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BIOMECHANICS RESEARCH: Experimental and Computational,
Proceedings of the Twenty Sixth International Workshop.

The National Crash Survival Data Bank

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ABSTRACT

This paper describes the design, development, and implementation of the National Crash Survival Data Bank[1] (NCSDB), a web-accessible, object-relational data base system housed at the National Biodynamics Laboratory (NBDL)[2] of the University of New Orleans (UNO). For over 25 years, NBDL has collected an exhaustive database of impact acceleration response data from human and manikin subjects. These data include accelerometer array and high-speed film data, processed three-dimensional head-neck motion data, as well as the equally important medical, physiological, and full body anthropometric data. The NCSDB gathers, organizes, and facilitates access to this data treasure.

INTRODUCTION

The former Naval Biodynamics Laboratory (NBDL), currently the National Biodynamics Laboratory of the University of New Orleans (UNO), conducted short duration impact acceleration experiments for over 25 years. During these tests, a restrained, fully- instrumented, seated human or anthropo-morphic manikin[3] was propelled along a horizontal or vertical track by a high-G acceleration system. NBDL collected various kinds of sensor, photographic, medical, anthropometric, and physiological data during

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[1] This work was performed under Cooperative Agreement N00014-96-2-0015 between the University of New Orleans and the Office of Naval Research, and continued under Grant No. N00014-98-1-0335.
[2] Formerly the Naval Biodynamics Laboratory.
[3] Animal data was also collected but is not included in the current data basing project.

these tests. NBDL also produced 3-dimensional (3D) head-neck motion variables by processing the photographic, sensor, and ancillary data through an in-house software package called EZFLOW [1-3].

At the time when UNO took over management of NBDL, the various collected data were stored in a variety of analog and digital mdia in various formats and locations. A basic Oracle database was also in place at that time. The Cooperative Agreement between UNO and the Office of Naval Research (ONR) recognized the need to maintain the integrity of NBDL's data, and mandated the development of a relational data base dubbed the National Crash Survivial Data Bank (NCSDB). The main tasks are preservation, archiving, and databasing of recoverable data. The database development project has been divided into five major tasks: gathering and identification of recoverable data, data preservation and archiving, data quality assessment, EZFLOW[1] Unix-to-PC conversion, and Oracle data basing [5].

The remainder of this paper presents the design, implementation, and contents of the NCSDB. Section II describes the contents of the NCSDB. The design and implementation is presented in Section III. Concluding remarks and suggestions for further work can be found in Sections IV and V, followed by references in Section VI.

DATA IN THE NCSDB

During an impact acceleration experiment a restrained, fully-instrumented subject sat on a sled which was propelled down a 215 meter-horizontal track, or up an 11 meter-vertical tower by a high-G accelerator system. Acceleration levels for the human and mannikin subjects ranged from 3 to just under 16 g's, with kinematic data being collected for about 0.8 seconds. Physiology data was collected for up to 20 minutes. Sensor and physiology data were sampled at 2 KHz, while photographic data was acquired at 500 frames per second.

Study Series

There are 90 human and/or mannikin test series in the data base. The thrust direction -changed by rotating and/or tilting the sled chair- and the approximate number of runs (total, female, male) for each are given in Table I.

Table I: Study Series in the NCSDB

Thrust vector	G-level range	Number of runs (total, f, m)
+X	2-16	(646,0,646)
+Y	2-11	(757, 0, 757)
-X+Y	2-13	(474,0,474)
+Z (hor)	2-13	(316,0,316)
-X+Z10	3-7	(90, 0, 90)
-X+Z30	7-8	(37,0,37)
+Z (vert)	3-12	(345,59,286)

[1] EZFLOW is the name of the NBDL impact acceleration data reduction system.

Data Types

The various data types collected during a typical impact acceleration experiment can be classified into kinematic, physiological, and ancillary. Subject-related data for each human research volunteer (HRV) and test dummy is categorized as subject data or medical data. These data types are discussed independently. The approximate number of runs for each data type in the NCSDB is shown in Table II.

