SIMULATION-BASED EDUCATION: DEVELOPING TOMORROW'S AUTOMOTIVE ENGINEER

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ABSTRACT

It's more relevant than ever before for practicing automotive engineers to not only understand how to use simulation tools, but to understand how to use simulation tools properly for design synthesis within a digital or virtual environment. This is the primary motivation for the joint effort between Kettering University and MSC.Software Corporation to develop the ***Vehicle Durability and Simulation Center*** at Kettering University. The innovative vision for the center is to develop future automotive engineers with a strong focus on design simulation and analytical validation

This paper will not only discuss the very important role of engineering education for the preparation of design simulation engineers in the automotive industry, but will also discuss the role of the *Vehicle Durability and Simulation Center* in the creation, documentation, and dissemination of design simulation knowledge.

Today's industry requires engineers to design better products, with improved performance, in less time, and with less cost. This is a result of increasing worldwide competition to decrease the time-to-market, which has necessitated the need to reduce the gap between design knowledge and cost commitment. This goal often necessitates incorporating interdisciplinary design and manufacturing constraints, which requires development of virtual or digital environments for real-world design simulations. This goal also requires both the development of sophisticated design simulation software and, of equal importance, engineers able to design and develop products in both the virtual and real worlds.

1.0 INTRODUCTION

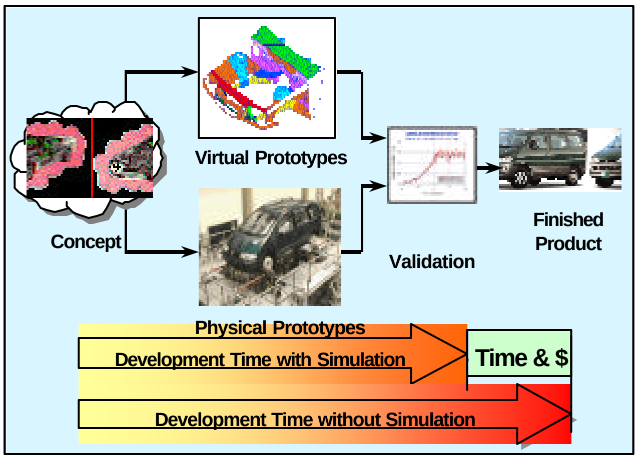
We live in a time of rapid change. The world increasingly relies on technology for economic growth and job development. At the same time the United States is making the difficult transition of refocusing a significant amount of its technology investment from national security to international economic competitiveness.

The automotive industry faces significant challenges including:

- international competition,
- environment concerns,
- an increasingly diverse population, and
- rapid growth in information technologies

The automotive product development process must be continually improved in order to meet the above challenges. Typically, the significant portion of a vehicle's development cost and design cycle time is related to hardware build, vehicle testing and proving ground validation. This equates to three to five years of effort and hundreds of millions of dollars. Additionally, a typical car program design cycle, from concept to prototype build, can only be fruitful if federal safety requirements and proving ground tests are successful.

