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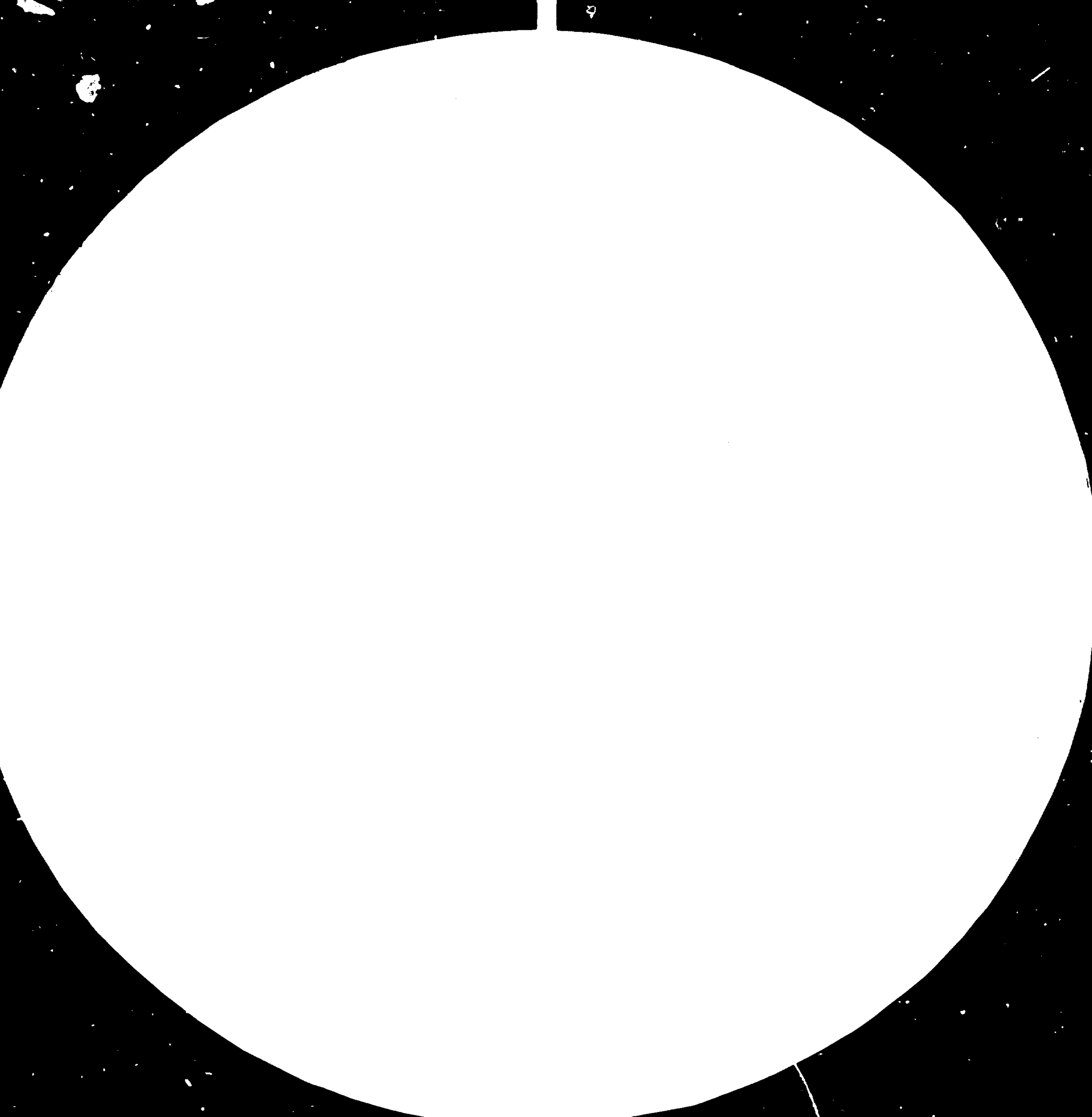

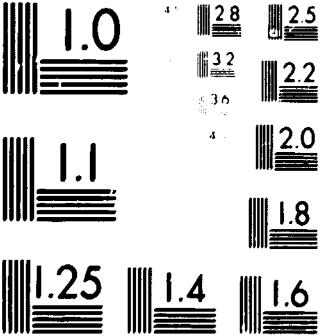

MICROCOPY RESOLUTION TEST CHART

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DP/ID/SER.A/423
25 February 1983
English

KIST-INDUSTRY CO-OPERATIVE PRODUCTIVITY PROGRAMME

(MECHANICAL ENGINEERING AND RELATED INDUSTRIES)

DP/ROK/74/006

REPUBLIC OF KOREA

Technical Report: Vehicle Dynamics*

Prepared for the Government of the Republic of Korea
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Hermann Bruns,
expert in vehicle dynamics

United Nations Industrial Development Organization
Vienna

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ABSTRACT

This report describes the activities, performed against the objective set during the assignment as technical expert for vehicle dynamics to the Korean Advanced Institute of Science and Technology (KAIST, former KIST), Division of Mechanical and Electrical Engineering (Annexure I), under contract No. DP/ROK/74/006/11-63/31.9.B.

The assignment at the mission station lasted from 3rd December 1982 to 18th December 1982.

