



Péter Pázmány programme

Established by the support of the National Office for Research and Technology.

## ADVANCED VEHICLES AND VEHICLE CONTROL KNOWLEDGE CENTER

ANNUAL REPORT 2008



ADVANCED VEHICLES  
& VEHICLE CONTROL  
KNOWLEDGE CENTER



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*Pictures shown on the screens of products in this annual report are simulated.*

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## PERFORMANCE INDICATORS

	2008	2007	2006	2005
<b>Usable result of project</b>				
Developed new				
products (pc) .....	4	3	4	0
services (pc) .....	2	2	2	0
technologies (pc) .....	2	7	4	0
applications (pc) .....	3	7	9	0
prototypes (pc) .....	4	9	17	0
Number of patents submitted				
domestic (pc) .....	0	1	0	0
PCT (pc) .....	1	0	3	0
abroad (pc) .....	4	5	4	1
<b>Scientific results</b>				
Publications (including lectures) .....	54	76	74	37
Inland (pc × impact factor) .....	31	29	51	7
International (pc × impact factor) .....	23	47	23	30
Dissertations				
PhD (pc) .....	7	3	2	0
MTA Doctor (pc) .....	0	3	3	2
Did it result in a new international project? (Y/N) .....	Y	Y	Y	Y
<b>Human resources (in total working time equivalent)</b>				
Are project results used in training/education? (Y/N) .....	Y	Y	Y	Y
Number of involved				
university students (pc) .....	31	31	33	15
PhD students (pc) .....	20	20	19	18
junior researchers (pc) .....	12	12	10	2
Number of researchers having obtained a degree (pc) .....	5	1	2	0
Number of workplaces created by the project				
in enterprises (pc) .....	7	7	6	2
in research facilities (pc) .....	5	3	3	2
researcher jobs thereof (pc) .....	3	1	3	2
<b>Economic utilization</b>				
Participation in the activities of the centre – number of				
research facilities (pc) .....	2	2	2	2
enterprises (pc) .....	5	5	5	5
Number of new enterprises created (pc) .....	0	0	0	0
Return from sales of new enterprises created (HUF) .....	0	0	0	0
Are project results utilized in the economy? (Y/N) .....	Y	Y	N	N
Number of company(ies) utilizing the results .....	6	5	0	0
Results of the project				
extra return from sales (HUF) .....	54	45	0	0
export return from sales thereof (HUF) .....	0	0	0	0
decrease in costs (HUF) .....	0	0	0	0

## MISSION STATEMENT

**Our objective is to attain the role of integrator in the vehicle industry, pooling know-how, generating and providing new expertise to the corporate sector in the fields of vehicle electronics and mechatronics. We aim to become a university-based development centre of European dimensions that is capable of providing integrated expertise and of operating successfully in the real economy, with understanding and routine in applying rules and practices of the real economy.**

With the state subsidised phase ending, the Knowledge Centre sees its last year of incubation in 2008, when the decisions made for the future will play a key role in determining the success for this enterprise. It was four years ago that the above mentioned mission statement was formulated and included in the tender for the realisation of this project. The results are already taking shape after four years of operation. In certain aspects we have outperformed and in other aspects underperformed the objectives laid down in the tender. Outperformance is seen in the scope of our operations, where we have received many more orders from external parties than targeted. This includes alternative vehicle drives and drive gear control, which were not covered in the original plans. Yet these areas brought in the most orders. We have achieved our objectives as the structures that are indispensable for successful operation under market conditions are now in place. We also established, launched, monitored and adequately adjusted our business operation processes. We have achieved acceptance of cost-based financial planning and accounting on the part of the university community lacking this expertise. We have estab-

lished business contacts with targeted SMEs that exceed our expectations, with cooperation ranging beyond core technological issues to include business planning also. The strategy for the future targets such engagements more extensively.

In some areas, we have failed to attain targets due to hard external facts rather than lack of genuine intent. Beyond EU projects, we were unable to establish significant foreign relations. It will take a long road before we can develop into an international competence centre, so we need to reassess this objective of ours. Knowledge integration has also failed to reach the full scope of potential, for which the reason lies in the university structure. Cooperation in an interdisciplinary structure is hard to manage.

In view of the above, the strategy for the future has been transformed as follows: *our objective is to establish effective cooperation with economic actors that need complex expertise for their operation that is in line with international trends and achievements, primarily to meet demands and needs arising in Hungary.*

November 2008



**Dr. László Palkovics**  
*development director*

**Dr. Csilla Bányász**  
*program director*

**Dr. József Bokor**  
*scientific director*

**Dr. Zsolt Stukovszky**  
*director*

## MESSAGE FROM THE DIRECTOR



Having been one of the successful applicants of the first round of the Péter Pázmány Programme of the National Office for Research and Technology, the Advanced Vehicles and Vehicle Control Knowledge Centre was established on 1 January 2005 under the leadership of the Budapest University of Technology and Economics. We undertook to carry out our mission off the beaten track. With no example to follow, we endeavoured to attain our objectives and meet our liabilities to the state in a way that could serve as a model for the future. We conducted our operations on the basis of the 3-year strategic plan drafted on the first year's experience. The use of the Balanced Scorecard methodology allowed us to develop consolidated business operations that could be communicated, measured and controlled well throughout the organisation. We laid a particular emphasis on defining business processes and establishing the set of tools supporting them. The REDEMT project management system we developed is one of the products we market today.

We used carefully formulated marketing communication tools to ensure widespread visibility of our activities. As a result, our work had considerable press coverage in the printed and electronic media alike. We were greatly assisted in achieving our objectives by the peer-reviewed scholarly journal "Jövő Járműve" (Vehicle of the Future), which we founded and publish in cooperation with the Regional Knowledge Centre for Vehicle Industry in Győr. The journal made it possible for a wide audience of professionals and vehicle enthusiasts to get to know the results of the scientific research and industrial developments carried out in the knowledge centre.

It is impossible to provide knowledge services for the vehicle industry or take part in the innovation processes as expected by the industry without creating an appropriate test infrastructure. Therefore, by concentrating our investment capabilities, we established a world-class laboratory capable of carrying out and approving functional and endurance tests on mechatronical structures of the automotive industry. The test laboratory has a set of tools unique in Hungary and fills an important gap in examining vehicle components. Most of its spare capacity was used by external companies.

One of our most important assets is the knowledge accumulated, which we market as a viable product, partly within university education, partly for external partners. Though special university regulations have not permitted us to emerge as an independent player in the field of education, we played a key role in developing and consolidating the theoretical professional foundations of vehicle mechatronics. We were successful in integrating our test laboratory and the vehicles with alternative drive that we developed into undergraduate and graduate education, as well as PhD training. We pride ourselves on services provided to large enterprises, like Magyar Posta, GM, MolTrans, but we are also proud of our cooperation with SMEs. The case of Trigon Kft from Salgótarján is a notable example; they had a resounding success on foreign markets with their products that were developed using the services of us.

We undertook to carry out 19 professional projects during the four years of sponsoring. We completed all the activities we had undertaken and achieved all the goals we set. It is worthy of note that several projects ended in remarkable success. The most important ones are the following: fleet tracking and management systems developed for special fleets; autonomous vehicle control solutions for electronic steering systems; solutions for integrated control of intelligent subsystems; management of security-critical systems; and systems based on compressed air insufflation for compensating turbo delay. Several of these systems have turned into industrial products and will be available on the market soon.

At the end of the incubation period we have an optimistic outlook for the future. The present knowledge of the AVVC, which was accumulated through state-funded projects, has given rise to a number of new fields: research has been launched into alternative vehicle drive, into the use of natural gas and bioethanol as fuel, and into the integrated control of the entire powertrain. All these fields require the appropriate use of the knowledge gathered at the Knowledge Centre. This knowledge is the cornerstone of our successful market presence and business activities, which, by this time, have been complemented with the role of integrator in the traffic and vehicle industry, symbolising our acknowledgement by our professional and business partners.



**Dr. Zsolt Stukovszky**  
*Director*

## EVALUATION OF PÉTER PÁZMÁNY PROGRAMME

*by Péter Kiss, Minister of Chancellery at the Hungarian Academy of Sciences*



The notion of establishing new relations and links between science, higher education and economy is of paramount importance. In addition to science, higher education and economy, it bears significance for Hungary as well. We are witnessing a pioneering enterprise here. Since their foundation in 2005, the Regional University Knowledge Centres have undertaken to lay a new platform for cooperation between science and economy with a view to promoting competitiveness, which is material regarding the route the country is to take. When launched, the goals of this enterprise included the establishment of research universities that cooperate closely with the economy. We had in mind to pool and generate a critical mass of expertise in a team of experts that is aware and capable of addressing local industry needs, promotes faster knowledge transfer and proves the applicability of scientific results in economy. Another objective was to involve university and PhD students in research and development and thereby strengthen research-oriented education, as well as enable these Knowledge Centres to promote the R&D efforts made by small and medium-sized enterprises.