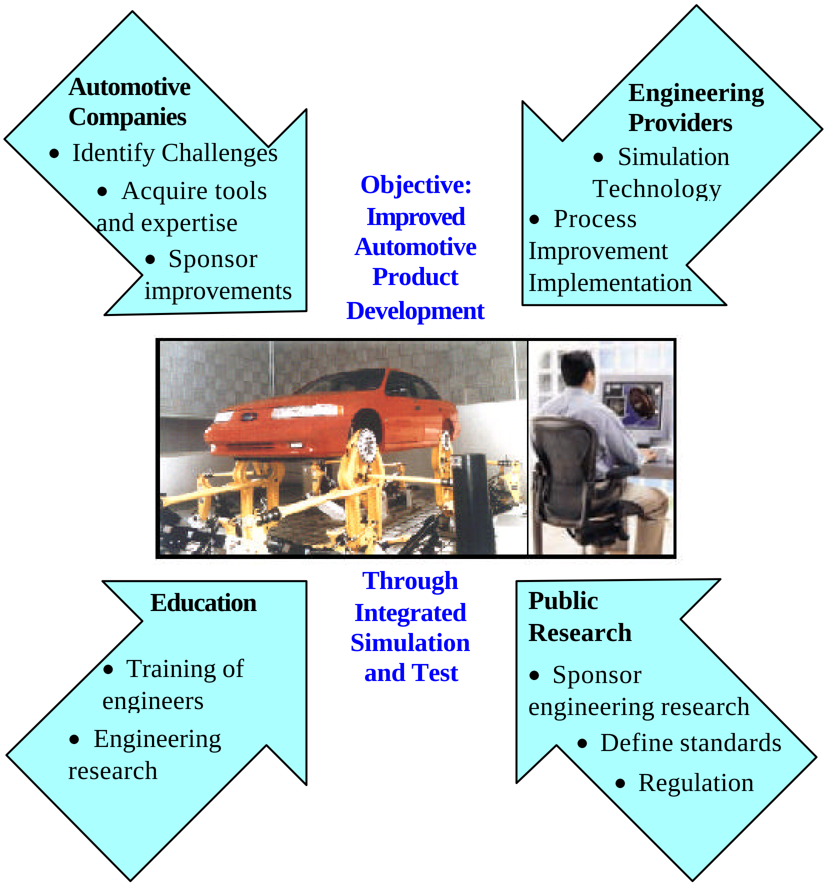
While several modeling and testing tools have been developed to design for safety requirements such as crashworthiness and occupant protection using finite element analysis and its derivatives, the proving ground durability tests are still governed by the old design philosophy: *"build, test, failure, re-build."* This philosophy, combined with the pressure of meeting production and tooling schedules, usually results in several iterations, long design cycles, wasted hardware, and loss of market share. While engineers and designers are very busy trying to meet production deadlines the knowledge gained during several iterations to successfully pass proving ground requirements is often lost and seldom carried to the next car program.



Finite element analysis is the cornerstone for the virtual evaluation of structural performance under environmental loading, while multi-body analysis is the cornerstone for virtual load prediction. Even so, the need to translate this performance to product attributes, such as durability, is the key for the development of critical analytical validation tools. As such, a promising process enhancement is to shift from using computer simulation as an analysis tool solely, to using it within a complete analytical vehicle design, development, and validation process. This shift accordingly creates a need for specialized tools to lead these analytical vehicle design processes.

1.1 Opportunity for Collaboration

Industry, educational institutions, engineering providers, and government agencies all have important roles in using simulation to improving the product development process. For example, ***Industry*** is required to acquire and develop the right tools and expertise to maintain their competitiveness. This will often involve sponsoring improvement programs where internal and external resources are brought together to collaborate. Accordingly, the automotive companies (OEMs and suppliers) have the role of assessing their competitive situation and determining what is required of their engineering process.



Educational institutions have the role of providing the core professional preparation for the technical professionals who carry out the automotive development process. The education of engineers must prepare them for the multi-disciplinary nature of the problems they will face. Accordingly, engineering research and education have a central role in our increasingly technologically based society.

Engineering Providers are organizations that provide software and/or services to improve engineering capability, competence and process. They have the role of responding to the needs of the automotive industry by providing the right engineering software and providing people who can help implement new technology developed by the engineering research community.

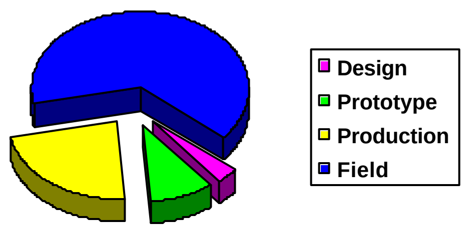
Government Agencies have three roles to play in automotive engineering. They have the opportunity of investing government funds to promote engineering research that lead to improved automotive engineering for increased public safety. The government also defines standards that help automotive companies interact with each other. Lastly, government agencies can help ensure that regulations are applied to serve the public good while not impairing the ability of the automotive industry to function with a reasonable level of business success.

Most interactions between the above-mentioned groups occur informally. We propose that a more formal interaction between the various groups will lead to increased value for all consortium members.

