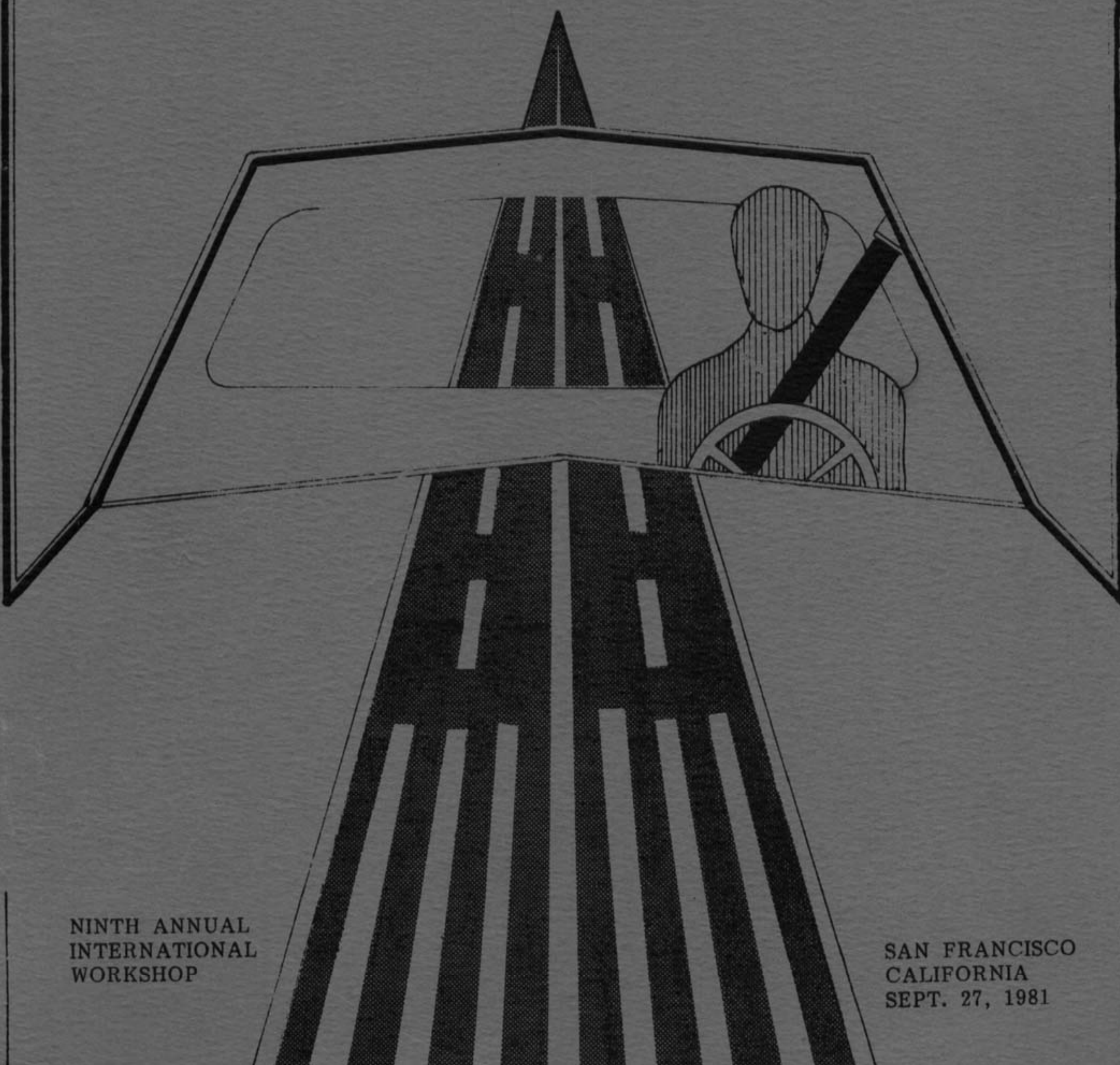
# HUMAN SUBJECTS FOR BIOMECHANICAL RESEARCH