The individual activities performed during the assignment are tabulated in Annexure II.

Overall, given the short time available, the major objectives were achieved. Up to 6 Korean members of the Institute were familiarized with the subject, including training on the usage of instrumentation and setting up experiments for vehicle vibration measurements, formulation of simulation models for the study of vehicle design parameters and application of computer simulation programmes.

Visits to two automotive companies (Annexure III) provided the necessary background information for the formulation of a carry on programme on the subject and for cooperation with industry.

A bibliography of about 200 titles on the main and related subjects was provided by the expert, allowing KAIST a rapid research into the subject.

No problems were experienced on the assignment.

The cooperation was cordially and very friendly and any support required provided by the counterpart party.

INTRODUCTION

The Automotive Industry in Korea has undergone a rapid development within the past 20 years. Production figures have risen from less than 2000 in 1962 to the respective figure of nearly a quarter of a million in 1981.
(Annexure IV)

The model-ranges manufactured range from models fully produced under licence (e.g. FORD Cortina) to vehicles of to some extend Korean design (PONY).

The situation for light commercial vehicles and trucks and busses is similar. The majority of vehicles is produced by three major production companies, HYUNDAI, KIA Industrial Co., and SAEHAN Motor Co.

Two years ago the Korean Government regulated the allocation of production facilities for different types of vehicles amongst the major producers in Korea in order to improve the overall industrial competitivness against foreign competitors on the world market.

A significant part of production is for export in about 50 different countries.

Present plans foresee to achieve production of up to 750.000 vehicles within the next five years to satisfy local demand for road transport capacity and increase the export of road vehicles.

A recent study performed by KDI (Korean Development Institut) predicts the number of passengers travelled on highways to go up from 4,9 billion in 1976 to 25,6 billion passengers by 1991, or as much as 97 percent of the total number of passengers travelling.

Regarding freight transport, highways carried 93 million tons of freight in 1976 or about 60 percent of total freight transport. This is projected to reach 630 million tons by 1991 or 79 percent of total.

But despite these achievements has the countrie's mechanical industry not yet matured. There are still many problems related to lack of capital and technology as well as the need to develop additional competent management and professional manpower. The domestic mechanical industry, the automotive sector being a major part, is still at the stage of imitative production, that is, production activities are still depending on technical ties with the more advanced countries.

In order to achieve more independance from foreign capital and gain free access to export markets the industry has to become more independant with the primery objective to get more self sufficient in the design and development of indigenous products.

This UNDP project is supporting this strategy through the assignment of technical experts in various fields related to the mechanical and automotive industry especially.

I. OBJECTIVES

In line with the job description DP/ROK/74/006/11-63/31.9.B the objectives for the consultancy on vehicle dynamics were established as follows:

1. Visit Korean factories to assess the local state of technology and to identify critical problems.

2. Provide consultation in the following areas:
   a. Fundamentals of vehicle stability
   b. Vehicle testing
   c. Computer simulation of vehicle dynamics
   d. Problems associated with sound abatement

3. Assist in defining research and development projects in the above fields.

4. Assist in the selection of a trainee and of a research topic for his study abroad.

5. Hold a seminar covering the present state of the art in this field for participants from KIST, the Korea Advanced Institute of Science (KAIS) and technical staff from industrial firms.

6. Report on his activities, findings of his mission and give recommendations to the Government on further action which might be taken.

The main activities performed to achieve the objectives outlined above are summerized in Annexure II.
An overview of the subject is given in Annexure V.

II. FINDINGS

A. Institute

1) The institute has young academic staff with the necessary academic background on the basic subjects of mechanical engineering to master the subject and achieve the standard of the subject presently existing within countries with more advanced automobile producers.

2) The staff has so far not been deeply envolved in the solution of problems on automotive engineering in general, the subject of vehicle dynamics specifically.

3) The staff of the institute envolved in the seminars has so far only made limited experience in the analysis and solution of practical problems within the automobile industry.

4) The academic staff so far had limited exposure to the execution of practical experiments and the use of instrumentation and measurement equipment.

5) The instiute and KAIST in general are well equipped with computer capacity in form of IBM 370 system, CDC-Cyber System, PRIME-Computer and a variety of interactive terminals for Graphic Outputs. Members of staff are familiar in programming and the application of the existing hard- and software. Simulation languages, e.g. CSMP III (IBM) or SIMSCRIPT (CDC) and DADS3D (PRIME) are available.

6) The range of instrumentation available at the institute is not fully sufficient to perform the majority of experiments in the field of vehicle dynamics. Especially the transducers available are in terms of frequency range not ideally suited for measurement of vehicle vibrations.

7) The head of the institute has a good relation to the automotive industry, based on projects already performed for the companies, but in generally the present liaison between industry and KAIST can only be considered the beginning of a fruitful cooperation.

B. Industry

1) Discussions with engineering staff from two major automotive companies (Annexure V) revealed the obviou. dependance from the original collaborator regarding product development information. (In both cases the companies produce original Japanese and American/German designs.)

2) The request for specific information on basic automotive design problems during the discussions identified the lack of product development experience and the limited experience on the systematics of product development.

3) Preoccupation with production problems and the execution of design modifications seem to distract the scarce engineering capacity from carrying out more fundamental design studies on vehicle dynamics.