2.0 MARKET ANALYSIS

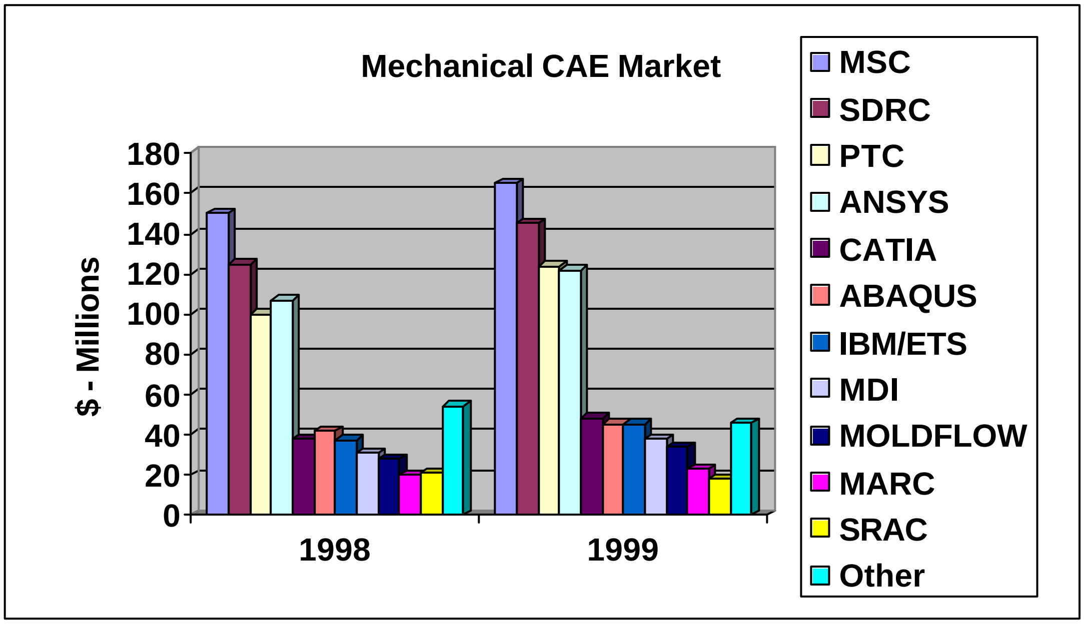
Although Computer Aided Engineering (CAE) has a significant potential to improve product quality, reduce manufacturing cost and time, and to reduce the time-to-market, the automotive industry has not fully achieved the available potential. Historically, CAE has failed to deliver results in a timely manner consistent with the rapid pace of the automotive engineering design process. As such, CAE has failed to exert a major influence on up-front design decisions. Rather, CAE simulation results are often used to merely validate previously determined designs. However, because design changes that are made later downstream can cost more than correct up-front decisions, CAE simulations can offer much higher benefits when employed in the initial up-front stages of product design.

For example, product design determines 75 percent of manufacturing cost. Roughly two-thirds of design cost result from decisions early in the design process. According to data collected from a broad spectrum of automotive manufactures over 15 years, durability design errors trapped early in product development cost less by factor of 20 as compared to durability failures detected after field release. The pie chart to the right shows the relative cost of automotive durability failures during the various phases of the product life cycle. The cost of product repairs increases more than threefold during the pre-production or prototype stage, compared with corrections prior to the prototype. This ratio increases to more than 7:1 for errors detected during production. The relative cost of correcting a product released to the field can be catastrophic - more than 20:1 as compared to pre-prototype corrections. Such product recalls or replacements can affect customer loyalty, and has an adverse affect on lost production time and potential sales. The automotive industry, therefore, benefits tremendously from the early detection of durability problems during the prototype or pre-production stages. Early failure detection means faster resolution at a lower cost and, an increased probability of product success.



A variety of CAE software can be applied to automotive durability analysis. For example, finite element analysis is the cornerstone for the virtual evaluation of structural performance under environmental loading, while multi-body dynamics is the cornerstone for virtual load prediction. Additionally, fatigue analysis software predicts component life depending on the accumulated damage over the product life cycle. Even so, the need to translate this performance to product attributes, such as durability, is the key for the development of critical analytical validation tools, and of even more importance, analytical validation processes. As such, a promising process enhancement is to shift from using computer simulation solely as an analytical validation tool, to using it throughout the analytical vehicle design, development, and validation process. This shift accordingly creates a need for specialized CAE tools, increased expertise, and sub-process enhancements to more fully impact these overall vehicle design processes.