Table II: The data types within the NCSDB

Data Type	Number	Comments
Sensor data	3000	Mostly linear accel. array.
Photographic data	2700	up to 16 photo-targets
Physiological data	2700	most have EKG
EZFLOW	3000	Derived data
Ancillary data for all runs	3000	Experimental parameters
Medical data for each HRV	250	Exams and reports
Subject data	250	Subject info. and anthro-pometry.

Kinematic Data. Piezoresistive linear accelerometers, seat load cells, and angular velocity sensors were used to collect kinematic sensor data, while high speed cameras acquired photographic displacement data. Subjects were instrumented with custom-made mouth and neck mounts on which the various sensors and photo-targets were placed (Figures 1 and 2). A few subjects were also instrumented with pelvic mounts.

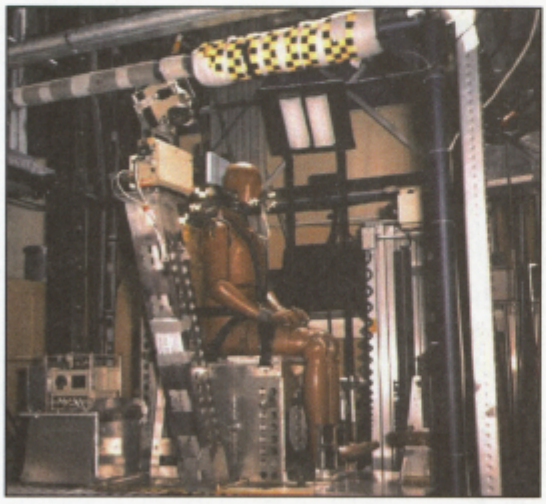

Fig. 1: Mannikin on vertical tower.

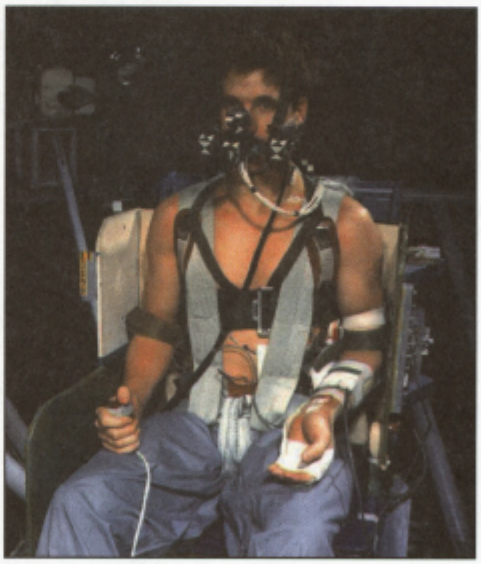

Fig: 2: Instrumented subject on sled chair.

Sensor and photographic data were processed with an in-house program which produces 3-dimensional translational and rotational displacement, velocity, and acceleration time traces in various instrumentation and anatomical coordinate systems [3].

EZFLOW, the impact data reduction system, originally resident on a Hewlett-Packard 9000 Unix-based computer, has been converted to operate on Windows 95-based computers. A visual interface (GUI) has been developed as a front-end to the PC version of EZFLOW. Details about the NCSDB kinematics
data are shown in Table III.

Table III: Kinematics Data in the NCSDB

Kinematics Category	Types Within Category	Comments
SENSOR	Sled Chair	Accelerometer
	Seat Chair	Load Cell
	Belt Left Chair	Load Cell
	Belt Right Chair	Load Cell
	Head	Load Cell
	Mouth Mount	Accelerometer
	Top of Head Mount	Accelerometer
	Neck	Accelerometer
	pelvic	Accelerometer
	Mouth	Angular Velocimeter
	Neck	Angular Velocimeter
	Nonstandard	Other sensors.
PHOTO	Sled chair	Photo target locations. Up to 16 photo targets.
	Mouth mount	
	Neck mount	
EZFLOW	Displacement	Variables generated through least squares processing.
	Velocity	
	Acceleration	
	Euler angles (or quaternion)	

Physiological Data. Physiological data include digitized evoked-potential electroencephalograms (EEG), electrocardiograms (EKG), electro-oculograms (EOG), and electromyograms (EMG). Associated IRIG timing information was recorded for all runs. See Table IV for details about physiological data in the NCSDB.