As we all know, the strongest needs addressed by science and higher education are generated by society as such, also via economic applicability. This is not just a theoretical social demand, but it involves practicality also, as it expects science and knowledge to materialise in everyday life. This enterprise is capable of providing this everyday applicability by creating a talent pool, new models of cooperation with the economy and is capable of addressing the needs of society in its entirety, in other words, shaping the country's characteristics.

This enterprise was launched at an initial capital investment of HUF 18-19 billion, and resulted in the establishment of a total of 19 Knowledge Centres. Although a thorough assessment involving each Knowledge Centre has not been completed yet, we can conclude that the experiment proved successful. With each step and stage of this new enterprise being monitored on a continuous basis, we can pronounce that the initiative has reached all major objectives it was meant to achieve.

As regards the Advanced Vehicles and Vehicle Control Knowledge Centre, it has made some achievements that are beyond the objectives set for phase one, paving the way for further advancement. It points to the new opportunities for development, which should be subsidised and assisted by the state – either through the Innovation Fund, the EU research and development funds or both – because no Knowledge Centre can currently finance its operation alone in the for-profit sector. The state should therefore back key development opportunities and projects as well as well-performing Knowledge Centres. The subsidy that the state provides should be proportionate to the achievements made as well as work performed by these entities, on a case-by-case basis. The relevant assessment should be made jointly.

The Advanced Vehicles and Vehicle Control Knowledge Centre pursues profitable activities, striking new links between applied and everyday science in specific areas and providing a sound technological background of strategic importance, which is an extraordinary achievement. This Knowledge Centre has created a point of interaction for academic scientists, higher education actors and business enterprises. In my opinion, this is another significant intangible asset.

I wish to mention three aspects that are crucial for the existence of Regional Knowledge Centres. Firstly, they are capable of creating a platform in both professional and scientific terms and acting as an integrator. This is especially important in technical sciences. Secondly, it is important that they provide training and education focusing on profit-oriented operation and the way of thinking it involves something that may be unusual in academic-university circles. Thirdly, universities may develop their role as vendors of products created in the course of their R&D projects. Lastly, we have moved forward from delivering lectures on the value of knowledge to discussing business models for sales of products resulting from R&D projects. This routine constitutes a significant contribution on the part of the Knowledge Centre to the advancement of the professional-scientific-economic conditions in Hungary.

Let me quote the example of Daimler's investment in Kecskemét. The Faculty of Transportation Engineering contacted the Government as regards a new type of cooperation that could be established in the Daimler investment project, which would pose a challenge with much greater dimensions, in addition to its training and educational feature. This is a Government issue, and involvement on the part of the Advanced Vehicles and Vehicle Control Knowledge Centre should entail participation by the Government also. This is where the Knowledge Centre could make its share of involvement and contribution. I am absolutely positive that the magnitude of the Daimler project provides room for a new platform for professional, scientific and educational cooperation, which should be addressed by the most flexible and market-oriented course of action developed in routine operation in this area.

Let me have some words about the future of Knowledge Centres. One of the future opportunities includes our support for the new key projects launched by Knowledge Centres, financed by the Innovation Fund. It is already an opportunity, which will continue beyond 2009. The Government wishes to continue the concept of Regional Knowledge Centres, beyond the end of this stage. The second opportunity I deem important is the issue of various R&D projects funded by EU programs. We shall continue these projects within the framework of biannual EU development programs. These developments are mostly funded through the Economic Development Operational Programme (GOP). I wish to note here that other branches of science should participate more actively by launching initiatives in higher numbers. Social sciences for example are quite active considering the number of initiatives they make. Medical sciences also prove active in this respect.

In my opinion, other branches of science and generally managers and other actors in science should also consider utilising the significant amount of expertise acquired in projects in technology, the Advanced Vehicles and Vehicle Control Knowledge Centre and other fields of science mentioned above to provide advice for the Government as to the content of programs to be launched for the period 2009-2011. The relevant decisions will be made in the next few months, at most within a year. This expertise and experience at the disposal of the Advanced Vehicles and Vehicle Control Knowledge Centre could be utilised to make reasonable suggestions to the Government. The higher education activities related to Knowledge Centres could also be aided by infrastructure and IT developments in this area.

All in all, in the Government's opinion - which I personally share - we have completed an important stage in this experiment that holds great prospects. I wish you success in the next phases of this great project.

Thank you for your attention.

*(The speech was delivered at the project-closing workshop of the Advanced Vehicles and Vehicle Control Knowledge Center on October 16, 2008.)*

## EXECUTIVE SUMMARY

**Year 2008 was dedicated to preparation for self-supporting operation. We had to establish and obtain approval for structures for which the need emerged on discontinuation of the legal, professional and financial framework required and provided by the RET tender specifications. These efforts were slowed down by the world economic crises, the internal university restructuring and the ensuing uncertainty on the part of partners. Despite these external factors, we have successfully completed the system that enables operation of the Knowledge Centre in the future.**

### Changes in economic conditions

The global financial crisis had its impact felt in real economy as early as the beginning of the year, affecting our corporate relations. The crisis affected the automotive industry the most severely; ordinary people cut consumption first by cancelling car purchases (primarily due to unfavourable terms of bank loans). Utility vehicle sales are affected by recession in the form of delayed purchases, and in prolonged use of current operator fleets. Partly through estimates, partly from released figures it is apparent that vehicle production in Europe in 2009 will correspond to 2003-year levels, which amounts to 60% of former projections. As the Knowledge Centre has business partners in both segments, the impact described above affects our projects at very short notice. Certain long term development projects have been cancelled or delayed, with development staff growth also falling behind the targeted rate.

On the one hand, it affects the future operations of the Knowledge Centre negatively as we will miss the opportunity to cooperate on partner projects. On the other hand, it brings new opportunities as well. Large companies – although cutting back on product development activities – will intend to rely on the development effort of their suppliers more intensively, which is the very business area we are targeting. The basic research and preliminary development financed from external sources will also gain significance. Another consequence that stems from the current economic conditions will materialise in shaping a new clientele, with companies equipped with large fleets of vehicles incorporating the “go-green” philosophy into their business model, seeking solutions that yield less load on the environment and an ensuing reduction in operating costs. These compa-

nies seek detailed technical and financial analysis in the decision preparation process, with technical expert and analytic services in the monitoring stage following introduction. The Knowledge Centre include a new element in its scope of activities, namely services rendered to lawmaking and enforcement authorities, whereby we can provide technical expert services in the preparation of legislation, as well as training and education. In summary: the Knowledge Centre will see some of its operations shrink and others expand under current market conditions.

### Change in Conditions at the University; A New Model of Management for the Knowledge Centre

The management of the Knowledge Centre was determined by two factors in the first 4-year incubation period:

- The consortium agreement and the ensuing mode of operation, which ‘modelled’ the future operation of the Centre and the way it cooperates with various types of partners in a determined manner;
- The independent central organisational unit formed at the university, under the direct supervision of the rector, which allows interdisciplinary knowledge to be built up by involving the relevant departments from each faculty.

As a consequence of the first point, the operational efficiency of the consortium is overseen by the Directing Body, and its management is required to give a regular account of its work. The university unit is directed by a manager appointed by the rector as laid down in the organisational statute. This model was essential in the incubation period, but when the

period comes to an end, the management structure will undergo a substantial change.

On the one hand, cooperation with partners will shift to an exclusively 'business interest' basis, and thereby the consortium agreement will be replaced by a direct business contract. The other significant change was brought about by a decision taken by the university leadership: Knowledge Centres (Regional University Knowledge Centre (RET), Coordination Centre for Transport Development (KKK), etc.) will be delegated to the faculties that are mostly in charge of the given discipline. The evaluation of this decision is still underway, the necessary structural modification it entails are still being worked out. On the one hand, it is bound to impair the interdisciplinary nature of the centres (though departments from other faculties will be allowed to participate in the work of Knowledge Centres, but solely on a contractual basis; the escalation model used hitherto cannot be used anymore). On the other hand, by delegating the Knowledge Centre to a specific faculty, the emphasis of the work at the Knowledge Centre will increase, allowing other departments to join its work, which, in the end, will diversify its portfolio.

