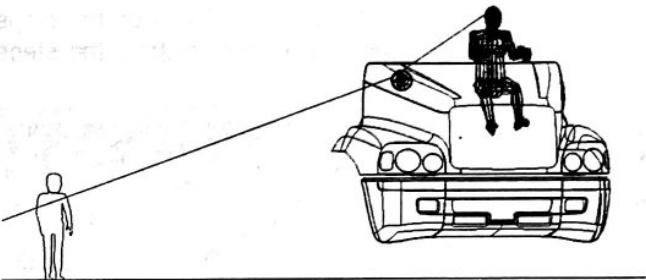


Figure 11. Front View of Mirror Reflective Ray Intersecting Child Manikin

In the arm reach and force evaluation example we show how we optimized the dash location of an automatic shifter handle.

Due to space limitations, the shifter had to be dash mounted with the shift action moving from right to left. First we determined the maximum 3-D reach envelopes for our driver population sample. These reach curves represent maximum reach zones on the dash in which the shifter handle should be located. Next, we optimized the shifter location within the dash reach zone based on maximum force analysis with 5% females. The criterion was to find the location that requires the least effort to engage the shifter handle. The study also provided us with design information on maximum allowable efforts for a new shifter design. Figure 12 shows an overlaid 5% female and 95% male reaching for the shifter. The figure includes 3-D reach curves for three sample manikins: 5% female, 5% male and 95% male in stature.

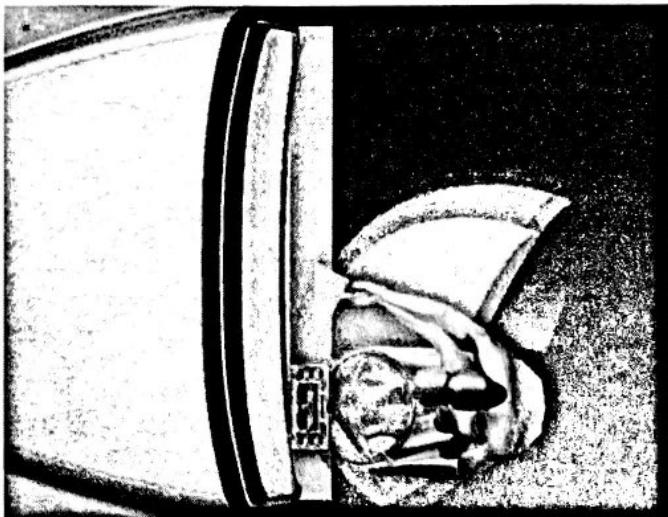


Figure 12. Overlaid 5% Female and 95% Male Reaching for Dash Mounted Automatic Shifter

ENTRY EVALUATION WITH RAMSIS – Cab Over Engine (COE) trucks are very difficult to enter and exit. Drivers have to pull themselves up into the cabin with handles. The steps are offset from the door opening due to tire space needs. After the driver climbs up the steps he/she has to move sideways to transfer from the steps into the cabin interior (Figure 13).

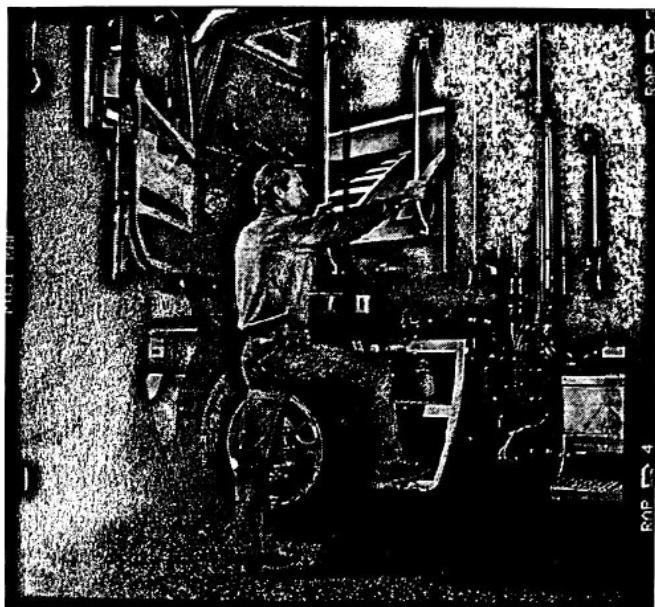


Figure 13. Driver Entering the Argosy Cab with Traditional Steps

With our Argosy COE we introduced swing out steps. This allows drivers to enter or exit a cab similarly to walking up and down stairs. With this design the stairs swing out from below the cabin, resulting in a reduced swing out angle for the door.