NINTH ANNUAL
INTERNATIONAL
WORKSHOP

SAN FRANCISCO
CALIFORNIA
SEPT. 27, 1981

# INTERNATIONAL WORKSHOP ON HUMAN SUBJECTS FOR BIOMECHANICAL RESEARCH

Ninth Annual Meeting
San Fransisco, California
September 27, 1981

TABLE OF CONTENTS

## INTRODUCTION

The Ninth International Workshop on Human Subjects for Biomechanical Research was held on September 27, 1981 in San Francisco, California. The attendance was in excess of 44 for the eight scheduled presentations and a discussion session. One of the attendees was somewhat dissatisfied with the material presented because he expected to learn of new safety devices for automobiles. It is perhaps appropriate to restate the purpose of this Workshop and to reiterate the status of written papers or abstracts contained in these proceedings. The Workshop was formed by a group of researchers in biomechanics led by Mr. Arthur E. Hirsch, formerly of NHTSA. The aim of the group was to provide the research community with a forum to present new and preliminary results before they can be published in a journal article or an extended abstract. This mechanism enables workers in the field to utilize new data and techniques before they are formally published. The Workshop is not meant to supplement or in any way replace the function of the Stapp Car Crash Conference. It is held in conjunction with the Stapp Conference to facilitate attendance of both meetings.

Papers appearing in these proceedings are not to be considered as formal publications and should not be included in the bibliography of other publications. Although references to these proceedings have appeared occasionally in the open literature, this recommendation has generally been observed by the research community.

The Ninth Workshop was organized by John Melvin and Albert King and not by Arthur Hirsch who handled all of the previous meetings. However, Chi Associates has been funded by NHTSA to publish these proceedings. The chairmanship of this meeting has been put on a rotating basis, to be shared by representatives of the three hosting universities of the Stapp Conference. Carley Ward of UCSD chaired this year's meeting.

On behalf of the participants and attendees of this Workshop, we would like to extend our thanks to the Stapp Conference Advisory Committee for their support of this activity, to SAE for administrative services and last but not least to Mr. David Foust who has served as secretary of this Workshop for many years.

Albert I. King and John Melvin

## [illegible]RODUCTION

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Albert L. King and John Helwig

NINTH INTERNATIONAL WORKSHOP ON

HUMAN SUBJECTS FOR BIOMECHANICAL RESEARCH

SEPTEMBER 27, 1981

JACK TAR HOTEL, SAN FRANCISCO, CALIFORNIA

MINUTES OF WORKSHOP

The Ninth Workshop was convened at 9:00 a.m. by Dr. Carley Ward, representing the University of California at San Diego Medical School, the "host" of the Workshop. Dr. Ward explained that the chair for the Workshop will henceforth rotate among the three host universities: UC San Diego, University of Michigan, and Wayne State University. Dr. Ward reminded attendees that the Workshop is informal and ad hoc in nature, a forum for open exchange of information, and the published proceedings are not to be cited as a reference. Approximately fifty persons attended.

COMMITTEE REPORT

Report on ISO ACTIVITIES IN HUMAN IMPACT, TESTING AND EVALUATION, J.W. Melvin, HSRI.

Dr. Melvin is chairman of Working Group 4 of Sub-committee 4 on Human Exposure to Vibration and Shock, ISO Technical Committee 108 on Mechanical Vibration and Shock. Working Group 4 on Human Impact Testing and Evaluation met the week of September 21, 1981, after being inactive for several years.

The Working Group has progressed in both of its major objectives:
1) Creation of a General Guide for Human Surrogate Testing. This guide will apply to testing with cadavers, volunteers, animals and instrumented dummies (if instrumented the same way as a cadaver). The guide will prescribe minimum requirements for reporting test methods and test results for all tests with such surrogates, in an effort to encourage standardization. To permit experimental flexibility, the guidelines to be established will pertain to reporting of methods and results, rather than requiring a particular test method.

To date, the Working Group has completed the section of the guide relating to characterization of input to experiments. It is preparing the section on system response measurements and instrumentation. The group's goal is to finish the draft guide for reporting requirements by Summer 1982, so that it can be reviewed by the ISO.

2) Determine Tolerance Values for Human Impact. The Working Group is reviewing and consolidating the SAE Injury Task Force (J885 Apr. 80) and EEVC working documents. These will form the basis for a draft standard on tolerance values.