Ancillary Data. In order to understand and process the raw kinematic and physiological data information related to experiment setup and calibration information --e.g. site surveys, camera calibrations, instrument mount surveys-- were also collected and are gathered within the NCSDB under the Ancillary sub-data base.

Subject Data. Most HRV's participated in several runs. All pertinent information about the test subject is collected in this sub-data base[3]. Each HRV was assigned a 'subject_id'. Head and neck X-rays (AP and lateral, some stereo), and full body anthropometry (up to 100 measurements [4]), are available for most subjects. The X-ray (mouth, neck, pelvic) information is used to transform the kinematics from the instrumentation coordinate system to the corresponding anatomical coordinate system. Anthropometry is used to classify subjects and is expected to be an important search criteria when querying our data base.

[3] Subject names will not be made available.

Table IV: Physiological Data in the NCSDB		
Physiology Category	**Types Within Category**	**Comments**
ECG	SNV2	V2 Sensor Location
	SNV4	V4 Sensor Location
	SENX	X Sensor Location
	SENY	Y Sensor Location
	SENZ	Z Sensor Location
EEG	FZ_S	Fz to S differential signal pair
	FZC4	Fz to C4 dsp
	FREF	Fz to Reference dsp
	FRTS	Fz to Right Side dsp
	FC11	Fz to C11 dsp
	FLSH	Fz to Left Shoulder dsp
	FC4P	Fz to C4' dsp
	C4RF	C4 to Reference dsp
	C4_S	C4 to S dsp
	ERBC	ERBS to C4 dsp
EOG	EYE1	EOG Eye Movement Sensor
	CENT	EOG Center Channel
	RIGHT	EOG right channel
	LEFT	EOG left channer
EMG	RECT	Rectified EMG Signal
	RECF	Rectified and Filtered EMG
	HFEQ	EMG HF
	LEFT	EMG left channel
	RIGHT	EMG right channel
	CH01	EMG Channel 1
	CH02	EMG Channel 2
	CH03	EMG Channel 3
IRIG	IRIG-B	Timing information

Medical Data. Medical data include extensive entrance and exit exams, pre- and post-run exams, some special exams, and long-term follow-up exams. These include impact medical test data, physician consultation/opinion reports, and summary information. A comprehensive list of exam types and how these are categorized is given in Table V. Various clinical data were collected from the human research volunteers (HRV) prior to, during, and subsequent to their participation in an impact acceleration test series. Each subject underwent a qualifying physical examination including psychiatric, orthopaedic, cardiology, ophthalmology, otolaryngology, and radiology evaluations. EEG, spirometry, blood chemistry and general internal medicine tests were also performed. Before each impact acceleration experiment, various clinical tests including vital signs, urinalysis, visual acuity, physical examination screen, medical history screen, medication history, narrative and pre-run self-evaluation were conducted on the HRV. Monitoring data were collected on the subject from the time of positioning on the sled for testing until removal from the sled. After the test, post-run clinical, self-evaluation and narrative information were again collected. Upon completion of their tour of duty, the HRVs underwent an exit physical exam equally extensive as the qualifying exam. Additionally, many HRVs were given a long term follow-up physical exam several years after their participation in impact testing.