There was a concern that a large truck driver would not be able to fit through the door opening, but in a very short time we were able to demonstrate that a very large male has ample room. We created a US male of 95% stature

with a weight of 270 lbs. We used this manikin to visually show how much space is available to such a large driver while entering the Argosy cabin. Figure 14 depicts a heavy set and an average weight manikin. Both manikins are of the same stature and proportions (leg to torso length) but differ in weight. Figure 15 shows the heavyset manikin entering the Argosy cab.

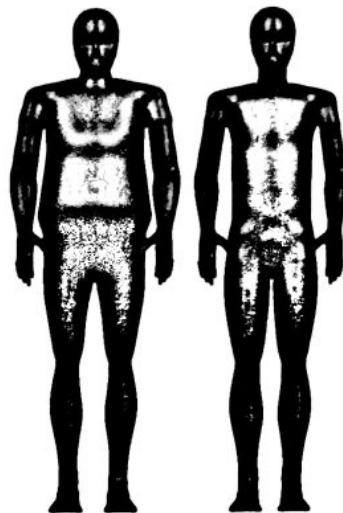


Figure 14. Heavy Set (270lb) and Average Weight Male Manikins of 95% Stature

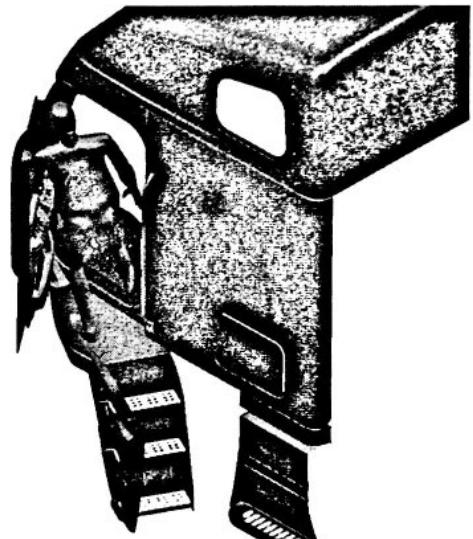


Figure 15. 95% Male of 270 lbs. Entering Argosy Cabin with Swing-Out steps

SLEEPER CAB EVALUATION – The sleeper cab is an important area for the driver to rest during breaks on long-haul trips. Often husband and wife teams are on the road and it is important to provide easy and safe access to the beds.

RAMSIS manikins are used to evaluate the ease with which short and tall persons are able to get into and out of the beds and to optimize grab handle locations (Figure 16).

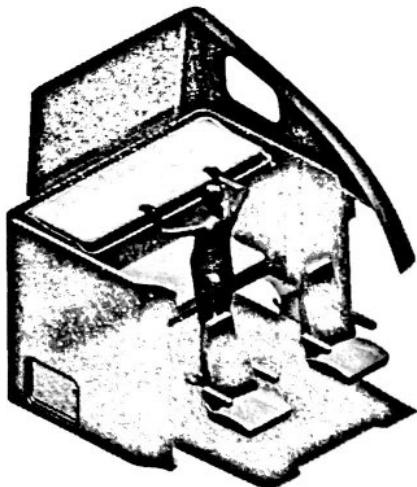


Figure 16. A 95% Male Getting into a Bunk Bed.

As these examples show, many of the ergonomics issues can be evaluated and solutions found with a 3-D human model. This can be done quickly and cost-effectively. Changes to a design in a CAD environment are faster and less expensive than when a change to an existing buck has to be performed or to an already designed structure. Another helpful feature of 3-D human modeling software is that the results can be put into the correct context and visually presented, which is easily understood by non-ergonomic experts (Figure 17). Thus it can effectively aids the decision-makers.