The 1999 Mechanical CAE market was approximately 860 million dollars with a projected growth to nearly one billion dollars in 2000. The breakdown for 1998-1998 is shown below as:



As previously stated, within the CAE software arena, several modeling and testing tools have been developed to 'design for safety' requirements such as crashworthiness and occupant protection using finite element analysis and its derivatives. However, although durability related failures are the single most expensive warranty cost, proving ground durability tests are still governed by the old design philosophy: *"build, test, failure, re-build."* This philosophy, combined with the pressure of meeting production and tooling schedules, usually results in several iterations, long design cycles, wasted hardware, and loss of market share. While engineers and designers are very busy trying to meet production deadlines, the knowledge gained during several iterations to successfully pass proving ground requirements is often lost and seldom carried to the next car program. As such, integration of design simulation or "virtual prototypes" as indicated above is critically important to reducing the gap between design intent and cost commitment. This allows engineers the opportunity to explore the design space, prior to cost commitment, and thereby refining (reducing) the range of design variables for physical testing.

There are four reasons why the automotive industry struggles with implementing CAE up-front in the design process. They are:

- A limited ability to translate qualitative design attributes (i.e. crashworthiness, ride & sound quality) to quantitative CAE design simulation targets (i.e. pressure, deflection).
- A limited ability to develop CAE knowledge tools that correlate with physical testing. These tools can ultimately guide the design process through experimental correlation of simulation software.
- A limited ability to integrate design, simulation, and synthesis, through enhanced engineering education and training to improve the product design process.
- A limited ability to integrate a CAE driven design processes within a historically corporate culture devoted to 'build-n-test."

To address these challenges, Kettering University and MSC.Software Corporation have a new, unique, and shared vision for improving the automotive product design process through the integration of physical testing and design simulation. This improvement requires the development of design methodologies for the concurrent application of simulation and test, or Analytical Validation. This vision is accomplished by:

- Improved CAE **software** tools allowing up-front digital design, analysis, and simulation, combined with design knowledge through experimental correlation.

- Improved engineering **education** that prepares engineers and engineering students with a firm foundation in design simulation and *Analytical Validation*. Also, there will be improved on-going training of practicing engineers on high-end CAE tools and training on state-of-the-art experimental equipment.

- Improved engineering processes that result in better **correlation** between physical test and simulation (i.e. experimentally-calibrated, and design-knowledge driven CAE software).

Toward these goals Kettering University and MSC.Software Corporation are establishing an industrial consortium for the development of the **Vehicle Durability Simulation Center (VDSC)** at Kettering University. The mission of the VDSC is to provide a full-vehicle analytical and physical durability educational facility to assist the efforts of the automotive industry to improve overall vehicle quality and concurrently reduce time-to-market. Other engineering suppliers (CAD/CAM, CAE, and Test) will participate in the consortium. Technical and financial support from automotive OEM's and suppliers is needed to move forward. The return on investments in this center will be many times over through improved automotive engineering processes. For example, as previously stated the 2000 CAE simulation market is estimated to be one billion dollars while the

2000 physical testing market is estimated as $500 million dollars world wide. Additionally, most OEM estimate an average cost of $100 million dollars for the development of any new automotive platform. As such, the anticipated consortium annual support level is on the order of less than 0.5 percent of the cost for a new automotive platform development.

In summary, the value of leveraging existing investments in physical test and simulation is high. Therefore, participants in this program will enjoy a competitive advantage over those who do not participate. This is especially important considering the fiercely competitive global world markets where a decreased time-to-market with an increased product quality is not only expected, it's demanded.

3.0 THE VEHICLE DURABILITY SIMULATION CENTER

The main objective of the collaborative efforts of Kettering University and MSC.Software Corporation is to establish a consortium for the development of a full vehicle analytical and physical durability simulation center. The mission of the proposed *Vehicle Durability Simulation Center (VDSC)* is to assist the efforts of the automotive industry toward improving overall vehicle quality and concurrently reducing time-to-market.