4) The lack of organized competitive product information and difficulties in the access to relevant and up-to-date technical literature provides difficulties in the establishment of clear design objectives and design targets for product specification.

5) Production facilities briefly visited made a well organized impression. Layouts of plants are very generous, and existing plant capacities seem to provide space for further expansions. A brief inspection of finished vehicles gave the impression of good standards of quality.

III. RECOMMENDATIONS

A. Institute

1) The institute should maintain its drive for recruitment of capable staff to maintain the present high standard of academic staff.

2) In order to build up the knowledge on the subject of vehicle dynamics, it is recommended to implement the proposed programme as outlined in Annexure VI.
While it may not be possible to strictly adhere to this proposal, it is recommended to at least procede broadly within the framework given, in order to ensure a proper foundation of knowledge on the subject. Liaison with one of the organisations listed in Annexure VII should be established to ensure a permanent update on the level of technology and research on the subject.

3) It is recommended to initiate an exchange programme in this way, that young members of the institute are placed in industry for a training of one to three months in order to familiarize themself with the practical side of the approach to problem resolution.

4) The institute should develop a short regular training course on the use of the existing equipment for members of their staff. This could be organized by a senior member of the institute and executed with the help of the academic section of KAIST.

Suppliers of equipment should be forced to at least give operating instruction courses with the supply of equipment.

5) The institute should make full use of the existing computer and programme capacity, especially the simulation languages available (see Annexure VI)

6) Annexure VIII provides a list of equipment which would enhance the present range of equipment available, especially in light of the application to experimental work related to the analysis of vehicle dynamics.

7) In order to establish a strong relation between KAIST and industry a regular schedule of meetings in form of a small working group should be set up. Only an extensive dialogue will ensure proper exchange of ideas and transfer of knowledge between the different organizations. Each side has to realise the strengths and weaknesses of the other in order to come to a fruitful cooperation.

B. Industry

1) -----

2) Industry should make more efforts to achieve a more systematic design and product development approach. KAIST could provide usefull assistence, as it may be easier for it to have access to the necessary information from advanced countries as an independant body.

   Industry could hire foreign experts for extended periods to introduce the necessary procedures and organisational requirements.

3) Industry has to realize the necessity of investment in research and development capacity - manpower and facilities - in order to achieve competitive standards. It should be recognized, that advanced automotive companies invest 2 % and more of total turnover in product development. Organizational modifications may have to be taken to ensure a certain engineering capacity being fully dedicated to the acquisition of more fundamental vehicle data and automobile related research activities.

4) It is recommended to establish firm relations with an independant organization in the countries with advanced automotive industry for the regular supply of information in the field of automotive engineering.
   It is recommended to build a computer based data base on technical information as well as on specific vehicle data.

This action will provide quick access to information and at least close the gap on competitive product data and will provide supporting information for the detailed analysis of trends of vehicle design parameters.

C. General

The institute may support industry through the establishment of laboratory facilities (test equipment) for the generation of performance data and design parameter of vehicle component. The design and development of test facilities would actively envolve the institute staff and experience could then be disseminated to the component industry as well.
Although no component manufacturing company was visited, it was made understood that they are not in the position to generate the necessary design data for the components they produce.

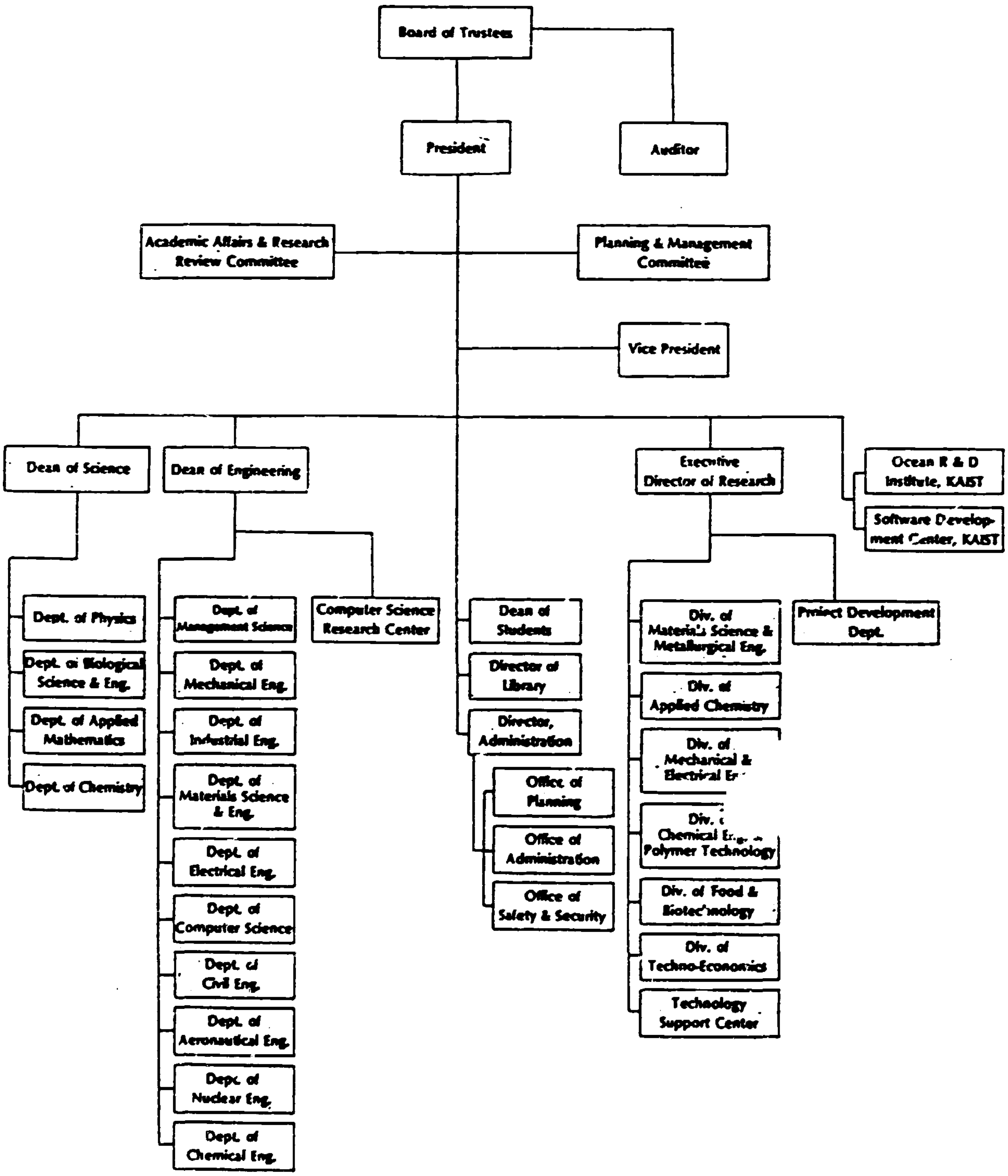
A list with examples is provided in Annexure IX.