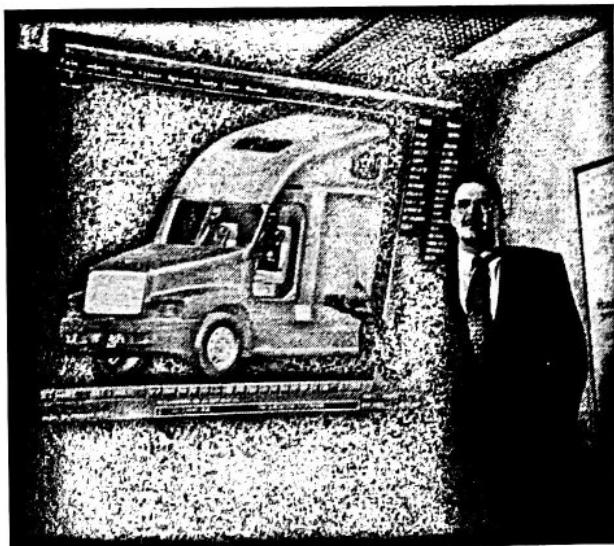


Figure 17. Presentation in the Ergonomic Visualization Room

BUCK AND FIELD TESTING

Once a concept has been developed with RAMSIS in the CAD environment we verify and optimize the design with test subjects in either bucks or modified driveable trucks, if needed. For this we must ensure our subject pool is representative of the truck driving population. In order to achieve this, we have established an internal

anthropometric database that allows us to draw on a subject pool that represents 5% females to 95% males of varying body proportions and weights. This subject pool includes engineers, managers and senior managers in addition to test fleet drivers. Figure 18 shows data collection during a buck study. The inclusion of senior management in our buck and drive evaluations is important in that they can experience disadvantages and advantages of certain design proposals, thus aiding in the decision making process.



Figure 18. Data Collection during Buck Study

EXAMPLES OF ERGONOMIC INNOVATIONS AT FREIGHTLINER

Recently Freightliner has introduced three ergonomic innovations to improve driver ergonomics, safety and comfort.

SMARTSHIFT – The SmartShift allows drivers to shift with fingertips while keeping their hands on the steering wheel (Figure 19). It is mounted to the steering column and provides a convenient interface with shift-by-wire transmissions such as the Meritor SureShift and the Eaton AutoShift. RAMSIS was used to ensure an optimized location and orientation to meet the following criteria:

- Minimize distance to steering wheel for easy finger tip reach for small hands
- Maximize distance to steering wheel to provide hand clearance for large hands when turning the wheel
- Ensure an unobstructed view to the SmartShift for drivers ranging from 5% females to 95% males.

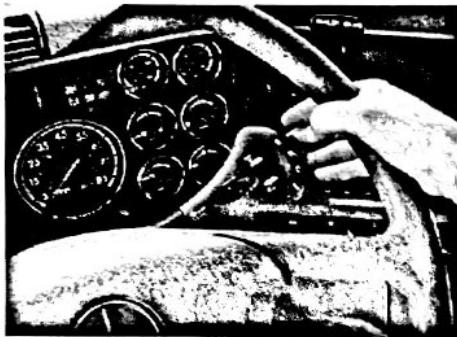


Figure 19. SmartShift

FREIGHTLINER PROPRIETARY SEAT PROGRAM: EZYRIDER – Since heavy-duty truck drivers spend up to 10 hours each day behind the wheel and the majority drives over 100,000 miles a year, it is essential to maximize seating comfort. The advantage of developing a seat in-house is that this allows us to optimize the seat and seat suspension to our truck chassis to optimize driver comfort and minimize vibration discomfort.

Updated anthropometric data and seat design practices were applied to develop seat dimensions that accommodate today's varied and changed driver population. It was critical to make the seat highly adjustable to meet the wide range of body types and the increasingly diverse driver population. The EzyRider's high back cushion is 38 mm taller than that of our standard seat, for better head and neck support, 75 mm wider in the shoulders, for better upper back support, and 38 mm wider in the lower seat cushion, to accommodate larger drivers. The lower seat cushion can be extended for drivers with longer legs.