Dr. Melvin plans to report to the 1982 Workshop, with a copy of the document prepared by Working Group 4. A question was asked about accelerometer positioning for head impact analysis. Dr. Melvin noted that Working Group 4 will use the guidelines adopted by these International Workshops. ISO will request reporting of methods used to link acceleration results to three coordinate systems - anatomical, vehicle, and laboratory. These data should be applicable to mathematical modeling.

## TECHNICAL SESSION

1. RECONSTRUCTION OF SPATIAL TRAJECTORIES OF IMPACTED ACCIDENT SURROGATES FROM HIGH SPEED FILM DATA WITH THE AID OF AUTOMATED DIGITAL IMAGE ANALYSIS, P.F. Niederer, Swiss Federal Institute of Technology.

Dr. Niederer, citing the problems associated with trying to analyze motion using planar methods, described a new technique for analyzing three-dimensional motion. The method was developed for use in cadaver simulations of pedestrian impacts, where motions are very sensitive to initial position, and where targets may periodically disappear from camera view. Although the system was developed to be applicable to tests with cadaver surrogates and is in routine use, it has not yet been tested with a cadaver subject.

The method involves a mathematical transfer of space coordinates from the object being filmed to film image coordinates. When at least two clear views are available, the coordinates can be resolved into two formulas with eleven imaging parameters.The position of the object in space is thus reconstructed. An automated computer analysis is used, and regression techniques are applied when the same target is visible in three or more views.

Four cameras are used, and the object space is calibrated prior to test with a grid of ping-pong balls suspended at known positons. The grid is removed prior to test.

A video dissector camera is used to digitize the film in a field of 4096 x 4096 per frame. A microcomputer searches for the highly-reflective ring-shaped targets of interest within the 4096 x 4096 field, using 1/156 of the area. The memory for each frame can be written at film speed, so analysis is very fast and the results can be plotted on a screen immediately for interactive analysis.

Markers that disappear and reappear can be tracked by the operator, and the system is capable of interpolating that marker's trajectory while it was covered. Resolution is sensitive enough to locate a marker within 3 mm in a 7 $m^2$ field.

Dr. Niederer responded to several questions. He noted that, with a total system memory of 128K, the memory is filled with each frame, then the microcomputer focuses on the markers. The same marker in two views, as well as reappearing markers, must be identified and concatenated by the operator, as those functions cannot be automated.

Since dynamic events require maximum usefulness from a limited number of film frames, Dr. A.K. Ommaya, NHTSA, asked about the slowest practical time rate for analysis. Dr. Niederer replied that the analysis gets complicated as to frequency and amplitude of trajectories. He has obtained useful information at velocities up to 150 Hz at 500 frames per second. An increase of tenfold in film speed does not result in ten times more accurate results.

Dr. C. Ward, Biodynamics Engineering, inquired about the cost of such a system. Dr. Niederer observed that it was hard to estimate, since most of the development had been an in-house effort. The main elements cost about $36,000, and the system could realistically be valued at $100 - 200,000.

2. DEFINITION OF A BONE CONDITION INDEX FOR HUMAN SUBJECTS USED IN THORACIC TOLERANCE STUDIES, A. Fayon, Association Peugeot/Renault.

Dr. Fayon described the development of a Bone Condition Factor, a technique which may be useful in classifying ribcage strength of cadavers used in frontal and lateral collision tests. The formula for the proposed Factor has been developed through analysis of bone characteristics obtained from rib tests of cadaver subjects. The more negative the Factor, the stronger the subject's rib cage.

Analysis of cadaver test results using the Bone Condition Factor has shown that height and weight were not related to thoracic cage strength, and that age and thoracic circumference were only slightly correlated. A stronger correlation was found to number of rib cage fractures in lateral free-fall and dynamic vehicle tests. Dr. Fayon has concluded that the proposed Factor enables prediction of numbers of rib fractures and allows projections to the general population.

There were several questions. Dr. R. Eppinger, NHTSA, asked about age in relation to the Factor. Dr. Fayon replied that the Factor was developed from physical and geometric properties and therefore did not correlate well with age (r=0.6). Dr. Eppinger further asked if age or BCF could better explain ribcage strength variability. Dr. Tarriere, APR, commented in reply that the BCF is thought to be useful in explaining variability within age groups. He also noted that, within age groups, the factor predictions were more reliable for male subjects than for female.