## Summary of the Professional Results of the Programmes

As 2008 was the last year of state funding at the Knowledge Centre, we cannot limit ourselves to just evaluating the results of the previous year and the projects defined earlier. We would also like to present the results that are related to specific programme groups and which used knowledge that had been built up earlier in the specific programme. In general it is safe to say that though the programme structure set up on handing in the application had professional considerations in view, time proved it right, as almost all projects have either direct industrial applicability or their results can be built upon in industrial applications.

As the change in the economic environment has shown in the past years, the three fundamental requirements for road transportation are the reduction of fuel consumption and environmental impacts,

and, at the same time, providing the greatest possible stable throughput on a given road. It has become obvious that there is no single, well-defined method for meeting these requirements, and therefore several various technologies have to be used simultaneously in any given situation. As is demonstrated in the summary below, each of the programme groups of the Knowledge Centre contributes to meeting one of the aforementioned requirements.

### Control of Vehicle Groups

One way of meeting the above requirements is synchronised control of a group of vehicles that are at the same place at a given time. Research had basically two directions in the group: on the one hand, in the field of modelling and controlling the fleet as a dynamic system; on the other hand, in the field of both ad-hoc and planned fleet control by means of systems installed in the vehicles. Primarily, both research projects sought to find a way to assure the throughput of a given road with the control system related to the infrastructure (traffic lights, control of motorway entrance) so as to secure steady flow, that is to prevent congestions and major disturbances (accidents). Though it was not part of the state-funded projects, the models were supplemented with a criterion optimising fuel consumption and minimising damage to the environment, as these factors have become increasingly important in the meantime. Consequently, the control objective now had environmental protection besides stability as its aim. For that reason, on the basis of calculation and measurements, we assigned an emission function to the constituents of the vehicle group, resulting in a model that is capable of examining fleets with an arbitrary combination of alternative drives and fuels. Moreover, we enabled a part of the models to use information on road geometry (the most relevant factors being slope and bend) in the onboard control system.

We developed extensive domestic and international relations in this programme: within the Cooperative Vehicle-Infrastructure Systems (CVIS) project, we examine the possibilities of vehicle-vehicle and vehicle-infrastructure communications with Hungar-

ian and international partners; within the Highly Automated Vehicles for Intelligent Transport (HAVE-IT) project, we closely cooperate with major European car manufacturers. We have come into contact with several major Hungarian companies with extensive fleets, which charged the Knowledge Centre with rendering their vehicles more environmentally friendly.

### **Vehicle-Environment Contact**

This group concentrates on stability, convenience and environmental protection features provided by means of traffic environment information (vehicles, infrastructure) gathered by the onboard electronics systems of the vehicle. As part of the programme, ThyssenKrupp has developed an automatic parking assistance system, which will be a marketed product soon. In 2008, Knorr Bremse introduced an adaptive speed control device for utility vehicles. At the same time, it started developing its European version with the collaboration of its development centre in Budapest. As an interesting consequence of the programme, Knowledge Centre associates participated in negotiations with the City of San Diego that aimed to develop a vehicle control system which would allow the use of previously unused lanes of the orbital motorway (service lanes beside the inner lane) for vehicles equipped with this system (mainly buses and parcel delivery vehicles). The technical feasibility of the project would only have been possible if the full responsibility for the vehicle control rests with the driver and the system only assists him or her in his or her duties, implying that decisions and reactions to unexpected situations would have to be made by him or her. This principle was rejected by the local government, thus negotiations have broken off. However, this is a good example for both the importance of the field and for the anomalies we face.

### **Control on Vehicle Level**

In 2008, it was not only the projects for control on vehicle level that yielded results in this field: there are examples of their application in other fields as well. We have successfully established the theoretical foundations of both the hardware and the software

platform. The major fields of basic research in this area were control theory and systems security. This was coupled with systems development in these fields. As a result of collaboration among universities, laboratories and industry, we developed the control system of an integrated brake and steering solution, for electronic power steering based on momentum as well as angle addition. The objective of using this system is an increased functionality, security and rentability. The system based on angle addition has distinct advantages in terms of vehicle dynamics: the effect of the brake-system based ESP can be delayed or improved, significantly improving the efficiency of the ABS feature under certain circumstances. A momentum-based system has mainly economic and security advantages: on the one hand, implementing such a system results in a significant cost reduction; on the other hand, in case of failure of the power wheel, the assistance is not completely lost. We created prototypes of both systems in our project.

The methods of control theory elaborated in the aforementioned project were applied successfully in other systems of similar complexity: within an assignment project, we developed a full powertrain HIL model, in which parts outside the gearshift are simulated with an electric motor to develop a fully automatic gearshift algorithm. As a component of the integrated control system, the pneumatic booster system, which had been developed in the next programme group, was integrated into this system.

### **Intelligent Actuators**

Most of the industrial products that have been or are being realised were created in this group. Both ThyssenKrupp's electronic car steering system with additional lay-off and Knorr Bremse's pneumatic booster system have entered the phase of industrial development. The feasibility phase of the electromechanic wheel brake has finished. Several prototype varieties have been made and will be tested in vehicles or on the test bench. This project was discontinued; as such brake systems are not demanded on the market at the moment.

As a non-state-funded project within the 'control of vehicle groups' programme, we initiated research

into gearshift automation and the development of mechanical automatic gearshift. In this project, we cooperate with an SME, the Salgótarján-based Trigon Elektronika Company. This innovative small enterprise produces a small number of products. The Knowledge Centre is charged with industrial approval, software development and assessment. With reference to this project, a member of the Board of Management of the Knowledge Centre participated as an expert in the negotiations of Trigon for establishing a Chinese-Hungarian joint venture.

## Challenges Facing the Knowledge Centre under the New Circumstances

The most important question in 2008 was how we could prepare for an efficient operation on our own, with no state funding and consortium partners. This was the main issue shaping our operation.

- We have started making use of the infrastructure procured and deployed in 2007. There was a heavy demand for the equipment procured then (salt spray test chamber, AGREE combined examination equipment, heat shock test chamber), given their unique nature in Hungary. Several large enterprise partners have presented themselves, complementing our consortium partners (Knorr Bremse, ThyssenKrupp). Moreover, numerous companies dealing with similar tests are ready to commission the Knowledge Centre. The most challenging task, besides technical installation of the equipment, was the elaboration of the business model of their operation, as university rules are substantially different from the generally applied principles (e.g. description). The business model and the cost of operation had to be elaborated accordingly.
- The basics of operation had to be drawn up, as demands from contractual operation quickly came into conflict with education, basic and applied research.
- A number of partners have expressed demands for state accreditation of our assessment laboratory and preparations have started to that effect.
- The advance of state subsidy was delayed for administrative reasons, which would have seriously delayed our projects. However, the management of the Knowledge Centre decided to provide these resources by regrouping other revenues, thus allowing all state-funded projects to be closed successfully by the deadline we assumed.
- Contact had to be established more rapidly with new partners and agreements had to be prepared more swiftly.
- After careful evaluation of the first four years of operation, we can clearly see that preparations for the independence of the Knowledge Centre are going well, but for the time being, efficient operation will be difficult without state sponsorship. For that reason, we have handed in several applications, mainly for thematic calls. Moreover, an application is being prepared for a call within the Economic Development Operational Programme for Knowledge Centres that could help cut costs and enable continued efficient operation of the centre.

Besides these, we have initiated intensive deliberation and workshop work on shaping the new mode of operation that responds to the new conditions. Preparations have been made to integrate the Knowledge Centre into the Faculty of Transportation Engineering. The Faculty Council has consented to the new statute that was modified to take note of the new conditions, thus laying the foundations of a long-term operation within the faculty.

## Development of the Scientific Community

The scientific community has become more and more thriving this year. We had a continued partnership with the Regional University Knowledge Centre for Vehicle Industry at the Széchenyi István University in Győr, and with the Knowledge Centre at the Budapest Tech Polytechnical Institution. To provide Daimler Benz with human resources for its investment in Kecskemét, we contacted the Kecskemét College, and we intend to participate intensively in

the cooperation between the Faculty of Transportation Engineering and the College. We went on taking part in the CVIS project, which is part of the FP6 of the EU, and have started work in the HAVE-IT project of the FP7.

As part of our work in the Hungarian scientific community, we continue to actively participate in the work of the Automotive Competitiveness Council, which was created by the Ministry for National Development and Economy. Knowledge Centre associates in the Council are charged with tackling issues related to automotive research and training. The Ministry for National Development and Economy asked the development director of the Knowledge Centre to coordinate, as an expert, the project on framing a Hungarian strategy for the automotive industry.