Table V: Medical Data in the NCSDB		
Medical Category	**Types Within Category**	**Comments**
Cardiopulmonary	CMPC	comprehensive report from the cardiologist
	SPIR	Spirometry
	EKGR, EKGE	EKG Resting, EKG Exercise
	VCGA	
	ECHO	Echo cardiogram
	PCGA	Hono cardiogram
Dental	EXMD	Dental exam evaluation
Otolaryngology	PBSC	perceptual and behavioral science
	AUDI	Audiometric data
	QUES	Self-report questionnaire
	CMPE	Request & Results
	ENGD	Raw Data
	PHYS	Physiological Optics
	VEST	Vestibular Physiology
Hematology/Urinalysis	LABR	Laboratory Results
Internal medicine	MEDX	medical history/exam
	CMPR	comprehensive report from occupational department
	CMPI	Internal Medicine Request/Results
	MEDX	Medical History and Exam
	CMPR	Comprehensive Report
Neurology	EEGR	EEG Report
Ophthalmology	EXMO	Ophthalmology exam evaluation
	CVEX	Color Vision Test
	VISF	Visual Field Data
	VSEX	Visual Searching Task
Orthopaedic	RADI	X-ray
	RMRI	NMRI
	CMPO	Report
	INPT	In Patient Surgery
Psychology	CMPP	Report
	WPTD	Wonderlic Personnel Test
	PERA	MMPI
	PERB	Temperament Survey
	PERC	Mental Health
	PERD	Interest and Preference
	PERE	E-I Scale
	PERF	Stai General Scale
	PERG	Inventory of Attitudes
	PERH	Desirability of Control
	PERI	SCL-90 R
	PERJ	Summary
	COGP	Memory

Data Quality. The quality of all the kinematic and physiological data is being assessed. This assessment is performed coincident with the data archiving and consists of the following steps: quality checking, troubleshooting, correction as necessary, and data basing of assessment results. The NCSDB human and mannikin kinematic database consists of: (1) the sensor-derived sled linear acceleration, velocity and displacement, (2) the sensor-derived head and neck linear and angular accelerations, and, (3) the sensor-derived and photo-derived head and neck linear and angular velocities, displacements and quaternions. The data quality assessment includes checking the individual components of the various photo and sensor kinematic quantities for offset, noise level, data gaps, oscillation, drift, and relative magnitude. The level of agreement of the sensor and photo-derived linear and angular velocities is the historical NBDL standard for kinematic data quality. However, all kinematic quantities which are both sensor and photo-derived are compared for agreement of initial value, phase, and the values and shapes of the major peaks. Times when significant disagreement begins to occur as well as probable causes are also stored. Reprocessing is performed if the data problems are deemed solvable.

The quality assessment of the processed EZFLOW data in the NCSDB kinematic database is done with an automated software package which integrates the DaDisp 4.1 display and analysis package with the Oracle 8.0 software. DaDisp 4.1 handles the I/O for the choice of series, type of variable (sensor, photo, sled), and type of analysis (single component or photo/sensor comparison). It also displays the various curves, drops down panels for automatic choice of assessment responses, stores the responses in ASCII files, and logs daily progress. Examples are shown in Figure 3.

In the physiology assessment process, the 16 channel data are de-multiplexed and imported into the DaDisp physiology assessment program. The data are then examined in detail for signal presence, signal deformities, missing sections, and validity. This process is performed in coordination with the digitization process to accurately track the methods and processes of the digitization staff. If inconsistencies are encountered, a trouble shooting protocol is performed to determine where the irregularity originated. In many cases, the abnormali-ties are quickly accounted for; in other cases, however, the problem has to be traced back to the original analog tapes, which are quickly deteriorating. The problematic signal is then either corrected or an appropriate comment is entered into the database detailing the problems encountered.

NCSDB IMPLEMENTATION

In order to make the data readily available in an organized manner, an Oracle 8 object- relational data base was designed and is being implemented. This implementation is based on a client-server paradigm with the server running Netware ' s Novell OS and Oracle 8 and its various suites (Developer 2000, Designer, Discoverer, Web Server, etc.). Graphical applications have been developed for the NCSDB using Oracle, Visual Basic, and C++. These applications include querying mechanisms, reports, entry and modification forms, and graphical display and plotting, which will soon be available over the WWW.