ANNEXURES

Annexure I:	Organisation chart of KAIST
Annexure II:	Activities performed by Technical Expert
Annexure III:	Reports on company visits 1. KIA Industrial Co. Ltd. 2. Hyundai Motor Company
Annexure IV:	Production and registration figures of Korean automotive industry 1962 - 1979
Annexure V:	Systematic of vehicle dynamics
Annexure VI:	Proposed programme for continuation of research studies into vehicle dynamics
Annexure VII:	Organisations and institutions for placement of a trainee on the subject of vehicle dynamics
Annexure VIII:	Proposed additional instrumentation equipment for vehicle dynamics laboratory
Annexure IX:	List of potential experimental work for vehicle dynamics analysis to be performed in the laboratory.

Annexure I

Organization Chart



Annexure I, Page 2

Division of Mechanical & Electrical Engineering

- Electrical Sensors & Devices Lab
- Machine Dynamics Lab • Tribology Lab
- Semiconductor Materials Lab
- Thermal Machinery Lab • Applied Optics Lab
- Electrical Control Engineering Lab
- Manufacturing Technology Development Lab

The efforts in this Division include the development of basic and applied technology for precision and high efficiency machinery, electronic machinery, and the manufacturing of optical fiber and its applications.

In the mechanical engineering area, research on computer aided design and computer aided manufacturing of machinery (CAD/CAM), mechatronics, robotics, flexible manufacturing system (F.M.S.), and tribology are included. For domestic dissemination of developed technologies, an educational system has been set up in collaboration with the KAIST Faculty of Engineering. In its collaboration with M.I.T (U.S.A), FHG-IPA (West Germany), the Productivity Technology Institute, the Korea Institute of Machinery and Metals, and other related industries in Korea, the Division continues to play a central role in developing and localizing the above-mentioned key technology which is advanced rapidly in the world market.

The energy-related area of research includes such energy-saving technological developments as cogeneration, district heating, the heat pipe and such application of technological developments on new energy sources as solar- and wind-powered generators, and small hydraulics.

In addition to these areas, reseach is performed on the combustion phenomena of the internal combustion engine, prevention of smoke from combustion systems, design and analysis of automobile body structures, development of the new transportation media of high speed-electric railways, and the transportation system as a whole.

The Manufacturing Technology Development Lab undertakes R&D and the proto-type production of labor cost-saving new machinery, automation of production-line equipment, precision machining, heat and surface treatment of machine parts, and the fabrication and repair of various testing equipment and devices. The Department also maintains a capability scope ranging from machine design and production to plating, molding and glass works.

Another important aspect is technical assistance and cooperation to labor-intensive, small-scale industry through the provision of energy-saving processes, improved production methods, and new technical know-how.

Electrical & Electronics Engineering Research encompasses the application of power electrics technology, development of control systems, precision sensors for industrial measurement, and nonlinear elements for system protection and control.

In the 1980's the Division is expected to play a major role in expediting the technological development in these areas.

In the newly highlighted applied physics area, the semiconductor materials lab and the applied optics lab will aim their efforts toward international competition with their silicon single crystals, and toward the manufacturing techniques of optical fiber in joint projects with the Government and related industries. Also, other efforts will be made to elevate technological levels in these areas.