For the recognition of mechatronics as a new academic discipline, the academic managers of the Knowledge Centre, in conjunction with other partners, have initiated the creation of a special committee on mechatronics within the Section on Engineering Sciences of the Hungarian Academy of Sciences.

The Knowledge Centre has entered into a strategic agreement with the Association of the Hungarian Automotive Industry as a background institute for the creation of an Automotive Industry Platform. Accordingly, the Platform is coordinated by the Association, but professional papers and analyses will be compiled by the Knowledge Centre and day-to-day operation will be carried out by the Centre, too.

## **Establishment of Operating Conditions of Assessment-Development Infrastructure**

A pillar of efficient operation of the Knowledge Centre (besides the accumulated knowledge and the relations) is the development and assessment equipment procured in the past years and deployed with the projects. In the first four years of operation, the main objective of using the equipment was the creation of knowledge materialised in the projects. However, we made clear in our strategy that at the end of the incubation period they are primarily to serve the

efficient business operation of the Knowledge Centre and, secondly, the imparting and socialisation of knowledge. On procuring and deploying the equipment, this was the principle we followed, and this was what we kept in mind on creating the conditions of operation as well. On operating the equipment, activities supporting the strategic operation of the Knowledge Centre take precedence (direct assignments, providing expert's opinion, and applications of our own). The conditions of operation of the equipment for external units (be they a university or a partner enterprise) have been modified for education and business projects: the equipment may only be operated for a fee. As a principle, we laid down that the fee depends on the purpose of operation: educational projects are expected to compensate for direct costs incurred (if any), while business projects are to pay full overheads on an hourly basis. The details are being elaborated.

## **Updating the Strategic Plan**

The strategic plan of the Knowledge Centre for the next period will be based on the principles defined earlier, with no major modification. The new elements are the ones necessitated by the discontinuation of state funding and the reorganisation of the Centre by assigning it to the Faculty of Transportation engineering, as well as the creation of a business structure within the university.

- The faculty supervision of the Knowledge Centre will pose a challenge in terms of knowledge and resources available, as the former basis with a wide spectrum (all the faculties of the university under the supervision of the rector, being at the highest level of escalation) has narrowed down. Hence, only the resources of the Faculty of Transportation Engineering are available directly, the dean being at the highest level of escalation. This modification might affect the feasibility of our business activities, and therefore, it must be taken into account in the business processes.
- To allow the marketability of the achievements of university units, as a new element of the business strategy, the university has created a joint stock

company which is capable of assuming legal and financial responsibilities as usual in economic circles. The Knowledge Centre takes part in the joint stock company through a so-called profit centre. The conditions of a joint stock company are simpler than those of a university business, thus stepping up competitiveness in certain scenarios. Unsurprisingly, the core of our activities is still carried out by the university units.

- The Knowledge Centre predominantly relies on the following types of resources:
  - We intend to continue to rely on community resources for funding basic and applied research activities, implying intensive work with applications.
  - An increasing part of our revenue must be from direct contractual work, which we intend to accomplish by research and development tasks for our economic partners.
  - It is very important for the Knowledge Centre to have a continuous, permanent activity that finances its basic operation. We intend to assure this operation by education and training.
- Coordination of the activities of the Automotive Industry Platform is a strategically important area. As a background institute of the platform won by the Association, we will have the possibility of shaping the Hungarian strategy for the automotive industry.
- We must lay particular emphasis on shaping the organisation and conditions of operation. The central body, which has been 'slim' up until now, needs extension, as many activities that were seen to by the consortium partners will have to be dealt with by the Knowledge Centre itself. In the phase of knowledge accumulation, we allocated our resources mostly to procuring equipment, software, and machines. We had minimal investments in buildings, as they were provided, in part, by our partners. In the next phase, we must allocate resources to buildings, too.
- Further development of the relations the Knowledge Centre has is essential. We may continue to build upon the relations of our former consortium partners, but the basis of cooperation will change inevitably. A cornerstone of the efficient operation of the Knowledge Centre is the maintenance of relations.

## RESULTS IN 2008

#	Project title	Tasks to be performed	Status
1.1	Modelling and control of traffic systems	Real-time implementation of control algorithms	✓
1.2	Control of traffic systems by communication networks, cooperative control technologies of fleet management	Real vehicle experiments performed on test-track	✓
2.1	Autonomous vehicle control	Automatic parking assistant system, lane-departure warning and lane-keeping system	✓
3.2	Scalable hardware platform of the vehicle on-board electronics	Vehicle dynamic sensor-network prototype	✓
3.3	Methodology and software tools for integrated braking, steering and suspension control in distributed real-time systems	Methodology of integrated vehicle architecture, integrated control algorithms	✓
4.2	Steering system realizing additional steering angle	Steering algorithms tested in vehicle, control unit prototype	✓
5.1	Determination of Safety Integrity Level of vehicle systems, function specification	Software prototype	✓
5.2	Behaviour of the driver in controlled vehicles	Integrated experimental system	✓
5.3	Development and release process, reliability analyses of vehicle mechatronic components	Development and qualification methodology of vehicle mechatronic components, technological and economic considerations	✓
5.4	Fault tolerant system architectures	Prototype system	✓
5.5	Research and development process and the related project management system	Software product	✓
5.6	Database and its management for the knowledge center	Measurement and control of knowledge base usage, upload of new data bases	✓
5.7	Development of the international regulation for vehicle dynamic control systems (UN-ECE WP 29 GRRF subcommittee)	ENSZ regulation	✓
5.8	Homologation of complex electronic systems	Homologation requirements	✓



## EDUCATION AND TRAINING

One of the most important products of the Knowledge Centre is the knowledge accumulated, which we intend to market as a viable product, partly within university education, and partly for our external partners.

A workgroup on training in the automotive industry is set up under the auspices of the Knowledge Centre with the involvement of the following companies: units of Bosch Hungary, ZF, ThyssenKrupp, Knorr Bremse, Continental Teves, and Continental Temic. This workgroup defined the qualifications and number of developers to be employed in R&D by our Centre in the next phase. Most of the disciplines defined by the industrial workgroup are ones whose training can be efficiently carried out at the University of Technology and Economics of Budapest in numbers laid down by the workgroup. The Knowledge Centre intends to take part in their training. The involvement of the Knowledge Centre in the activities of the above industrial partners is significant because of its interdisciplinary nature and of its activities closely linked with the industry.

In research into public road transportation systems and traffic processes, the Knowledge Centre aims to adapt the top achievements described in the international scientific literature, discover new relations, and integrate them in the Knowledge Centre. The new and highly promising research projects are the continuation of former EU-funded projects and provide young researchers with a wide range of possibilities and international relations. The achievements of the project also serve the purpose of raising the standard of education in the field; our own developments and accumulated literature are now being transformed into university lecture notes.

The basic and applied research into cooperative vehicle control and related developments mainly involved the Systems and Control Lab Department of the Computer and Automation Research Institute of the Hungarian Academy of Sciences and the Department of Transportation Automation of the BME through graduate and postgraduate students. Work was carried out in two fields: on the one hand, it entailed research into principles and methods that can be used in designing and implementing cooperative vehicle control. On the other hand, it required research into the possibilities of communication among the vehicles and the applicability of ad-hoc digital communication networks in this field.

The two departments taking part in the project 'Development of an electronic car steering system with additional lay-off' have used the results at many points in their training activities. The results were presented in the course Controlled vehicle dynamics I by the Department of Automobile Engineering. Several students joined the project. Their work was overseen by department associates and the experienced engineers of ThyssenKrupp Nothelfer Kft.

We have advertised modules in university training in the field of development, approval procedure and methodology, reliability analysis and prototyping of mechatronic vehicle components, and an increased presence in education of alternative drives playing a more and more important role in the development of the vehicles of the future. Integration of the laboratory of the Knowledge Centre into university education and PhD training has started.

Although we are unable to be present independently in the abovementioned fields, we strongly support the departments with our industrial partners and help them elaborate curricula. Moreover, professionals of our industrial partners (Knorr Bremse, ThyssenKrupp, and Inventure) participate in university education as full or part-time tutors.



## UNDERGRADUATE/POSTGRADUATE STUDENT LIST

Involvement of postgraduate and senior students in the re-search work is very successful. However, new regulations – that is scholarship can not be paid, and student's wage became chargeable of payroll taxes – made our business difficult, even so during 2007 we employed 22 M.Sc. and 19 Ph.D. students in our work, of whom several students were involved in more than one project.

As a new element appeared in our educational strategy that – mainly as a result of the above extension – Knorr Bremse concluded a contract of 2 years with the Knowledge Center to participate to the professional training of integrating new employees, within the framework of which, the engineers shall obtain, besides general professional and qualifying trainings specific education in some fields, too.