When asked about applications of the Factor, Dr. Fayon indicated its current use is to compare test results among cadaver subjects, particularly for restraint system tests. Eventually, they hope to have a basis for predicting ribcage injury for a given at-risk population.

Dr. Eppinger noted that U.S. accident files contain only age, sex and weight data and asked if the proposed Factor could be applied to such data to preduct injury potential. Dr. Fayon believes that such applications will soon be practical as the Factor is developed for more age groups.

3. PEDESTRIAN KNEE IMPACT EXPERIMENT, M.J. Walsh, Calspan Corporation

Dr. Walsh described progress to date in an NHTSA - sponsored study of bumper effects on knee injury. Much of the initial effort was devoted to preparing an automobile front end test device which accurately simulates a real car. This device was used together with other impactors to establish characteristic knee impact data for modified and production automobile bumpers.

A significant finding is that cadaver test results can now be predicted based on impact test results with instrumented anthropomorphic dummies. The researchers are now confident that they can demonstrate trauma mitigation in cadaver tests with production and modified vehicle bumpers. They are now attempting to develop a cadaver "matching" technique so that "matched pairs" of cadavers can be tested in such a way that trauma differences can be traced directly to bumper design.

Dr. Walsh was asked if the Bone Condition Factor described earlier would have application to his research. He believes it would and he welcomes the possibility of additional standardization. He would be willing to calculate the BCF as a post-test evaluation. However, he prefers a pre-test selection test and continues to determine percent cortical area from a cross-section of long bone (usually an arm which will not be relied on for dynamic test results).

When asked about the effects of ligament strength on knee test results, Dr. Walsh noted that ligaments do not provide a good measure of knee joint strength. Rather they are useful to evaluate damage to the knee. Current post-test autopsy protocol determines percent permanent disability based on ligament damage. Dr. Walsh knows of no technique for determining ligament strength.

Dr. Tarriere asked if maximum force in the knee occurs prior to fracture. Dr. Walsh replied that he thinks so, but since the event is only 3 - 4 msec long, he has no technique for establishing time of fracture. Cineradiography might provide the answer, but while knowledge of injury mechanisms is useful, the more critical problem being addressed by Calspan's research is the mitigation of knee injury from production vehicles.

4. THE MEASUREMENT OF THE ANGULAR AND LINEAR ACCELERATION SENSITIVITIES OF THE ENDEVCO MODEL 7302 ANGULAR ACCELEROMETER, R. Sill, Endevco

Dr. Sill reported that the Model 7302 angular accelerometer is his design and described for the Workshop the measurement techniques used to evaluate the instrument's sensitivity. He described the accelerometer as a six-degree-of-freedom, single-axis piezoresistive device in which the voltage is proportional to angular acceleration around the axis. Fluid is the inertial medium and the unique design feature of the accelerometer is a pressure transducer which produces a signal in response to fluid pressure changes. The resonant frequency of the device is about 2300 Hz.

Frequency response to angular acceleration is relatively easy to determine, since x-y planes are in the plane of rotation of the sensitive axis (z-plane is parallel to sensitive axis). The design geometry tends to cancel x-y plane fluid pressures at low frequency, but at higher frequencies, higher cross-axis sensitivity occurs because of fluid buildup at the sensing diaphragm. The z-axis sensitivity is easier to measure. He has noticed occasional "ringing" effects from the instrument's natural frequencies. However, cross-talk between axes is consistent and linear.

When using the Model 7302 with signals having high-frequency components, Dr. Sill recommended: 1) Pre-filter the signal; 2) keep the gain down; and 3) apply digital filtering.

In answer to questions, Dr. Sill noted the mass of the accelerometer is approximately 17 g, but another (shorter) design configuration is being developed. The instrument is fairly fragile, in keeping with its sensitivity. C. Ward, Biodynamics Engineering, asked about signal loss due to ringing and filtering. Dr. Sill replied that signal loss is a function of the filter's phase characteristics and his filtering tests to date produced only expected results.