The major research projects to be carried out in the 1980's are:

I. In the Electrical & Electronics Area
   A) Thyristor invertor for AC motor control
   B) Sequence controller and electronic robot for system control
   C) ZnO varistor for circuits protection and system devices
   D) Temperature, strain, light and integrated sensor

II. In the Applied Physics Area
   A) Large diameter silicon single crystal growing, wafering, and characterization
   B) III-V compound semiconductor crystal growing and characterization
   C) Optoelectronics devices fabrication and application
   D) Semiconductor microwave devices fabrication and application
   E) Optical fiber manufacturing and characterization
   F) Laser optics development and application.

Annexure II

Daily activities

Date	Morning	Afternoon
Fry. 3.12.	Arrival	
Sat. 4.12.	Meet institute head - get background information develop activity plan - establish outline work schedule for expert	
Sun. 5.12.	— — — —	Preparation on project - literature study
Mon. 6.12.	UNDP-office- meet SIDFA + Mr.Putnam (Unido, Vienna)	Work at Institute - (Visit computer installation) Introduction lecture to 4 members of institute on the subject
Tue 6.12.	Visit laboratory- discussion + introduction to instrumentation to 4 members of IWST	Seminar a.working session on vehicle dynamics (vertical system) random process theory with 4 to 6 KAIST members
Wed.8.12.	Study computer programmes - evaluate computer capabilities at KAIST-seminar on multiple degrees of freed.systems for simulation of vertical vehicle vibrations.	Visit KIA Industrial Co. Ltd.
Thurs 9.12.	Lecture on instrumentation -transducer technology signal conditioning, recording equipment	Practical seminar on the application of instrumentation - introduction to equipment supplied under UNDP-project - Discussion on application of CSMP-computer modelling

Annexure II, Page 3

Date	Morning	Afternoon
Fry. 17.12.	Discussion of expert proposal for further work on the subject and discuss recommendations for cooperation between KAIST and automobile industry	Meet SIDFA at UNDP-Office and outline achievements of assignment
Saturd. 18.12.	Work on report	Departure 20.40

Annexure III.1

Summary of visit to KIA Industrial Co. Ltd., Seoul on Dec. 8th, 1982

Discussions on the subject of vehicle dynamics with up to 4 members of the Engineering section of KIA were held, covering the following points:

1) Present situation regarding design and development capabilities of the company.

2) Plans for development of own vehicles outside present agreements with foreign collaborators.

3) Description of present model range (5 - total production about 43.000/year).

4) Situation regarding vehicle design in Korea.

5) Testing and evaluation of prototype vehicles for main vehicle performance data. Measurement and instrumentation capabilities for specific vehicle vibration problems are limited. They mainly rely on subjective appraisal without control through objective measurement.

6) Discussion of various points, e.g.

   a) vehicle pitching - influence of main suspension parameters

   b) Definition of damper characteristics and influence of different damper characteristics on vehicle vibration mode.

Annexure III.1 Page 2

c) Tramping effect of dead-axles

d) Design and layout of engine mounting.

7) The situation regarding legislation governing vehicle design in Korea was briefly discussed. There seems to be little legislation controlling the design and performance of vehicles. Specific information was not provided.

Annexure III.2 Page 3

Summary of visit to Hyundai Motor Company, ULSAN, on Dec. 14./15th, 1982

Discussions were held with up to 8 members of Hyundai Research and Engineering Centre on the subject of vehicle dynamics, layout of steering systems especially, vehicle design approach and systematic, specification of test facilities for vehicle testing and analysis of subjective and objective testing.

The engineering centre consists of five departments:

- Passenger car design
- Commercial vehicle design
- Test and development
- Engine engineering - design and testing
- Engineering release

The main objective of Hyundai regarding passenger cars is to develop a front-wheel drive passenger car for production in the late eighties. They are presently studying some competitor's vehicles to obtain specific data. But the overall discussion revealed a lack of a systematic approach to vehicle design. The complex correlations between the variety of parameters influencing vehicle layout do not seem to be fully understood.

Annexure III.2 Page 4

The following subjects have been discussed in some detail:

- Test and calculation methods for measuring moment of inertia and center of gravity for vehicle bodies.

- Vehicle endurance test methods and accelerating vehicle durability on pave-roads and special test tracks (available at Hyundai, new vehicle test facilities under planning) Extensive discussion on layout and construction of new pave-tracks.

- Layout of front wheel suspension of light commercial vehicles.

- Influence of steering and front wheel parameters, e.g. camber, castor, toe-in, off-sett etc. on vehicle handling and stability.

- Discussion on selection of evaluation criteria for defining vehicle handling, e.g. yaw-angle velocity, rolling angle etc.

- Discussion of layout of bus-suspension systems and selection of springs for different road conditions.

- Design of leaf-springs and analysis of spring-failures.

- Techniques for establishing correlation between objective and subjective testing methods.

- Discussion on a specific problem of high steering effort on PONY 2 as result of modifications of front-wheel-track.

- Comparison of independent suspension against dead axle
- Advice given on sources for information on vehicle and automotive technology.

The visit included a test drive on PONY 2 on the Hyundai test track and steering pad.