Name	Degree	Topic	Supervisor
Gergely Bári	Ph.D.	Integrated vehicle control	Dr. Péter Gáspár
Gergely Bári	Ph.D.	Behavior of the driver in controlled vehicles	Dr. Zoltán Benyó
Péter Bauer	Ph.D.	Behavior of the driver in controlled vehicles	Dr. Zoltán Benyó
Imre Bíró	Ph.D.	Fault tolerant system architectures	Dr. András Edelmayer
István Bosznai	M.Sc.	Behavior of the driver in controlled vehicles	Dr. Zoltán Benyó
Gábor Bózsavári	Ph.D.	Integrated vehicle control	Dr. Péter Gáspár
Gábor Bózsavári	Ph.D.	Development of vehicle dynamic control system	Péter Koleszár
Tamás Csermák	M.Sc.	Development of alternatively driven vehicle	Dr. Zsolt Stukovszky
Attila Egri	Ph.D.	Fault tolerant system architectures	Dr. András Edelmayer
Sándor Fazekas	M.Sc.	Traffic modeling	Dr. Tamás Péter
Róbert Fekete	Ph.D.	Cooperative control for fleet management	Dr. Alexandros Soumelidis
Tímea Fülep	Ph.D.	Fault tolerant system architectures	Dr. András Edelmayer
Attila Gubovits	M.Sc.	Cooperative control for fleet management	Dr. Alexandros Soumelidis
Attila Gubovits	M.Sc.	Development of vehicle dynamic control system	Péter Koleszár
Tamás Haidegger	Ph.D.	Behavior of the driver in controlled vehicles	Dr. Zoltán Benyó
Tamás Hegyi	M.Sc.	Development of steering system	István Jánosi
Viktor Kálmán	Ph.D.	Development of alternatively driven vehicle	Dr. Zsolt Stukovszky
Tamás Kiss	M.Sc.	Integrated vehicle control	Dr. Péter Gáspár
Dávid Klug	M.Sc.	Development of vehicle dynamic control system	Péter Koleszár
Dávid Klug	M.Sc.	Development of alternatively driven vehicle	Dr. Zsolt Stukovszky
Gábor Kocza	Ph.D.	Fault tolerant system architectures	Dr. András Edelmayer
Gábor Kovács	Ph.D.	Integrated vehicle control	Dr. Péter Gáspár
László Lemmer	Ph.D.	Behavior of the driver in controlled vehicles	Dr. Zoltán Benyó
Gábor Lugosi	M.Sc.	Development of autonomous vehicle control	István Wahl
Enikő Mándoki	M.Sc.	Development of steering system	István Jánosi
Gábor Marton	M.Sc.	Development of autonomous vehicle control	István Wahl
Zs.Molnárné Török	M.Sc.	Determination of SIL level of vehicles	Géza Szabó
Gábor Oláh	M.Sc.	Development of steering system	István Jánosi
Sándor Oroszi	M.Sc.	Development of autonomous vehicle control	István Wahl
Gergő Pálfi	M.Sc.	Fault tolerant system architectures	Dr. András Edelmayer
Gábor Pintér	M.Sc.	Development of vehicle dynamic control system	Péter Koleszár
János Puskás	M.Sc.	Development of vehicle dynamic control system	Péter Koleszár
János Puskás	M.Sc.	Development of international regulation for vehicle dynamic control systems	Gábor Brett
Antal Strobl	M.Sc.	Traffic modeling	Dr. Tamás Péter
Bálint Szabó	Ph.D.	Cooperative control for fleet management	Dr. Alexandros Soumelidis
Bálint Szabó	Ph.D.	Integrated vehicle control	Dr. Péter Gáspár
Emese Szádeczky-Kardoss	Ph.D.	Development of autonomous vehicle control	István Wahl
Tibor Takács	Ph.D.	Development of alternatively driven vehicle	Dr. Zsolt Stukovszky
A. B. Tóth	M.Sc.	Development of autonomous vehicle control	István Wahl
László Török	M.Sc.	Behavior of the driver in controlled vehicles	Dr. Zoltán Benyó
György Várallyay	Ph.D.	Behavior of the driver in controlled vehicles	Dr. Zoltán Benyó



## TECHNOLOGY TRANSFER

One of the most important questions of the objectives of the Knowledge Centre is that of technology transfer among present and future partners of the Centre. When talking about technology transfer, we have to distinguish between clearly business-related transfer of knowledge and general information of the society. Furthermore, another distinction is to be made on the basis of the direction of the flow of knowledge, discerning the transfer of knowledge from the Centre to other parties and the other way round. In terms of technology transfer, the past two years were a landmark for the Knowledge Centre, as the direction of technology transfer has been reversed: previously, by communicating the demands towards the Knowledge Centre, our industrial partners, in effect, were transferring technology to the Centre. Last year, however, based on the information gathered from the partners and on its own knowledge, the Knowledge Centre was able to provide a larger quantity of information that it received.

The main target of technology transfer is university education, a field in which we actively participated by developing new syllabi with the help of partners, and presented the knowledge that we had accumulated through our projects. The results of this technology transfer are not shown in the receipts of the Knowledge Centre; however, its social return is outstanding, as graduates of the university meet actual market demands, and as such, can be considered as the product of the university.

Collaboration with other local Knowledge Centre in related fields and support for development of such relations are also considered to be non-profit technology transfer. Cooperation continues with the Centre for Automotive Mechatronics in Salgótarján (with the Knowledge Centre entering into a long-term strategic partnership agreement), as well as with the innovation enterprise in Székesfehérvár with close ties to the Hungarian Academy of Sciences, aiming at meeting the needs of the automotive industry in the region. The relations with the Creative Knowledge Centre of Kecskemét and with the Kecskemét College have become particularly prevailing: as part of the preparations for establishing a Daimler Benz factory in Kecskemét, together with the Faculty of Transportation Engineering of the BME we suggested that the two institutes form closer ties in education. To that effect, we have obtained political and professional support alike.

Activity in the UNECE WP.29 committee workgroup on ESP systems is a prime example of technology transfer towards the community. On request by the Hungarian government, the technological background in the committee was provided by the Knowledge Centre, which led to significant contribution to the wording of the final piece of law. We directly benefit from and make good use of the professional expertise gained during drafting the law in our ESP application project with Knorr Bremse.

The Knowledge Centre acts as a professional/economic integrator when it represents interested parties (legislature, law enforcement, service provider, SMEs, research laboratories) in cases of economic interest that also bear social relevance (environmentally friendly urban traffic) and are based on solely technical projects (use of natural gas in vehicles). The year 2008 is especially important in this respect: projects for vehicles with alternative drives are booming; we are getting numerous new assignments in this field owing to our heightened social activities.

As business-related technology transfer we must mention the cooperation with Trigon Elektronika in Salgótarján, which was primarily in a technical field, but later on continued with the establishment of a joint venture company in China, and might possibly carry on with a direct interregional or intergovernmental relation.



## COOPERATIVE LINKAGES

In 2008, we initiated cooperation that is not within the scope of state-funded projects chiefly with our large enterprise partners in the consortium, Knorr Bremse and ThyssenKrupp. This cooperation points beyond the incubation period of the Knowledge Centre. We concluded an agreement with Knorr Bremse on the training of their newly employed personnel. Furthermore, agreements are being prepared with both companies regulating the use of the Knowledge Centre equipment and services by the two companies in the future. ThyssenKrupp commissioned the Knowledge Centre to carry out assessments by means of the jointly deployed equipment. As for Knorr Bremse, an agreement is being prepared on the participation of the Knowledge Centre in the development of electronic driver assistance systems.

We have completed assignments for Opel South-East Europe and Chevrolet Hungary on the basis of our earlier projects. The two previously successfully concluded projects served as reference and on the basis of that, we prepared two projects of larger extent, which are scheduled to start in 2009. The CVIS project earlier awarded to the Knowledge Centre within the framework of the FP6 is an excellent opportunity for cooperation with large European enterprises, along with the possibilities of the financial support of the FP7 that was awarded to the Knowledge Centre in the second semester of 2008 in conjunction with the HAVE-IT consortium. Within FP7, the Knowledge Centre will cooperate with companies like Daimler-Chrysler, Volvo, and Siemens VDO in the field of vehicle electronics, which will provide an excellent opportunity for developing international relations of the Centre.

As regards SMEs, partly as a result of successfully concluded projects we have concluded several comprehensive agreements covering new areas. It has been confirmed that our privately funded basic research into alternative drive was a right choice to make, as a significant part of our latest projects originate in this field: we have concluded an agreement with Magyar Posta concerning postal vehicles with electronic drive and other alternative drive possibilities; we have written a letter of intent with Főgáz Zrt. on the evaluation of practicability of compressed natural gas in vehicles in Hungary. A number of additional projects are being prepared at the moment.