5. EVALUATION OF THE ENDEVCO MODEL 7302 ANGULAR ACCELEROMETER, A. I. King, Wayne State University.

Dr. King reported that WSU had briefly evaluated the Model 7302 accelerometer at the request of NHTSA, using the instrument with Part 572 dummies in sled tests. Results from a nine-accelerometer package and from film analysis were compared with those from the Model 7302. Linear sensitivity tests were also performed with the accelerometer bolted to the sled.

Test results:

Part 572 dummy. Some ringing was noted. He also discovered that analog filtering is inappropriate - only digital filtering is acceptable. Integration of the Model 7302 signal produced angular velocity results comparable to the nine-accelerometer system, and angular displacement results compared well to film data. Dr. King concluded the accelerometer is acceptable in this application.

Sled tests. With the y-axis mounted for maximum pitch effect, the accelerometer was subject to ringing. Integration of the signal produced error, but Dr. King noted that the linear accelerometer method also produces error.

Human volunteer. A 3g test was conducted, and the Model 7302 was found to have lower sensitivity at the higher natural frequency ranges.

In answer to a question on digital filtering, Dr. King said that WSU used a Fast Fourier Transform method with no analog filters. An unfiltered signal was recorded during each test.

6. A METHOD FOR THE RIGID FIXATION OF AN ACCELEROMETER PACKAGE ONTO THE SKULL OF PRIMATES, Y. K. Liu, University of Iowa

With primate subjects, measurement of angular acceleration using linear acceleration packages has been very difficult due to the thinness of the primate skull. Self-tapping screws have proven unsatisfactory. A bite plate provides reliable data but it is of limited usefulness in acute experiments and it is very expensive because a custom-made bite plate is required for each subject.

Dr. Liu described a technique which permits rigid attachment of accelerometer mounting plates. He uses a quick-setting polymethylmethacrylate called Aneuroplast as a mounting base. The resin adheres well to metal but not to fat-impregnated tissue such as the skull. To bypass this limitation, the technique involves the placement of 0-80 machine screws in the outer table of the skull. A soft rubber dam is placed surrounding the screw, then the Aneuroplast is poured and the accelerometer plate pressed into place. When the resin hardens, the rubber dam is cut away, leaving a rigid mount. This technique is being applied to planar motion experiments.

In response to several questions from Dr. Melvin, Dr. Liu stated that the technique was applicable to nine-accelerometer packages if they are mounted on a flat plane plate and supported by wider spacing on the skull. Wave motion can also be minimized by wide spacing of mounting screws. The mounting has stayed securely in place even under comminuted fracture conditions. Dr. Liu has not measured skull deformation in his tests and had no comments on the effects of skull deformation on test results using the skull mounting method. Dr. Melvin commented that HSRI has been using a maxilla/orbital ridges mounting method to avoid mounting nine-accelerometer packages at one point, and because those mounting locations do not participate in skull dynamics.

Dr. Liu answered other questions by noting that the head of the screw is against the skull for better fixation and the resin flows around the screw head. Also, the mount has remained viable over time (the longest experience to date is eight days), but bone resorption might eventually loosen the screws.

7. THREE-DIMENSIONAL MATHEMATICAL MODELLING OF DUMMIES AND CADAVERS IN SIDE IMPACT, J. Wismans, TNO.

Dr. Wismans summarized work performed in the past six months with the MADYMO human simulator model. MADYMO was developed as part of an EEC project and is used primarily in Europe. It's principal characteristics are:

- 2-D or 3-D version availability;
- arbitrary number of linkage systems and elements;
- user-defined force interaction routines.

Recent work has explored 3-D model applications to side impact, in three phases:

1) Simulation of drop and sled tests with two types of dummies. MADYMO simulated left-side-down drop tests onto spaced blocks of a Part 572 and the APROD 80 dummies. Also simulated were published sled tests of Part 572 into rigid wall and padded blocks and the APROD into rigid and padded blocks. Simulation results were consistent with test results, especially in predicting shoulder response to rigid impact. Dr. Wismans considers the model to be generally reliable in this simulation mode.

2) Simulation of a cadaver drop test. Contact loads, padding deflection and thorax deflection were predicted adequately, but chest acceleration, pelvic acceleration, time, and peak loads were not. Differences are probably due to incorrect assumptions for flexion characteristics, and a more detailed model of the thorax (currently one element) is needed.