The main data types have been classified into the following sub-data bases: kinematics (or "run engineering" for historical reasons), physilogy, medical, subject, and ancillary. Further classification can be made within each of these classes. A broad view of the NCSDB is presented in Figure 4, where only the major blocks are shown.

NCSDB Tables

The NCSDB is an Oracle 8 relational data base management system (RDBMS) with a few elements from an object-oriented DBMS (ODBMS), yielding a sometimes called ORDBMS. As such, it is primarily constituted by a variety of tables, each table containing a number of fields where the

individual records are stored. Keys, primary and secondary, many of them compound, are used to link these tables and to maintain the relationships among them. The sub data bases are currently named ***Kinematics***, ***Physiology***, ***Subject***, ***Medical***, and ***Ancillary***. Details about the sub-data bases, tables, and fields can be found in [5-6].

NCSDB Forms

A graphical user interface (GUI) with proper data checks, easy-access buttons and menus, querying capabilities, forms, and online help facilities is being developed using Forms 5.0. Refer to [6] for full details about the various forms. Only exemplary forms are presented in this paper. Figure 5 we shows the *SERIES* form, which is the first form in the hierarchy of GUI forms. It is used for entering data into, or modifying the base table SERIES_ID. This form gathers series-specific information from various tables of the data base and presents the summary in the form on the screen. The form *RUN_ENGINEERING* shows the basic test configuration information of each run, as shown in Figure 6. The user can open it either from the menu or from the *SERIES ID* form. Buttons have been provided to navigate to other forms. Constraints and triggers have been written at appropriate events to ensure the integrity of the data. Lists of values (LOV) are provided for the items *run_id, subj_id* and *series_id*. An option is provided from these lists to enter a new value for the parent table. A final example is given in Section 4.

Menus

The GUI being developed to access the NCSDB includes menu options. These menus look like standard Windows menus and won't be discussed further, except to mention that links to all the forms and help files are provided as menu items. The help feature is context sensitive.

Queries

The most important feature provided for the NCSDB is data access for the remote user. We expect the Query forms to be heavily utilized. After appropriate log on procedures, a user will be presented with a main Query form from which she/he will select the parameters to search on. All data will be available so, if no criteria are specified, all runs will be returned by the query. The more restricted the search, the fewer the number of runs that will become available. For Example, the user may start by selecting the range of acceleration (in g's), followed by the thrust vector direction and the accelerator type (horizontal and/or vertical). These three options have 'drop down' menus that inform the user of the available types and parameter ranges. To further specify the query, the user selects the type of data (kinematic, physiological, medical) desired. A user may then choose anthropometry to further narrow the search. Two options are provided: a simple query where the criterion is sitting height or weight, or a complex search where a list of about 100 body measurements is provided.

Figure 7 shows the preliminary version of the main querying form. Once Oracle processes the query, a list of runs that satisfy the criteria chosen by the user will be returned. The user may then further narrow or expand the search. Once the user is satisfied with the query, she/he will be given the option to spawn an ftp transfer process to receive the data files.

CONCLUSIONS

Basic descriptive information about the National Crash Survival Data Bank, emphasizing the types of data available and the operation of the data base system, has been given. All data collected, raw and processed, will be available over the Internet in 1999.

FURTHER WORK

The NCSDB is an Oracle 8 data base that a remote user will soon be able to access over the world wide web (WWW). We expect the system to be online around July 1999, with a prototype available a few months prior to that date. Meanwhile, NBDL can also provide users with CD-ROMS containing the desired data. Past and potential applications of NCSDB data include: better design of biofidelic manikins, restraint systems, and aircraft ejection systems. Analysis of combined sets of data, such as kinematics and medical data, can be used to assess risk of injury during automotive crashes and other potentially hazardous events. Integrated analysis of human, manikin and animal data should yield qualitative and quantitative information as to the role played by human surrogate data in determining human response. NBDL will perform further work, in collaboration with other interested agencies and institutions, in exploring these areas.