We have to underscore the orders that are related to the use of our assessment infrastructure that is unique in Hungary. As companies providing assessment services in Hungary do not possess such equipment, large enterprises like Bosch have commissioned our Knowledge Centre to carry out the assessment. We have also launched the procedure of accreditation of our laboratory as a response to market demand.

We have also made steps forward with SMEs: we have initiated professional cooperation with several partners of the non-profit innovation company in Salgótarján, expanding our expertise mainly in the field of powertrain.



## INTEGRATED MARKETING-COMMUNICATIONS

Since the beginning, we have intended to introduce our work to the public by means of deliberately formed marketing communications. Our immediate goal is to make the results of the Knowledge Center's R&D works available both to our limited professional environment and to the wider public interested in automotive technology. Indirectly, we intend to take part in social conscience-forming, concerning the sustainable development of transportation, improving personal and property security and environmental problems.

As a closing of the four-year work of the Knowledge Center we organized a conference at the Hungarian Academy of Sciences. The conference was opened by Péter Kiss, Minister of Chancellery, moreover, József Gyulai (the President of the Dept. of Technological Sciences at HAS) and Ilona Vass (Vice-President of NORT) are also delivered speeches.

We also organized international workshops with leading foreign lecturers, e.g. Gary Balas (USA), P.M.J. Van den Hof (The Netherlands), David Mayne (England), Gerard Gissinger (France), and Martin Pölöskey (Automotive Innovation Center, Aachen).

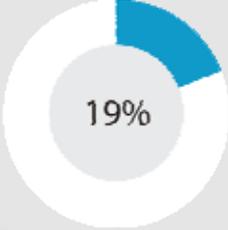
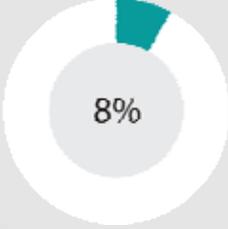
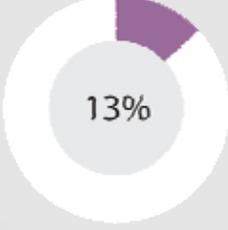
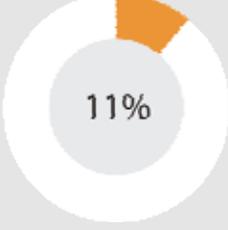
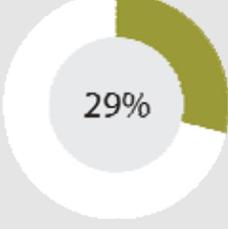
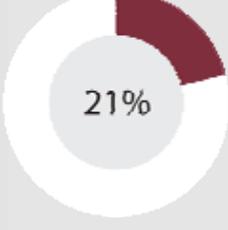
This year two (double) issues of the journal 'A Jövő Járműve' (The Vehicle of the Future) were published. As an important element of information sharing, we – together with the Automotive KC, Győr – decided to start a much needed professional newspaper that aims at multiple goals equally important both to us and to our partners. We would like to make the results of scientific research and industrial development made in the KCs – which are exemplary even by international standards – widely available to the Hungarian professional audience. In addition to providing knowledge, another of our public goals is a kind of professional community building by concentrating the knowledge of the article authors and the audience, through establishing an interactive professional forum in Hungarian. Moreover, we intend to provide an opportunity for the junior researchers of the KCs to introduce themselves before a professional audience.

In addition to our limited professional neighborhood, we also endeavor to inform our possible partners and the wider public of the results of our R&D projects to the greatest extent possible. It is interesting to mention that there is a noticeable – and glad, at the same time – transformation of outlook in the Hungarian media: recently we have been requested to write articles not only into professional journals but into media that are quite far from our field of interest in the professional sense.

The acknowledgement by professional policy of Advanced Vehicles and Vehicle Control Knowledge Center can be characterized mostly by the fact that our executive members have been requested by the Ministry of National Development and Economy to participate in the work of the Vehicle Industrial Competitiveness Board that aims at elaborating the long-term strategy of the Hungarian vehicle industry.

It is a special tribute to the Knowledge Center that we were exhibited to the representatives of the German higher education and industry on the "Innovation Forum – Technology from Hungary", that was organized by the Hungarian Embassy in the Collegium Hungaricum Berlin.

## AT A GLANCE

RESEARCH PROGRAMME	COSTS	PROGRAM MANAGER
CONTROL OF VEHICLE GROUPS	 19%	Dr. Tamás Péter
VEHICLE-ENVIRONMENT CONTACT	 8%	István Wahl
CONTROL ON VEHICLE LEVEL	 13%	Dr. Péter Gáspár
INTELLIGENT ACTUATORS	 11%	István Jánosi
PLATFORM SYSTEMS	 29%	Dr. András Edelmayer
OTHER ACTIVITIES	 21%	Dr. Zsolt Stukovszky

## PROJECTS

1.1. Modeling and control of traffic systems  
1.2. Control of traffic systems by communication networks, co-operative control technologies of the fleet management

2.1. Autonomous vehicle control

3.2. Scalable hardware platform of the vehicle on-board electronic  
3.3. Methodology and software tools for integrated braking, steering and suspension control in distributed real-time systems

4.2. Steering system realizing additional steering angle

5.2. Behavior of the driver in controlled vehicles  
5.3. Development and release process of mechatronic components  
5.4. Fault tolerant system architectures  
5.5. Project management of R&D process  
5.6. Database and its management for the knowledge center  
5.7. Development of the international regulation of ESP systems  
5.8. Homologation of complex electronic systems

Development projects based on industrial order  
(OPEL South-East Europe, Chevrolet Magyarország, Porsche Hungária,  
Magyar Posta, Fógáz Zrt., Fővárosi Csatornázási Művek  
Mechatronic examination and approval laboratory

## PUBLICATIONS

Inland: 5  
International: 1  
PhD thesis: 2  
TDK: 1

Inland: 1  
International: 1

Inland: 8  
International: 9  
PhD thesis: 1  
Master's thesis: 4

Inland: 1  
PhD thesis: 1  
Master's thesis: 2

Inland: 5  
International: 6  
PhD thesis: 2

A detailed list of public presentations and popular publications can be found on pages 26–27.

# 1. CONTROL OF VEHICLE GROUPS

The goal of this program was to cover a relative new scientific field – co-operative vehicle control. Such systems are expected to help to reduce the environmental burden and to improve passenger safety. The same applies for both vehicles traveling on a given road section (so-called ‘caravan’) and for groups of logically connected vehicles (so-called ‘fleet’). In the case of a caravan, only the driver of the first vehicle is working: the work of the other drivers is taken over by systems that implement inter-vehicle communications and monitor the environment of the vehicles. This is like creating a virtual train of vehicles and thus – at least theoretically – minimizing the risk of accident and optimizing fuel consumption.

We expect results from the research work on two levels. On the one hand, the results obtained will be checked in an actual development environment after clarifying the theoretical background of vehicle group control. On the other hand, one of the industrial participants of the consortium will develop a simplified fleet management system (a real technological platform), which will then allow practical testing of the efficiency of smart control strategies – at first, of course, in a laboratory environment, with model cars. With the simulation system, we will test various traffic situations, even with the involvement of vehicles without any smart control.

## 1.1. Modelling and control of traffic systems

The project “1.1 Modelling and Control of Vehicular Traffic Systems” of the EJTT of BME is based on the strong cooperation of the four institutes: BME Dep. of Control and Transport Automation, BME Dep. of Control Theory, HIS CARI Control Theory Labor, Inventure Ltd.

The tasks of organization, research, development and publication was managed by seven university teacher: Dr. József BOKOR, Dr. Tamás PÉTER, Dr. Béla LANTOS, Dr. Péter VÁRLAKI, Dr. István HARMATI, Dr. István VARGA, Dr. Tamás BÉCSI and four young researchers: Dr. Erzsébet NÉMETH, Szlárd ARADI, Tamás LUSPAY, Tamás TETTAMANTI; and two students: András STÓBL and Sándor FAZEKAS.

The project at the year 2008 aimed the modelling of intelligent road traffic networks, and the development of online cooperative network control systems. On the field of software development, our goal was to develop such intelligent model-creation applications, which are able to minimize the human interaction, thus the efficiency of these system greatly emerges.