3) Simulation of real collision. The collision involved side structure deformation and arm-rest involvement. So far, only a reconstruction test with a dummy has been simulated, with good model prediction results.

Improvements to be made to the model include better definition of joint characteristics, the possible application of finite element modelling for definition of contact area geometry and size, and modification of the velocity-sensitive ramp model for friction.

Dr. Wismans concluded that the 3-D model is workable for the conditions validated, and that for simple side impacts, 2-D simulations are adequate to predict arm-shoulder response. Among the possible future applications of the 3-D model are analysis of real collisions, computer-aided design of dummies and padding, analysis of biomechanical tests, and theoretical analysis of four different side-impact dummy designs (APROD, SID, OID, and MYRA) with both 2-D and 3-D simulations.

In the question period, Dr. Wismans noted that a large CDC computer is currently being used, but the model requires only 28K of 60-bit memory. Damping force in the model is assignable and can be zero; it is dependent on linear velocity and values have been based on "rough" experiments. Friction causes diversion of simulations compared to test results and leads to unobserved changes in direction of elements. The model requires continuous calculation and balancing of friction.

8. CRITICAL ISSUES IN FINITE ELEMENT MODELLING OF HEAD IMPACT, D. C. Viano, General Motors Research Laboratories.

Dr. Viano presented a review and critique of current models which simulate the mechanical response of the head to impact. He noted his review was from the viewpoint of understanding the programs and their limitations. He also intended to raise a "warning flag" - that none of the available models, in his opinion, truly predict head impact response. Therefore, extension of simulation results to prediction of injury is an even more remote goal.

Dr. Viano described his concept of a true "model" as one which could reasonably predict results under a large majority of impact environments without the need for adjustments and fine-tuning to accommodate the environment being simulated.

Dr. Viano briefly reviewed the several sophisticated and better-documented finite element models of the skull and brain which are currently in common usage (Ward's, Shugar's, and Hosey's). In this review, he cited what he considered to be a number of problems and "cautions to users". He stressed that these were his opinions based on his study of the available literature.

1) With linear finite element modelling (FEM), the best that can be hoped for in human situations is a reasonable response, since it is not possible to accurately model nonlinear human response using linear methods;

2) FEM requires discrete elements (boxes and time segments), while real human impact conditions are continuous tissues, abrupt boundary condition changes, and a time contiuum. Boundary conditions are not well defined;

3) FEM is limited in the number of elements which can be economically incorporated into the model. This can lead to incorrect predictions for short time impacts, because there are too few elements affected. Users should be cautious of FEM applications to short duration impacts - at least ten time and ten spatial representations are required to capture the input and response pulses;

4) Sophisticated models may be tuned to limited or even invalid experimental data and may be misleading.

5) There are many "empirical simulations" and "representations" of head impact response, but no "model" since all of the representations still require adjustment of parameters to match experimental data.

Dr. Viano restated his conclusion that current models have too many discrepancies and cannot truly predict mechanical response. Therefore, it is not yet possible to predict injury using these models. He suggested that the scientific community needs agreement on two basic guidelines relating to mathematical modelling.

- The minimum information which should be published with the simulation so that the model can be reasonably and completely evaluated from the technical evidence;

- The minimum set of requirements (range of applications, etc.) a simulation should meet in order to be called a "model" of the system response.

Dr. Viano's presentation sparked a lively discussion among the Workshop attendees. There were many comments about the adequacy of experimental methods which provide data for the models, the design criteria and validation of the models reviewed, the physical properties of the skull and brain, and the philosophy of modelling. Many of the points made in the discussion are consolidated and summarized below, by topic and not necessarily in chronological order.

Experimental Methods and Physical Properties.

Intra<u>cranial</u> pressure measurements may not be intra<u>brain</u> pressure measurements. Pressure transducers currently in use may not adequately record the high-frequency content of impact response, and thus not provide adequate basis for the model. Also, pressure transducers may miss tensile components of response. Modelers must be aware of limitations in the measurement of responses they are trying to simulate.