The seat design was evaluated and optimized based on feed back from test drives. During these test drives, each driver team drove several thousand miles non-stop with each seat to evaluate long term seating comfort.

In addition we tested and developed easy to see, reach and use seat controls that are intuitive. Seat height and lumbar support are adjusted by a control with the shape and motion of the seat itself. For team drivers, the seat features easy to see fore/aft and back rest seat position numbers printed on the controls. To return the seat to the desired configuration, the driver needs only adjust the seat to the numbers that mark his or her preferred seat position (see Figure 20).

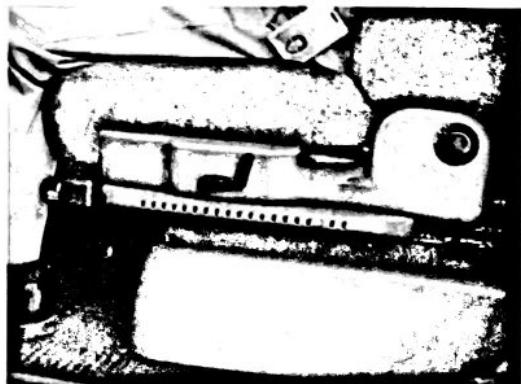


Figure 20. Seat with Seat Controls

FREIGHTLINER ADJUSTABLE PEDALS – To increase driver comfort and accommodate varying body sizes, Freightliner is the first truck manufacturer to offer adjustable pedals in heavy-duty trucks. The adjustable throttle, brake and clutch pedals move 75-mm rearward from the standard position, toward the driver and are controlled by a switch on the dash (Figures 21 – 22). Drivers of shorter stature or those with shorter legs are able to more comfortably reach the foot pedals. This is especially important for women truck drivers, who tend to be shorter than men. The adjustable pedals also benefit heavier drivers since these individuals can move the seat back to increase belly room and at the same time adjust the foot pedals rearward for easier reach.

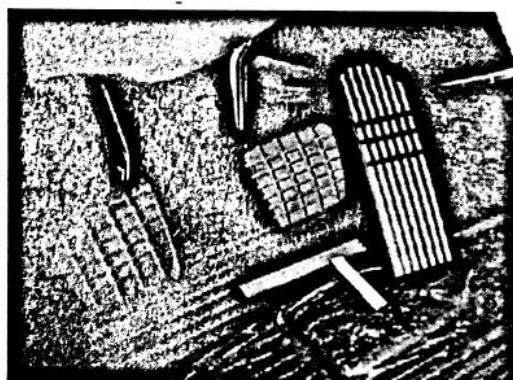


Figure 21. Adjustable Pedals in Full Forward Position

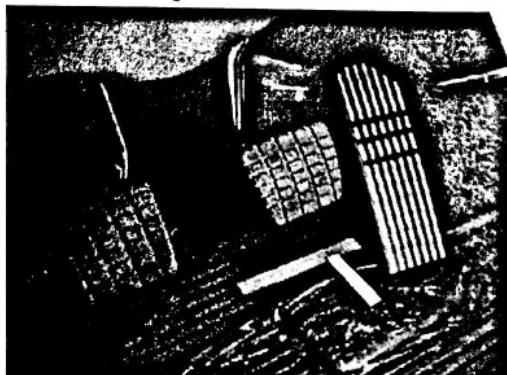


Figure 22. Adjustable Pedals in Full Rearward Position

CONCLUSION

To optimize driver comfort, trucks have to be designed and tested with a view to ergonomic issues. This is especially important since truck drivers spend long days in their trucks, often driving 100,000+ miles a year. To achieve this Freightliner has a dedicated Ergonomics group to test, develop and implement optimized ergonomic designs in its trucks. The use of the 3-D CAD Human Model RAMSIS for ergonomic design allows us to provide high quality information early on in the truck development cycle without expensive subject testing and physical mock-ups. Not only can we provide this information faster, but we are also able to investigate many different design iterations quickly and cost-effectively. In addition, we can generate RAMSIS ergonomic information as powerful images with correct driving environments that are easily understood. This can aid in review and decision making during the design and engineering process.

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