Annexure IV

KOREA - PRODUCTION 1962-1979

Year	Passenger Cars	Trucks	Buses	Total
1962............	1,710	67	-	1,777
1963............	1,063	191	-	1,254
1964............	216	33	-	249
1965............	106	35	-	141
1966............	3,117	313	-	3,430
1967............	4,983	1,385	236	6,604
1968............	11,630	5,085	942	17,657
1969............	19,494	9,618	1,882	30,994
1970............	14,487	10,529	3,803	28,819
1971............	12,428	7,511	3,063	23,002
1972............	9,525	6,542	2,581	18,648
1973............	12,751	10,069	3,494	26,314
1974............	9,069	17,276	3,945	30,290
1975............	17,483	14,973	3,808	36,264
1976............	25,605	19,219	3,468	48,292
1977............	42,284	35,263	5,453	83,000
1978............	85,693	63,446	7,279	156,418
1979............	113,564	78,576	12,307	204,447

KOREA AUTOMOTIVE INDUSTRY COOPERATIVE

1979 & 1978
PASSENGER CAR PRODUCTION
(by cylinder capacity)

	1979	1978
1300 cc & less	84,497	66,521
1 1 cc - 1600 cc	15,250	13,479
1700 cc & over	13,817	5,693
Total	113,564	85,693

1979 & 1978
TRUCK PRODUCTION
(by loading capacity)

	1979	1978
1.9 tons & less	47,381	36,086
2 - 4.5 ton	25,310	24,942
6 - 8 ton	2,469	238
Over 8 ton	1,501	2,180
Others	1,915	0
Total	78,576	63,446

1979 & 1978
BUS PRODUCTION
(by Persons Capacity)

	1979	1978
29 persons & less	3,290	1,155
Over 29 persons	8,218	5,622
R.R. Engine	799	502
Total	12,307	7,279

KOREA AUTOMOTIVE INDUSTRY COOPERATIVE

Annexure IV

KOREA - TOTAL REGISTRATIONS 1962-1979

Year	Passenger Cars	Trucks	Buses	Other Vehicles	Total
1962.........	8,733	13,093	6,747	2,241	30,814
1963.........	9,569	13,929	8,132	2,598	34,228
1964.........	11,409	14,951	8,617	2,838	37,815
1965.........	13,001	16,015	9,316	3,179	41,511
1966.........	17,502	19,432	10,888	2,378	50,160
1967.........	23,235	22,955	11,499	3,008	60,697
1968.........	33,112	31,582	12,786	3,471	80,951
1969.........	50,229	40,134	14,237	3,999	108,669
1970.........	60,677	48,901	15,831	4,772	129,371
1971.........	67,582	53,405	17,411	5,939	144,337
1972.........	70,250	55,292	17,550	6,943	150,035
1973.........	78,335	64,584	18,771	8,925	170,714
1974.........	76,462	76,833	20,060	10,198	183,544
1975.........	84,212	82,862	22,358	11,629	201,061
1976.........	96,097	93,839	23,643	13,739	226,320
1977.........	125,613	118,150	26,710	4,839	275,312
1978.........	184,886	161,886	30,597	7,392	384,536
1979.........	241,422	206,822	37,697	8,437	494,378

KOREA AUTOMOTIVE INDUSTRY COOPERATIVE

Annexure V

VEHICLE DYNAMICS - CLASSIFICATION AND SYSTEMATIC

I. VEHICLES

A) Road-vehicles (tyres)

- 2-wheelers
- 4-wheelers
- multi-axle-combinations

B) Road-vehicles - (tracks)

- Military vehicles - i.e. tanks, semi-tanks etc.

C) Rail-vehicles

- Standard railroad
- High-speed railroads
- Mono-rail a) 1. top-suspended
  2. bottom-suspended

  b) 1. friction
  2. no-friction

Annexure V , Page 2

II. DYNAMICS

A) Longitudinal (1-directional)

- braking
- accelerating
- towing
- vehicle flow - traffic analysis, prediction and improvement

B) Longitudinal and lateral (2-directional)

- Vehicle performance
- Manœuvering, steering

C) Vertical

- Passenger-comfort
- road-holding

D) Transients

- Behavior of structures under impact (e.g. vehicle crash)

E) Noise

Annexure V, Page 3

III. RESEARCH OBJECTIVES

1. Vehicle-safety
2. Improved vehicle design-optimisation
3. Driver - training
4. Accident-analysis
5. Road-layout
6. Traffic-flow improvements

IV. RESEARCH -ANALYSIS-METHODS

1. Full-vehicle testing (limited)
2. Theoretical analysis
   - analog computer
   - digital computer
     Simulation languages
   - hybrid-computer
     (complex simulation tasks)
3. Simulators
   - with 3-degree of freedom-full-motion simulation for driver
   - with no motion simulation
   - real picture-simulation
   - synthesized picture-simulation

Annexure V, Page 4

V. EVALUATION - METHODS

- Subjective
- Objective - standards and methods under development. Highly sophisticated instrumentation required.

Annexure VI

Proposed programme for continuation of research studies into vehicle dynamics

Elements of Program

1) Literature Study -
Build up of Reference library on subject, (there are about 200 important references on the overall subject.)

2) Develop experience in modelling and simulation techniques using existing programmes (CSMP III) on IBM at KAIST
Suitability of SIMSCRIPT (CDC) to be evaluated.
Develop Graphic output programme (Post processor) for CSMP III either on IBM or other computers available at KAIST. Interactive operation of the program will significantly increase speed for build up of models and parameter varations.