The physically correlated analytical tools developed by the VDSC will be used to support activities as they relate to teaching, applied research, and on-going training for industry engineers. This center will help the automotive industry to utilize durability information from past car programs to guide the "design for durability" efforts of future programs. The laboratory will focus on fundamental research for the development and validation of physically correlated analytical multi-axial synthesis durability tools, which currently do not exist. The developed multi-axial durability tools can be applied to different design phases of automotive structures, systems, and components under multi-channel durability schedules. These physically correlated analytical durability tools utilize proving ground data of previous vehicles to relate the entire multi-channel durability schedule to the fatigue life on the sheet metal critical planes and welds. The resulting correlated durability simulation using advanced CAE tools integrated with analytical load data from dynamic simulation, will help decrease the design cycle time and reduce or eliminate hardware cost. This, in turn, will help bring new automotive products to market in a shorter time and increase the productivity of the American automotive industry.

The Vehicle Durability Simulation Center will be housed in the new Mechanical Engineering and Chemistry Building currently under renovation. Originally constructed in 1941, has 82,000 gross square feet on two floors and will be expanded to include a third floor for Environmental Chemistry. The Mechanical Engineering and Chemistry Building historically represents the assembly location for the original Corvette prototype and was donated to Kettering University by GM Delphi in June 1995.

In addition to the Vehicle Durability Simulation Center, the Mechanical Engineering and Chemistry Building will house several classrooms, faculty offices, engine test cells, an hemi-anechoic chamber, a machine and fabrication shop, the SAE Design Center, the Bioengineering & Occupant Protection Laboratory (i.e. crash lab), and other research and teaching laboratories for Mechanical Engineering and Environmental Chemistry.

The Mechanical Engineering and Chemistry Building renovation involves 3000 square feet for the Vehicle Durability Simulation Center computation and testing facilities. The renovation will include the installment of hydraulic systems, cooling systems and seismic foundation required to operate the actuators of multi-axial multi-channel variable amplitude durability simulation equipment. The renovations will allow for the virtual simulation and physical tests to exist jointly. This configuration will facilitate the continuous correlation between testing and analytical simulation.

The computational facility will consist of thirty-five state of the art workstations, computational server and several PC's. The durability simulation software installed on these machines will be MSC.Nastran® for structural analysis, and MSC.Fatigue® for fatigue damage calculation and MDI ADAMS® for analytical load dynamic simulation MSC.Patran ® will be used for graphical representation, pre, and post processing of data.

The physical test facility will have one 17-channel full vehicle MTS model 329 multi-axial road simulator and several component and subsystem durability testing equipment. The 17-channel simulator will be used for the durability testing of full vehicles under durability schedule measured load data. The additional testing equipment will be used for component such as doors, hoods, cradles and subsystems such as front and rear suspensions.

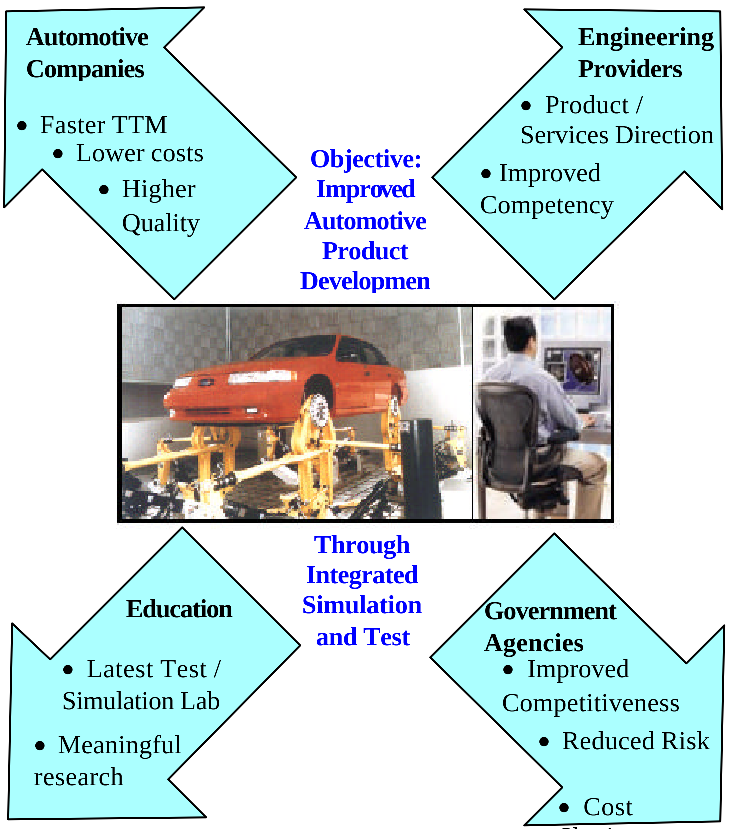
The Vehicle Durability Simulation Center facility will be used for research, development teaching and training. To conduct research in the area of fatigue and durability, accurate simulation for the major damaging events of the multi-axial multi-channel variable amplitude loading conditions is required. The simulation software will be used to simulate the different durability schedule events and profiles to predict load histories at the critical locations. These loads will be correlated with the measured proving ground measured loads and load correlation factors will be developed before conducting fatigue life simulation. The load correlation factors will be continuously developed, compiled and studied for different vehicles, proving ground events and critical locations. The developed correlated database will be used to enhance the software prediction and/or as input factors in the design analysis process. The correlated database loads will be also used to drive the full vehicle simulator in order to correlate the physical damage with that of the measured loads. The ultimate objective for the load correlation research is to reduce or eliminate the dependence on load measurement vehicles.