Repressurization of cadaver vascular systems for head injury research received much discussion. Because of incomplete purging and refilling of the vascular bed, repressurization, while important and necessary, is not a true representation of the living tissue. It is likely that localized overfilling and underfilling produces artifacts. Also overfilling stiffens the brain unnaturally and can change the skull/brain mechanical system - the brain is very sensitive to vascular pressure. Overfilling can stiffen the brain and prevent motion between brain and skull which some researchers have observed. Other researchers claim there is virtually no relative motion between the skull and brain at impact. The parameters of proper repressurization technique which may be universally applied have not been worked out.

In interpreting experimental data, it is important to separate the "injury" response from the system response. It is possible to adjust intracranial pressure to achieve a known injury, but a non-representative mechanical response may result. Also, when comparisons are made to actual accident victims, it is important to note that survival is critical to establishing acute neuropathologic changes and vascular injuries - they do not occur with instant death.

Accident studies, even with the lack of controlled conditions, can provide useful information. A recent study was cited which indicated that the principal brain traumas leading to death were focal lesions, diffuse shear in white matter, and bridging vein ruptures. The focal lesions are thought to be pressure-related, while the diffuse shear and vein ruptures are probably related to rotation.

Design and Validation of Models.

(Most of the discussion of this topic was directed to the brain model developed by Dr. C. Ward. Dr. Ward participated in depth in the discussion.)

Boundary conditions between the skull and brain are not critical to simulations with the brain model because the brain is in a container (the skull). The inertial input to the brain model is defined as the result of cranial response which moves the surface nodes of the model in three degrees of freedom. As currently configured, the model does not allow motion between the skull and brain, eliminating resonant frequencies in the simulations which are not observed in experiments. The interface effects of the human brain being in a fluid-filled sac may not yet be defined.

A procedure was used to select the number and size of elements in the brain model. After initial selection, the number of elements was doubled or tripled and the model was exercised through very small time steps. Variations in overall response were examined and the largest feasible element was selected. Based on modelling results with ten times the usual number of elements (the results were no different), Dr. Ward is confident the elements in her brain model are not too coarse and the model is not critically sensitive to element size. She noted that changes to element size and shape are evolutionary as model applications are broadened. The published papers are often obsolete as to element details, but it is not always possible to publish these detailed changes.

Poisson's ratio, classically, is fixed for a given material. However, Dr. Ward uses a variable Poisson's ratio (in the range .49 - .499). after simulating 30 live animal and more than 100 cadaver impacts, as well as displacement and vibration experiments, she found that good correlation was not possible unless Poisson's ratio was varied. She uses a higher value for short-duration pulses and a lower value for long-duration pulses. She is now convinced that, for short pulses, the brain acts more incompressible. (Dr. Viano cited the difficulties in modelling actual material using linear models. He can find no engineering explanation for the need to vary Poisson's ratio, even though the model requires it for adequate simulation.)

Dr. Ward noted that she has validated the model to enough different experiments to have confidence that the model does predict the impact response of the brain. Shear response is being addressed in a new model. She also noted the model could be made non-linear at a tenfold increase in the cost of running a simulation. The linear FEM predicts response with acceptable confidence.

Philosophy of Modeling.

There was some discussion on the definition of a model. Dr. R. Eppinger, NHTSA, noted that a global model of head impact applicable to all conditions would be ideal, but such models are not currently feasible. It is also valid to have more specific models so long as the user is aware of the model's range of validity. A model should be gaged by the type of information desired from the model - that is what determines the needed quality of data from which the model is developed. The level of detail should be balanced against the applications. This leads to an empirical process guided by an analytical process.

9. OTHER DISCUSSION TOPICS

The value of detailed analysis of real accident data was discussed. For an effective comprehensive study of head injury mechanisms a comprehensive team must be organized at an investigative center. This requires a long term committment by a wide range of disciplines, but sufficient financial support for such a team is not available. The head injury problem will probably have to be addressed by specialized teams working in a coordinated manner on different elements.

Reconstruction of real accidents using detailed head injury models is not likely to be fruitful. Models should be used to efficiently identify where experimental effort should be directed.

Identifying priorities for research funding is partly a political process. It would be valuable for the research community to determine priorities, then make those known to appropriate legislators at the most opportune time.