3) Build up of library of models for different applications to study vibration phenomena of Automobile Systems

Annexure VI, Page 2

3 a) Execute parameter studies on industry-related problems, e.g.:

a) Selection of damping for given vehicle parameters

b) Effect of different tyres on passenger comfort

c) Minimizing pitching for a defined vehicle through variation of spring characteristics

d) Calculation of resonances for existing vehicles

e) Effect of overloading of trucks on road damage

4) Develop a vertical complex model - 3-dimensional (7 to 10 mass system for study of vertical vibrations, linear and non linear parameters.)
Execute parameter studies for analysis of vehicle suspension systems.
Establish effectiveness of model through comparison with measurements on vehicles.

4 a) Hold seminar on subject with related personnel from industry. Demonstrate the possibilities and opportunities of computer modelling for suspension and vehicle design.
Discuss the present situation regarding vehicle dynamics in the Korean automotive industry, establish the major problems regarding to e.g. vehicle safety and accidents and develop research projects for their solution.

Annexure VI, Page 3

5) Verify computer modelling through vehicle testing.
   1. Phase simple measurements of vehicle vibrations, e.g. 2 to 3 acceleration levels, e.g. on one wheel and two positions on body (against 4-degree of Free-dom-System) and measure effect of vehicle parameter variation, e.g. influence of different dampers.

   (Institute presently not fully equipped for this task).

6) Develop instrumentation package for study of complex vehicle dynamics problems.
   System for measuring and recording of up to 10 para-meters, e.g. accelerations, steering angle, roll angle etc.

7) Develop optimisation strategies and programmes for the evaluation of parameter studies, especially in light of optimising, e.g. riding comfort on vehicles with given restraints of vehicle parameters.

8) Develop model for study of lateral vehicle behavior -
   a) two degree of freedom system (-no rolling)
   b) complex non-linear model for simulation of horizontal and lateral dynamics.

Annexure VI, Page 4

9) Develop mathematical model for description of driver-behaviour for studying the vehicle-driver system for optimisation of vehicle design parameters related to vehicle dynamics and for establishing parameters for safe driving.

Execute parameter studies on non-linear vehicle model describing lateral and horizontal vehicle dynamics (with and without driver model), e.g.:

a) Develop evaluation method on model, e.g. step input function on steering system and analyse responses for non-linear system

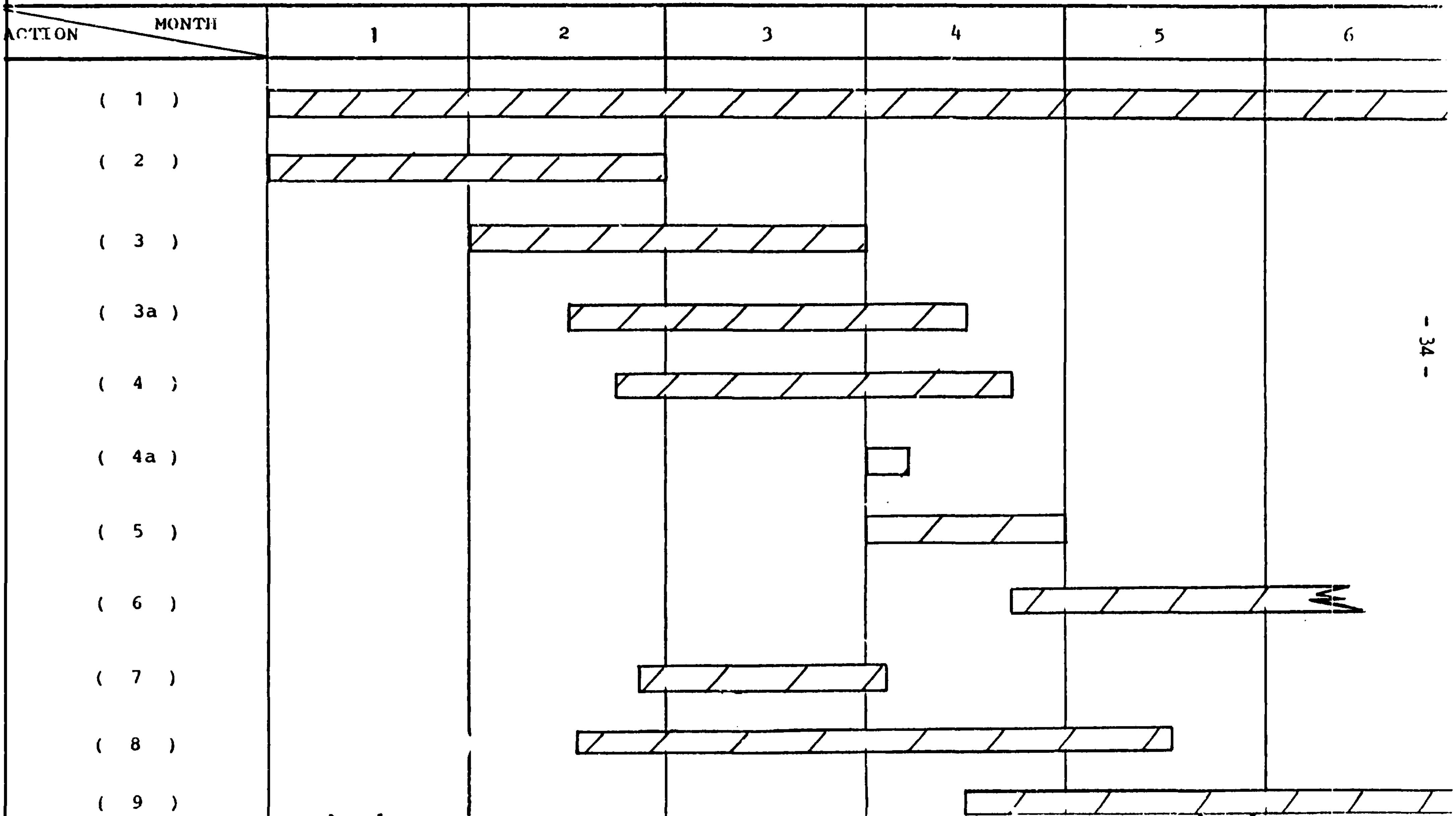
b) Evaluate the influence of different tyre characteristics