The correlated analytical loads and the measured loads will used as loading conditions to perform structural analysis MSC.Nastran® to obtain the stress history at the critical locations. These stress histories along with the material fatigue properties will be used to predict the fatigue lives at the critical locations. The predicted fatigue lives from the analytical loads and the measured loads will be used to correlate with the fatigue lives of the physical tests. The fatigue life correlation factors will be continuously developed, compiled and studied for different vehicles, proving ground events and critical locations. The developed correlation database will be used to enhance the software prediction and/or as input factors in the design analysis process. The ultimate objective for the fatigue life correlation research is to reduce or eliminate the dependence on durability vehicles in the design and development process.

In addition to helping the automotive industry consortium members in their analytical design and validation, the center will also provide their suppliers with the most needed analytical design and validation tools for the development of subsystems and components to meet the Vehicle Technical Requirements. This will help the consortium automotive members meet their design targets without revealing their proving ground data and loads.

4.0 Vehicle Durability Simulation Center: Impact and Benefits

Our society faces significant challenges including international competition, the global environment, an increasingly diverse population, and a rapid growth in information technologies. As a result, we live in a time of revolutionary change. Not only is the world relying increasingly on technology for economic growth and job development, but also the nation is making the difficult transition of refocusing a significant amount of its technology investment from national security to international economic competitiveness. At the same time, we view technology as important in helping solve many difficult societal problems.



Industry, government agencies, and educational institutions all have important roles in meeting these challenges. Higher education, in general, has the role of providing the professional preparation for the next generation of business leaders, technical professionals, government officials and educators at all levels. Engineering research and education, in particular have a central role in our increasingly technologically based society. The education of engineers must prepare them for the full disciplinary nature of the problems they will face. As such, the VDSC will benefit higher education through the training of students on state-of-the-art testing equipment and education of the latest CAE design simulation methodologies. This focus will subsequently provide better engineers well equipped to support the increasing demand for higher quality products with reduced time-to-market, which of course is a benefit for the automotive industry. Automotive OEM's also benefit from having access to an on-going training facility for engineers and not affecting their internal production facilities which are profit driven.

Engineering providers benefit from the development of improved products, tools, and services to aid OEM's and suppliers. They also benefit from increased technical competency of their engineers, which contributes to the intelligent capital of the organization.

Government agencies, such as NSF (National Science Foundation) and DOT (Department of Transportation), benefit from supporting the automotive industrial sector through developing safer products for public use and through the education of engineers more tuned to public safety transportation design issues. Additionally, the design for durability tools and processes could be applied to other transportation industries such as aerospace, ships, and rail transportation.

In addition to helping the automotive industry consortium members in their analytical design and validation, the center will also provide their suppliers with the most needed analytical design & validation tools and processes for the development of subsystems and components to meet the Vehicle Technical Requirements. This will help consortium automotive members meet their design targets without revealing their proving ground data and loads. This will be the most significant impact for suppliers seeking to reduce time-to-market through collaborative efforts, while maintaining their competitive position within the market.

Finally, establishing the Vehicle Durability Simulation Center at Kettering University will help in attracting graduate and undergraduate engineering students, and practicing engineers, seeking training to Michigan and the Flint area.