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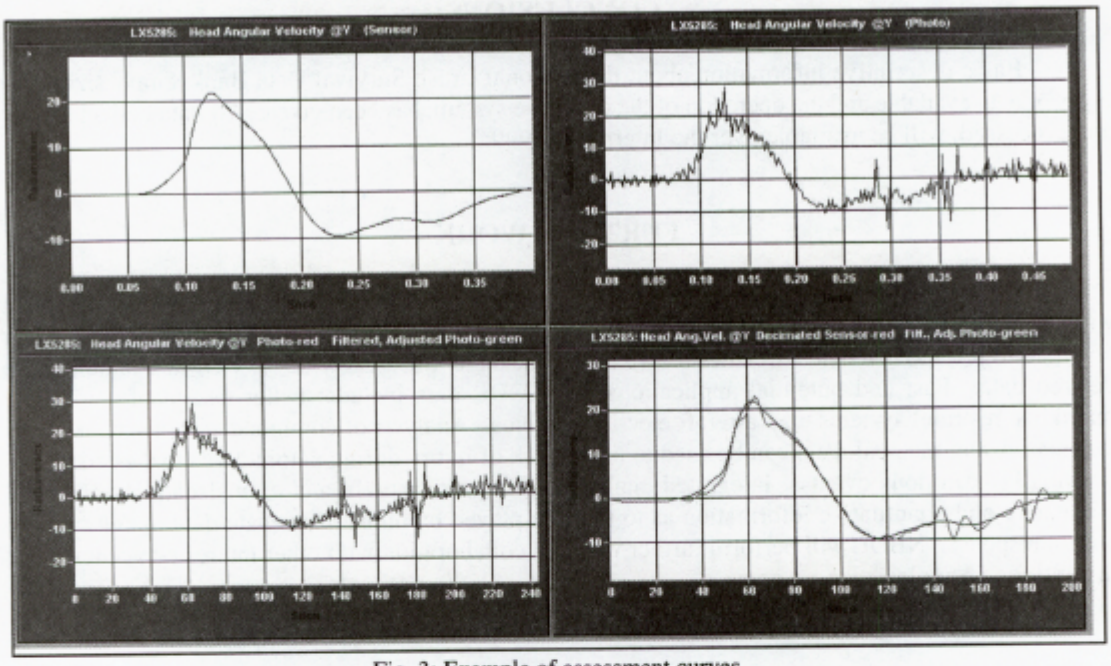