On the subject of priority-setting, Dr. A. Ommaya, NHTSA, noted that two reports from the recent Head Injury Workshop were due to be published by the end of 1981. These contain a good summary of key research issues. These summaries are not now, but should be, put into a rank order of recommendations for future research.

There was discussion about setting up a special workshop to establish a plan and timetable for research. Such a workshop would be international in attendance, and would best be established under the auspices of a governmental organization such as the National Academy of Sciences. Properly constituted, the results of such a workshop could provide the impetus for both public and private funding of research.

The International Workshop on Human Subjects for Biomechanical Research adopted a resolution to convene a specialized workshop with the purpose of establishing head injury research priorities.

Several attendees expressed their pleasure at the amount of open discussion which had occurred in this year's International Workshop. The consensus was that the value of the Workshop is enhanced by such discussion. Dr. Ward then adjourned the Workshop.

The Tenth International Workshop on Human Subjects for Biomechanical Research will be held in conjunction with the 26th Stapp Car Crash Conference in Ann Arbor, Michigan, the week of October 18, 1982.

Respectfully submitted,
David R. Foust
Secretary to the Workshop

NINTH ANNUAL MEETING

INTERNATIONAL WORKSHOP ON HUMAN SUBJECTS

FOR BIOMECHANICAL RESEARCH

SEPTEMBER 27, 1981

AGENDA

GENERAL SESSION

| | |
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| 9:00 - 9:10 | Remarks by the Chairman |
| 9:10 - 9:30 | Report on ISO Activities in Human Impact Testing and Evaluation (Working Group 4 of Sub-Committee 4 on Human Exposure to Vibration and Shock, ISO Technical Committee 108 on Mechanical Vibration and Shock)<br><br>John Melvin, Highway Safety Research Institute, University of Michigan, Ann Arbor, MI |
| 9:30 - 9:50 | Reconstruction of Spatial Trajectories of Impacted Accident Surrogates from High Speed Film Data with the Aid of Automated Digital Image Analysis<br><br>Peter F. Niederer and F. Mesqui<br>Institute of Biomedical Engineering<br>Swiss Federal Institute of Technology<br>Zurich, Switzerland |
| 9:50 - 10:10 | Definition of a Bone Condition Index for Human Subjects Used in Thoracic Tolerance Studies<br><br>J. Sacreste, A. Fayon, C. Tarriere and G. Walfisch<br>Laboratory of Physiology and Biomechanics<br>Peugeot S.A./Renault, La Garennes-Colombes<br>C. Got and A. Patel<br>Institute of Orthopaedic Research<br>Garches, France |
| 10:10 - 10:30 | COFFEE BREAK |
| 10:30 - 10:50 | Pedestrian Knee Impact Experiment<br><br>M. J. Walsh, B. J. Kelleher amd W. E. Levan<br>Calspan Corp., Buffalo, NY<br>R. Vergara, Battelle Columbus Labs<br>Columbus, OH<br>Y. Kulkarni, NHTSA, Washington, DC |

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| 10:50 - 11:10 | The Measurement of the Angular and Linear Acceleration Sensitivities of the Endevco Model 7302 Angular Accelerometer<br><br>Robert Sill, Endevco,<br>San Juan Capistrano, CA |
| 11:10 - 11:30 | Evaluation of the Endevco Model 7302 Angular Accelerometer<br><br>Paul C. Begeman and Albert I. King<br>Bioengineering Center, Wayne State University<br>Detroit, MI |
| 11:30 - 11:50 | A Method for the Rigid Fixation of an Accelerometer Package onto the Skull of Primates<br><br>Y. K. Liu and C. Gross<br>Biomedical Engineering Program<br>University of Iowa, Iowa City, Iowa |
| 12:00 - 1:00 | LUNCH |

MATH MODELLING SESSION

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| 1:00 - 1:20 | Three-Dimensional Mathematical Modelling of Dummies and Cadavers in Side Impact<br><br>Jac Wismans, TNO, Delft<br>The Netherlands |
| 1:20 - 1:40 | Critical Issues in Finite Element Modelling of Head Impact<br><br>T. Khalil and D.C. Viano<br>Biomedical Science Department, GM Research Labs<br>Warren, MI |
| 1:40 - 3:00 | DISCUSSION |

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