4.1 KETTERING UNIVERSITY

Kettering University has been providing up-to-date, engineering education and research training for over seventy-five years and is the nation's only 5-year private cooperative engineering and management college which requires an undergraduate research thesis. Through a close relationship with over 700 North American businesses as well as industry and government agencies, Kettering University provides undergraduate engineering programs in mechanical, electrical, industrial, and manufacturing engineering, in addition to applied science degrees in applied mathematics, applied physics, computer science, environmental chemistry, and management systems. These programs combine academic studies with a 5-year cooperative industrial experience. The engineering graduate program at Kettering offers a Master's of Engineering with specializations in one of the fields of Mechanical Design, Automotive Systems, or Manufacturing Engineering, and is accredited by the Commission on Institutes of Higher Education of the North Central Association of Colleges and Schools.

Building for the Future

As industrial and education leaders, Kettering University and MSC Software Corporation prepare for the 21st Century challenges affecting engineering practices and education. First and foremost, technological advancement is faster and more complex now than at any time in modern history. This advancement has allowed Corporate America to drive toward the development of technologically advanced products that are cheaper, are of higher quality, and can be manufactured in a global economy, faster. This drive has necessitated the following attributes for mechanical engineering graduates and practitioners:

1. Training on state-of-the-art software and laboratory equipment.
2. Education with the latest computer aided engineering design tools.
3. Knowledgeable on current-day design methodologies.

To accomplish this vision, the Department of Mechanical Engineering at Kettering University *initiated* ***"Vision 2000: Curriculum Innovation for the 21st Century."*** The new ME/2000 curriculum is designed with the following desired attributes:

- Integration of Design, Practicality and Relevancy
- Integration of Technologies
- Integration of Quality
- Integration of Subject Matter

This new paradigm shift in engineering education requires the development of high-end laboratories to adequately prepare our graduates to meet the educational and research training needs of: 1) Our corporate partners, and 2) A technologically driven society. One laboratory that is vitally important to support the *Vision 2000* initiative is the proposed ***Vehicle Durability Simulation Center***.

For Kettering University to continue its growth as a private institution, it is more important than ever for students to have a strong applied research background in preparation for new challenges and opportunities evolving in today's changing world. Our response to this challenge is the renovation of current mechanical engineering research laboratory facilities to accommodate increased sponsored research and research training needs. These state-of-the-art facilities will not only enhance Kettering University's fundamental research abilities, but will also serve the research needs of mid-Michigan. It will improve the interdisciplinary and collaborative research between regional educational institutions, government agencies and industry. The planned 2001 development will allow Kettering University to accomplish its mission to remain on the leading edge of engineering education.

KETTERING UNIVERSITY – BENEFITS FOR 21ST CENTURY STUDENTS

In an era of increased competition and automotive globalization, companies can no longer afford to spend 4-6 years training graduate engineers. Kettering University VDSC would help produce engineers trained on industry standard equipment, thereby shortening the time to train engineering graduates. Additionally, the following benefits are noted:

- Students trained on state-of-the-art equipment will enhance their chances for sponsorship.
- Improved student teaching through enhanced faculty skills and knowledge gained from their applied research on state-of-the art equipment.
- Students will have exposure to, and have training and education on, new and emerging technologies.
- Development of new courses and specialties due to newly emerging technologies will enhance students education.
- Sponsorship and scholarship opportunity for undergraduate students, funded by on-going applied research. The experience gained will assist in long-term sponsorship.
- Provide facilities not available at sponsor's location for students' 5th year thesis work.
- Enhance students' performance and participation in national competition projects through the use of state-of-the-art testing and simulation equipment.
- Create opportunity for funding graduate students through applied research & consulting.

The fundamental guiding principle for Kettering University to maintain its competitive edge as America's leading educational partner in automotive engineering design, and applied automotive engineering research, is to provide the automotive industry with state-of-the-art facilities combined with advanced technical and educational services to help develop automotive products 'faster', 'better' and 'cheaper.'

4.2 MSC.SOFTWARE CORPORATION

MSC.Software Corporation (MSC) is the world's leading supplier of mechanical computer-aided engineering (MCAE) software and services. MSC's solutions are used by the aerospace, automotive, electronics, shipbuilding, power generation, consumer products, industrial machinery, medical, civil, and general manufacturing industries.