Fig. 3: Example of assessment curves

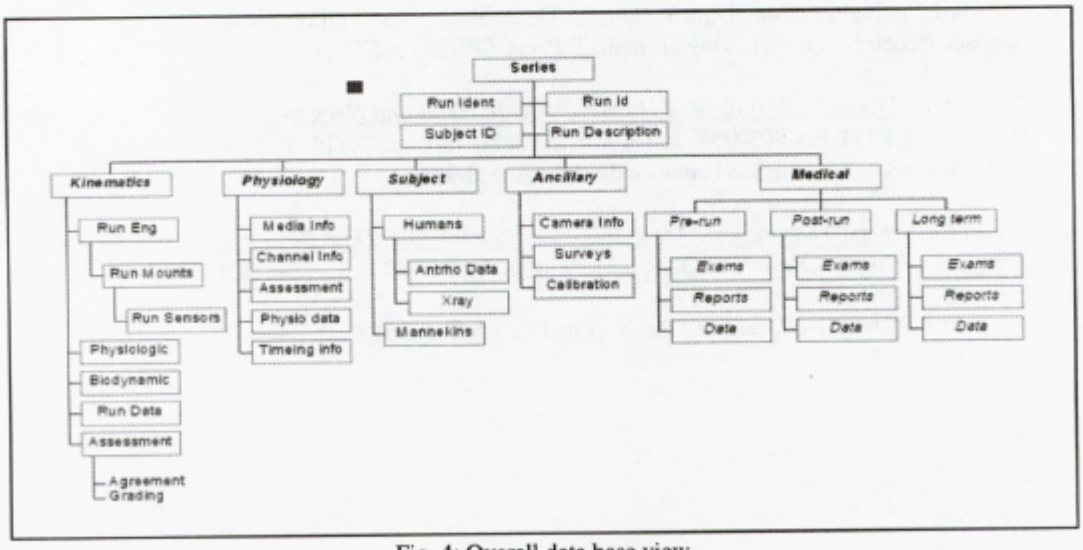

Fig. 4: Overall data base view

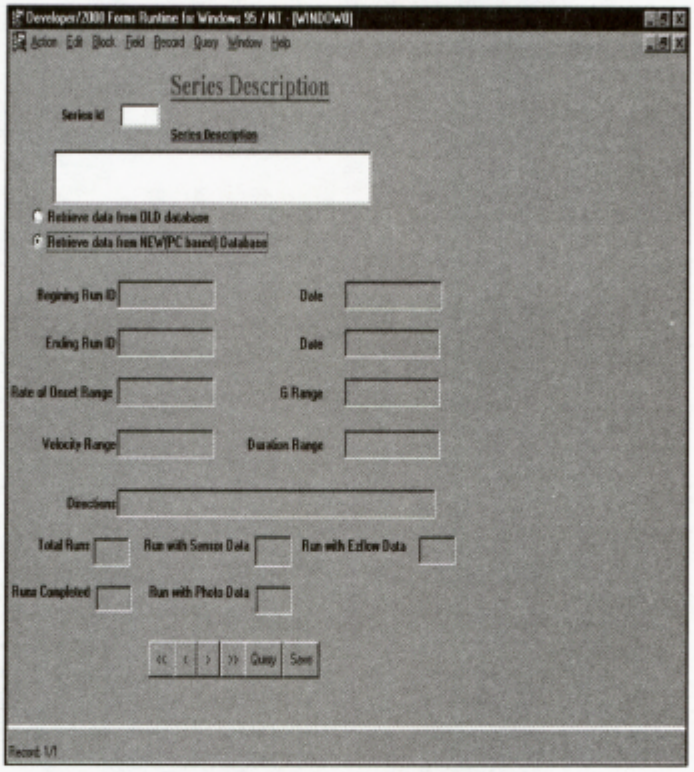

Fig. 5: The *SERIES* form.