c) Evaluate the influence of different loading conditions and load distributions

d) Evaluate the influence of steering systems with different transfer functions

e) Evaluate the influence of traction force on the dynamics of a front-drive vehicle.

PROPOSED PLAN FOR ESTABLISHMENT AND BUILD UP
OF VEHICLE DYNAMICS LABORATORY AT KAIST



Annexure VII

Organizations and Institutions for placement of trainees on the subject of vehicle dynamics

1) Institut für Fahrzeugtechnik
Technische Universität Berlin
Professor Dr. Ing. H.P. Willumeit
Straße des 17. Juni 135
D 1000 Berlin 12
West Germany

2) Institut für Fahrzeugtechnik
Technische Universität Braunschweig
Professor Dr. Ing. M. Mitschke
Hans-Sommer-Str. 4
D 3300 Braunschweig
West Germany

3) Institut für Fahrzeugtechnik
Technische Hochschule Darmstadt
Professor Dr. Ing. B. Breuer
Petersenstraße
D 6100 Darmstadt
West Germany

Annexure VII , Page 2

4) Motor Industry Research Association (MIRA)
Director Dr. C. Ashley

Watling Street,

Nuneaton/Warwickshire CV 10 OTU

E n g l a n d

5) Technischer Überwachungsverein e.V. Köln
Institut für Verkehrssicherheit
Dr. Ing. R. Rompe

Postfach

D 5000 K ö l n
West Germany

6) Technische Hochschule Delft
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Annexure VIII

Proposed additional instrumentation equipment for vehicle dynamics laboratory:

1) 2 - 4 channel - light weight - chart recorder
(e.g. BRUSH, U.S.A.)

2) Storage screen oscilloscope - Small size
2-channel (e.g. TEKTRONIX, U.S.A.)

3) Low-frequency range, strain-gauge type, acceleration transducers (e.g. GOULD/STATHAM, U.S.A.)

4) Amplifier, filters and data acquisition systems for mobile application
(e.g. HOTTINGER, Germany, BB-ELEKTRONIK, Germany, BELL & HOWELL, U.S.A.)

5) Displacement transducers - 10 to 100 mm range
(e.g. HOTTINGER, Germany, BB-ELEKTRONIK, Germany, SCHAEVITZ, U.S.A.)

6) Accessories, cable, connectors

7) Specialised instruments and transducers for vehicle dynamics measurements, e.g.:
Stabilized platform (gyro), low-frequency transducers for vehicle acceleration and braking (deceleration) steering angle and -torque.
(Advise from e.g. TÜV-Rheinland, Germany, 5000 Köln, Vehicle manufacturer in U.S.A. or Germany, MIRA, England)

Annexure IX

List of potential experimental work for vehicle dynamics analysis to be performed in the laboratory.

For the final evaluation of vehicle vibrations and vehicle handling actual driving tests, requirering complex instrumentation equipment are necessary. Presently the institute is equipped neither in terms of vehicles nor in terms of test tracks to carry out these types of experiments. Nevertheless, for the evaluation of vehicle components of mainly passenger cars or light commercial vehicles experimental work can be carried out, for example:

1) Measure dynamic characteristics of suspension elements like springs, dampers, torsion bars, rubber mountings, engine mountings.

2) Study tyre characteristics, under static and dynamic conditions. For the dynamic data a dynamometer type test rig is required. This could be developed as a research project.
   The following criteria could be established:
   - Vertical and lateral stiftness as function of speed
   - Traction-Lateral-Force diagramme
   - Establish comering coefficient, i.e. lateral force as a function of slip angle for locally produced tyres.

   This project could be realized in cooperation with a Korean tyre manufacturer.

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3) Study suspension components under extreme conditions, e.g. Dampers at high velocities (on damper piston) and rubber mountings under high frequency vibrations.

4) Develop test procedures for components for recommendation to Industry, vehicle manufacturers as well as component suppliers.

5) Develop test data analysis techniques through simulation of test data and adapting different analysis techniques for definition of an optimum data analysis formula for a given test objective.

6) In an advanced stage a driving simulator could be developed.