On the area of measurements, we aimed the development of measurement actuator systems, from whose results, the development of efficient marketable industrial solutions are expectable. With our re-

search, we would like to contribute to the development of national highways and road traffic, with giving proposals on control techniques using real-time traffic data. The project aimed the further development of traffic modelling, the development of further efficient control strategies, and their feasibility studies. But one of our most important task besides the development of ITS concepts, were to involve university and PhD students and the industrial feasibility of our research. And finally it is intended to implement our research results into out educational materials.

The research of the project in the year 2008 was organized to five areas:

*K1 Traffic Flow modelling.* This year, we’ve had great achievements on the area of the study and feasibility of optimal control of high scale nonlinear road traffic networks. Connected to this research new software solutions were born for the process analysis, and the optimal control of networks. The developed new model can handle the whole network with all relationships taken into considerations. Network nodes are not implemented directly in our model, since these nodes are part of the whole network relationship system. In our network, generic sections cooperate, and they give the nodes of our graphs. The edges of these directed graphs are the state de-

pendent dynamic relations. This graph structure resulted in a positive nonlinear dynamic system and proved to be highly efficient tool for this task.

*K2-Development of video based traffic network measurement systems.* This task aimed the development of an automated measurement-evaluation system for the detection of road side objects, using video data. The subproject holds the development of the relating software solutions too.



*K3-Identification and evaluation of car-following models with a special respect to individual behaviour.* The subproject aimed the identification and evaluation of car-following models with a special respect to individual behaviour. In the research process the determination of the parameters of five microscopic traffic models take place.

*K4 Traffic management system.* The task of this subproject was the study a traffic control system consists of a Vissim based model and a MATLAB or VTC-3000 realized control loop. This application area is wide-ranged, so it holds the simultaneous control of the highway traffic flow, an the on-ramp traffic flow by using speed limits. The task consisted of the traffic estimation of the highway section too.

The other main research area was the urban traffic light control of real geometry and data based urban road traffic network by using MPC tool.

*K5- Nonlinear predictive control and optimal reference trajectory design in fast prototype systems.* This subproject dealt with the following problems: Study of the Necessary Conditions for Integration of Automatic Collision Avoidance System of Cars in Real Time Environment and the Testing Possibility in Quick Prototype Systems Using MATLAB/Simulink, Real-Time Workshop and dSpace Target Compiler Tools. The necessary condition of embedded game theoretic urban traffic control methods in real-time environment. The verification analysis of embedded

game theoretic urban traffic control methods in real-time environment.

Besides the research and development work, the leaders of the project pay high attention to the application of results in the education. The writing of a new educational material has been begun using the research results, and the knowledge acquired from the State of the Art literature.

## **1.2. Control of traffic systems by communication networks, cooperative control technologies of the fleet management**

The project designated 1.2 within the framework of the Electronic Vehicle and Vehicle Control Knowledge Center is devoted to the basic and applied research upon the cooperative control of vehicles. Within the project several areas have been covered from the theoretical aspects of cooperative control, through the application of digital communication networks, until specific vehicle control issues arisen from the practice.

Basic research has fundamentally been accomplished by the researchers of the Systems and Control Laboratory of the Computer and Automation Research Institute (HAS) and the Department of Control and Transport Automation of the Budapest University of Technology and Economics (BME) by involving graduate and postgraduate students. The activity has been focused on two basic fields: on the research of principles and methods of designing and realizing cooperative vehicle control systems, as well as on investigating the opportunities of inter-vehicle communication, and application of ad-hoc wireless networks in the cooperation. An independent partial task of the project – accomplished by the Department of Mechatronics, Optics, and Information Engineering of BME – has been applied research and development of an optical signalling system that is useful in the detection of the movement of the vehicles participating in a cooperative environment. The Department of Automobile Engineering of BME, as well as enterprises as Knorr-Bremse Brake Systems Ltd, and Thyssen-Krupp-Nothelfer Ltd provided for technological expertise in the automotive field. Finally TÜV Nord Ltd was responsible for investigating the conformity problems and legal issues in accordance with cooperative control.

The theoretical basis of the research has been arisen on the one hand from the field of formation control originally worked out in aeronautical area, on

the other hand from the field of the automated highway systems (AHS). Transferring the principles and methods known in these fields to the area of the road vehicles resulted in setting two major fields in the research: transporting vehicles in parallel trajectories, as well as crossing junctions by groups of vehicles.

The problem of transportation in parallel trajectories stands near to both the formation control and the automated highways; however the cornerstone of solving the control problems arises from the use of inter-vehicles communication. The measurements performed in the individual vehicles – position, orientation, velocities, and accelerations – can, through the communication, be shared with the other vehicles in a given group, hence both their individual and common goals can be fulfilled in a common, distributed control scheme. With the purpose of applying inter-vehicle communication the field of ad-hoc wireless communication networks has been investigated, and several communication schemes that work in real-time with high reliability and security and low response time.

Realizing cooperative control in passing of vehicles through junctions has got great significance in the improvement of efficiency of city transport. Besides the sensors placed upon the individual vehicles, as well as the data sharing between the vehicles through inter-vehicles communication a new component is appearing: the significance of the communication between the vehicles and the infrastructure established in the junction. Investigation of the opportunities of connection with the traffic control systems required collaboration with the project No. 1.1.

The goals that should be fulfilled by the cooperative control both in the field of transportation in parallel trajectories and passing in junctions are the improvement of the permeability of the given road or junction, cutting back the travel time, and besides them avoiding the accidents. Increasing the efficiency of the road transport positively affects also to the environmental load caused.

Participation of vehicles in cooperative control schemes suggests some level of autonomous operations that can be realized either independently of the driver, or as a complement of the driver activities. In the case when an autonomous action is realized, the

question of responsibility is arisen; the driver cannot be liable for an autonomous action taken by mistake of an automatic system. Clarification of this issue is subject of a broad public contest; the solution is probable in the future. Involving the methods that require autonomous vehicle actions in practical applications can only be realized in limited level that is originated from the confidence of the society on these solutions, as well as legal regulations, rather than opportunities offered by the science and technology.



Upon recognizing this fact the project – in contrast to the original plans – focused in realizing model based experiments rather than attempting tests on real vehicle environments. A vehicle model test field has been established within the site of SZTAKI that is able to run multiple electrical vehicle models in the scale of 1:10 and 1:18. The test field is equipped with indoor positioning systems based upon ultrasound and camera vision, as well as a wireless communication infrastructure based upon the IEEE802.15.4 standard. The test field and the set of the vehicle models will get great significance in the research and in the high level education in the field of cooperative control for a long time after the end of the current project.

As a part of the independent development project accomplished by the Department of Mechatronics, Optics, and Information Engineering a prototype of the optical signalling system has been realized and successfully tested in real vehicle environment, furthermore it has been registered as a patent.

## 2. VEHICLE-ENVIRONMENT CONTACT BASED CONTROL

In order to improve road traffic safety and help drivers in driving, vehicle systems able to intervene in vehicle movement or warn the driver are necessary. Using vehicle-installed sensors that provide information about the immediate vicinity of the vehicle, it is possible to develop such systems. The program includes R&D tasks in the field of system modeling control technique, mechanics, electronics and communications that are necessary for developing autonomous vehicle control systems.

The program resulted in vehicle-level control systems that can affect vehicle movement according to the immediate vicinity of the vehicle. Such results are: 1) automatic parking management system, 2) lane-tracking or lane crossing detection system based on an image recognition system.

### 2.1. Autonomous vehicle control

In the project 2.1 the Department of Control Engineering and Information Technology, Department of Road Vehicles at BME, TÜV Nord Ltd. and MTA SZTAKI has been assisted during the year 2008.

This year the goal for the Automatic Parking Control System (APC system) was the system testing in vehicle, and the previous qualitative certification of the system. For the video based lane departure and lane following system (VLF system) the aim was to improve the image processing and lane detecting algorithm, real-time implementation of the lane following algorithm, and the system testing in vehicle.

The following results were realized for the APC part of the project:

During this year not the logic of the parking system has been created not only for the parallel parking, but for the parking row situation as well.

The integrated system has been tested in test vehicle, and its right operation has been confirmed.

We have created a solution based on a new scientific result for that case, when the driver defines the parking speed in a vehicle, which is equipped with manual gear box. In this case a time scaling is required due to the vehicle speed defined by the driver. The driver of the vehicle and the amount of the error scales the time along the reference path together with defining the travelling speed.

During the project the following prototype has been developed:

Driver assisting safety and comfort system, which in case of the driver's intention at low speed manoeuvre can map the vehicle's close environment, identifies the possible parking slots, and if the driver

wants while the driver controls the vehicle speed it helps to execute the parking by intervening into the steering system with keeping the vehicle on the trajectory required for parking. The system communicates to the driver via a screen during the whole parking process.