MSC's corporate headquarters are in California, USA, with major development facilities there, in Los Angeles (California), Costa Mesa (California), San Francisco (California), in Lowell (Massachusetts), and in Gouda (The Netherlands). MSC employs more than 900 people in 47 offices in North America, Europe, and Asia.

MSC was founded in 1963, and is a public company with stock traded on the New York Stock Exchange (symbol MNS). Revenues for the most recent fiscal year (which ended December 31, 1999) were $135M. By region, 46% of the revenue is in the Americas, 28% is in Europe, and 26% is in Asia Pacific. By industry, 44% of the revenue came form aerospace and defense, 27% is in automotive and land-based transportation; and 29% is in other industries.

MSC is the world's largest provider of mechanical computer-aided engineering (MCAE) strategies, software, and services. These solutions are built on an unmatched foundation of engineering expertise, technology leadership, and superior customer support. MSC's strength is its ability to anticipate the emerging needs of its customers, identify their requirements, tailor software products to those needs, and then follow up with implementation and strong user support.

MSC.SOFTWARE IN THE AUTOMOTIVE INDUSTRY

All major automotive manufacturers in the world use MSC software and services. While most companies use the same MSC software products, the level of interaction between MSC and auto manufacturers vary. MSC prefers to establish deep relationships with its customers. MSC understands the importance of protecting each customer's proprietary information and the importance of protecting the relationship.

Substantial MSC resources are invested in software testing to ensure that only proven technology is brought to market. MSC places a great deal of emphasis on end-user support through documentation, training, hotline support, users' conferences, and Web communications. MSC works closely with customers to help them integrate MSC software and professional services into their design, analysis, and manufacturing environments. With the largest development, technical support, and sales organizations in the CAE industry, MSC is uniquely positioned to serve its customers in every location throughout the world.

MSC's market leading position is very beneficial when working with computer hardware vendors and other software vendors. MSC has over 60 third parties in the Global Partner Program. For example, hardware companies work with MSC to tune MSC software to run better on their hardware. In the case of Hewlett-Packard, MSC is their *only* global MCAE partner. In addition, every major CAD supplier has an interface to MSC.Nastran. Every major modal testing package has an interface to MSC.Nastran, as do the kinematics programs. MSC takes very seriously its role as the MCAE industry leader.

MSC.SOFTWARE - BENEFITS

MSC joined Kettering University in the earliest stages of this project, when the concept of the Vehicle Durability Simulation Center was developed. The motivation for our interest is explained below.

Benefits of the Vehicle Durability Simulation Center for MSC's Software Products

The purpose of MSC technology is to simulate reality, doing on the computer what is otherwise done with physical testing. The correlation between the results predicted by MSC's Software Products and physical testing should be close. Our customers are able to achieve good correlation, but some of them would like additional resources to help them.

The Simulation Center will help provide needed resources to our customers while helping us refine the simulation process that is contained in our software. We hope to refine our software to help our customers get more accurate results through best practices and correlation procedures that become embedded within the software.

Additionally, the following benefits are noted:

- Increase opportunity for collaborative applied research efforts with academia and the automotive industry.
- Opportunity for educational sabbaticals for MSC's scientists
- Opportunity to identify talented students who are well suited to become MSC employees after graduation.
- Attract talented faculty to do research that results in improved MSC Software.

Benefits of the Vehicle Durability Simulation Center for MSC's Customers

The Simulation Center can function as an extended training facility for MSC customers, where they can learn about the process of simulating reality side-by-side with the physical testing process. Automotive suppliers may not have access to an integrated facility such as the simulation center. Their experience with the Simulation Center will help them use MSC software more effectively.

The Simulation Center will give our automotive OEM customers access to addition simulation/test capacity and will provide them with a facility where they can direct their suppliers as the need may arise.

In summary, our mission of '*Simulating Reality*' will be enhanced by the Vehicle Durability Simulation Center.

REFERENCES

[1] Helpern, M.,“Pushing the Design Envelope With CAE - Part II”, Mechanical Engineering Magazine, December 1998, Page 72.

[2] Helpern, M., “Pushing the Design Envelope With CAE – Part I ”, Mechanical Engineering Magazine, November 1998, Page 66.