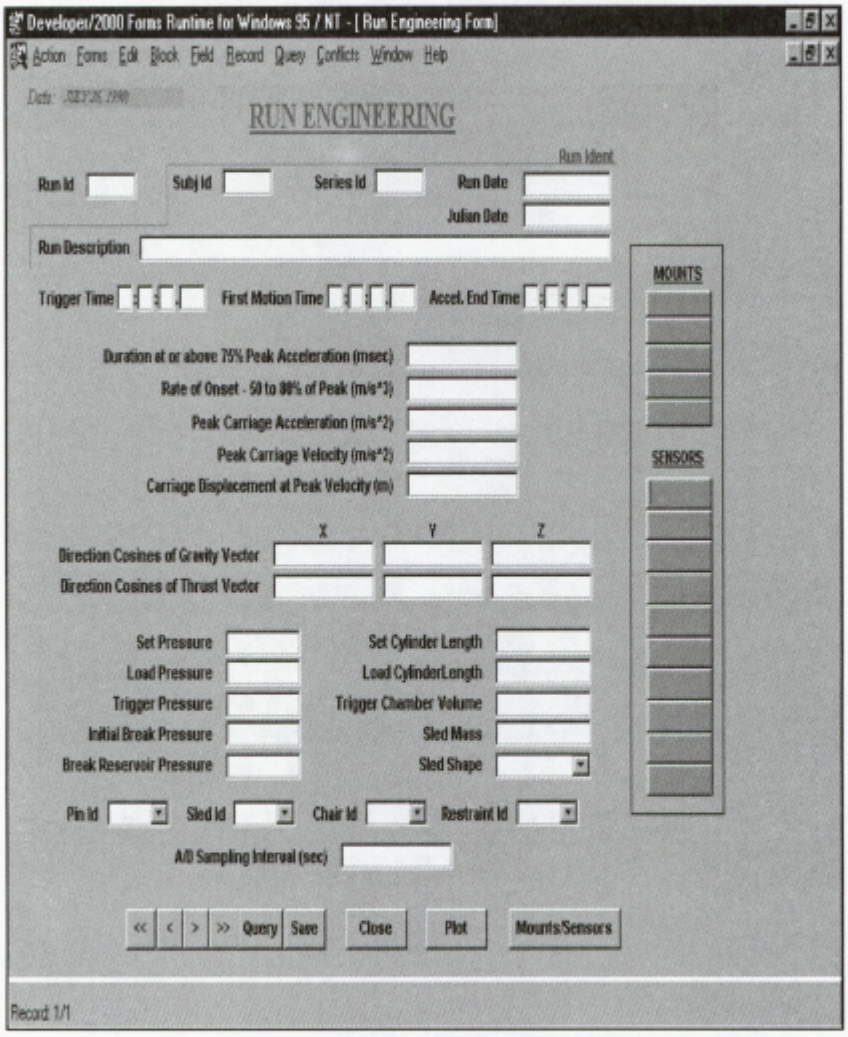

Fig. 6: *RUN_ENGINEERING* form

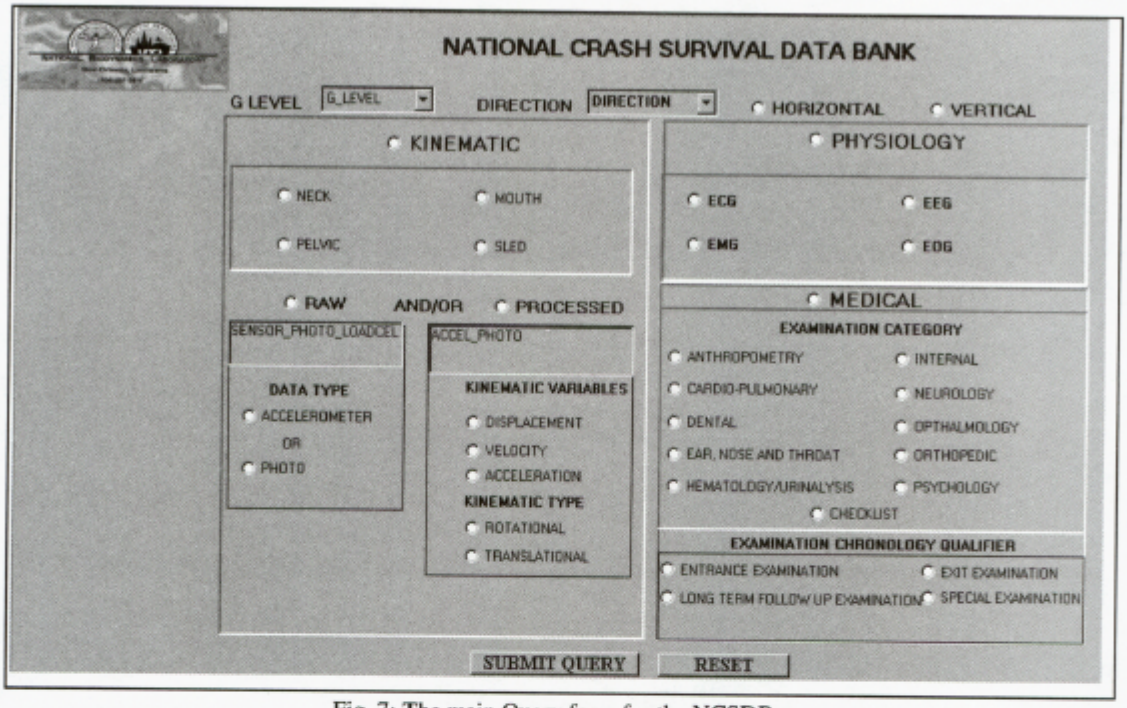

Fig. 7: The main Query form for the NCSDB.