The following results were realized for the VLF part of the project:

The system integration into test vehicle and its tests have been executed, and based on that we can say the followings:

We have created a large base-distance, stereo, machine-based vision system, which is capable to determine the vehicle position and orientation, and the shape of the actual lane with a spatial geometric reconstruction of the lane based on the lane detection algorithm created by us.

Applying stereo-camera and the synchronization of the cameras allowed us to create the 3D vision, and to identify the spatial curvature of the path. The lane detection system can be completed later with a stereo-vision based obstacle/vehicle detection, which is capable not only for the lane following, but also for avoid an accident, or create a vehicle following system.

During the project the following prototype has been developed:

Driver assisting safety and comfort system, which in case of the driver's intention at high speed manoeuvre can warn the driver to the non-intentional lane departure or in case of the driver's intention intervenes into the steering system autonomously that way, that the vehicle follows the marked lane. One of the basic components of the system is the so called

stereo-camera system, which detects the lane, and defines the vehicle's actual position based on that in all moment.

Both (APC and VLF) prototype system can be further developed to an industrial product. Thus based on technical aspects we propose to industrialize both systems in the following years beyond the goal of the actual project.



### 3. CONTROL ON THE VEHICLE LEVEL

The program's goal is to develop software products and procedures which can be used in vehicle dynamics control systems or the development thereof. As road traffic increases, the effects of vehicles on the environment get greater and greater attention. This poses increasingly strict requirements on vehicles, which can now be complied with only by means of electronic systems. Development of electronic system control software now requires a significant part of the development capacity of vehicle manufacturers and has become a separate business branch. Software is becoming a product, which gives the opportunity to individual enterprises to become automotive suppliers in the field of software development.

The result will be a software module or procedure that can be used in vehicle control systems such as 1) software modules for vehicle control systems; 2) bases for developing vehicle control system software; 3) an individual vehicle control system.

#### 3.2. Scalable hardware platform of the vehicle on-board electronics

Institutional project participants were two departments from the Budapest University of Technology and Economics (IIT and KAUT), the Knorr Bremse, and the Inventure Ltd.

Even in 2006 we developed at the Department of Control Engineering and Information Systems the original concept of a self-calibrated autonomous 3D navigation system. From that time till now we could implement the prototype of the device. The solution is primary based on the real-time evaluation of camera input(s) (feature tracking, multiple view geometry, 3D reconstruction, visual servoing, sensor fusion, etc.). We also worked out a robust wireless communication of intelligent sensor network - efficiently applicable in vehicles. Scientifically relevant results were continuously published.

Main implementation results in 2008:

*VPOC - implementation of an open FPGA – micro-controller based platform for automotive applications of image processing and sensor fusion.* Having the first implementation experiences on KLT we could analyse how to design an optimal solution according to the given time criteria – by means of moving the border of the hardware-software partition. Based on such experiments we decided which implementation technologies would be most beneficial for the given application.

We realized that pure FPGA implementation could not considerably accelerate KLT compared with the severe application demands. In future appli-

cations ASIC implementation of KLT seems to be reasonable. As a further development, the whole KLT algorithm could be implemented in a single chip. Later, other feature tracking algorithms like SSD, Optical flow, etc. will also be implemented in the hardware, in order to be able to switch automatically on the optimal solution in very different application scenarios which may occur during 3D navigation in an unexplored environment.

One of our efforts in 2008 was to realize a prototype system for traffic monitoring since vehicles represent a tightly constrained class of shapes, undergoing predictable patterns of motion. First applications were recently introduced in different publications.

We were also working on the video-rate FPGA implementation of image window operation (e.g. convolution) which is another core building block of a consistent universal image preprocessor concept briefly introduced in this summary. The work was done by BME-IIT.



*Implementation of a wireless communication platform for automotive applications.* It was an important goal of the project to replace a wired CAN bus with a novel wireless connection of sensor network elements within the range of 50-100 m. Design metrics for our automotive applications had to meet with severe time- and safety-critical demands. The finally selected, implemented and tested solution is briefly illustrated on the next figure.

The work was done in the frame of a cooperation of the participants: BME-IIT and Inventure Ltd.

### **3.3. Methodology and software tools for integrated braking, steering and suspension control in distributed real-time systems**

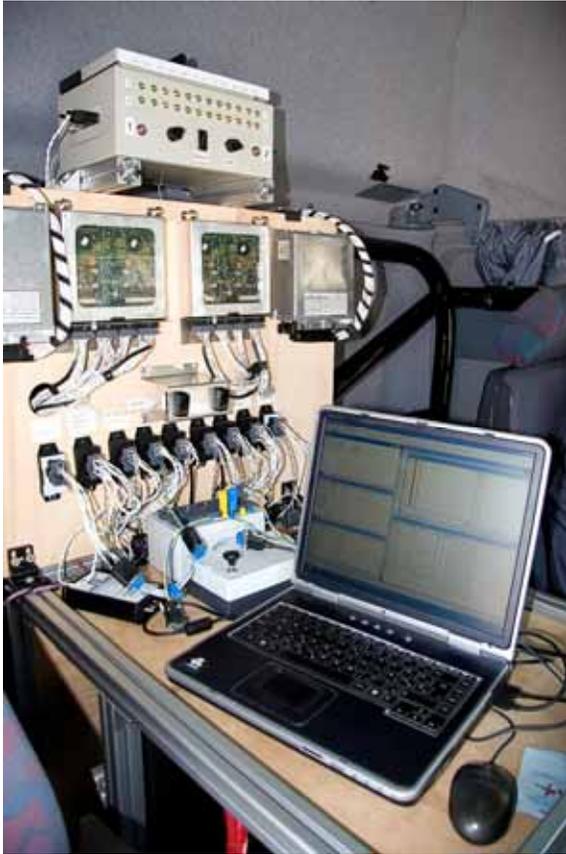
The aim of integrated control is to combine and supervise all controllable subsystems affecting vehicle dynamic responses in order to improve traffic safety. In the integrated vehicle control the steering, the brake and the suspension systems are integrated in such a way that different performance specifications are taken into consideration simultaneously within one unit. The role of the suspension system is to improve passenger comfort, i.e. reduce the effects of harmful vibrations on the vehicle and passengers. The role of the steering system is to follow a path defined by the driver. The role of the brake mechanism is besides the deceleration of the vehicle to reduce the effects of the lateral tire forces on the roll dynamics. The performance specifications are road holding, roll stability, pitch stability and passenger comfort. Using integrated control the operation of a partial control system can also be extended with a reconfigurable structure. The reconfigurable control is able to change its operation and adapt to new conditions and thus focus on other performances instead of the actual performances.

Several methods for solving different vehicle tasks have been elaborated. By integrating differential brake and suspension systems road holding, roll stability and safety are improved. The pitch stability is also improved by modifying the operation of the suspension system. A path-following task is realized by using an active steering, brake and suspension system. In these tasks the conflicts between the different performance demands can be avoided by a suitable reconfiguration of the active components. If an actuator fault occurs in the active suspension system, the control system assumes the role of the faulty suspension component to enhance rollover



prevention. In the case of a detected failure the operation of the control mechanism must be modified.

The dynamics of road vehicles is described by nonlinear models, in which the motion differential equations are concerned with the longitudinal, lateral and vertical directions. The approximation of nonlinear models with linear models is based on the quasi Linear Parameter Varying (quasi-LPV or LPV) description. This approach is based on the possibility to rewrite the plant in a form in which nonlinear terms can be hidden with suitably defined scheduling variables. The advantage of LPV models is that in the entire operational interval nonlinear systems can be defined and a well-developed linear system theory to analyze and design nonlinear control system can be used. The LPV control design methods are also proposed for integrated vehicle control systems. In these structures several active components are used in cooperation. In the control design, besides the performances and uncertainties, even fault information is taken into consideration. The control system can adapt to the dynamic properties of the faulty plant or changes in the environment. If in the combined structure an actuator fault occurs in the active suspension, the brake is activated in a modified way in order to guarantee the reduction of rollover risk.



The main difficulties in the design of integrated vehicle control are the following. The control design problem is based on a vehicle model which is augmented with a large number of performance specifications. However, the handling of the control prob-

lem based on a high-complexity model is numerically difficult. In order to overcome this difficulty, the control problem is divided into partial tasks in such a way that the integrated nature of control design can still be guaranteed. In the design of a path following task the model is divided into two tasks: a task for suspension design and a task for the tracking and rollover problems. The second difficulty is that the actuator dynamics introduces significant nonlinearities and delays to the vehicle model. Thus, a two-level controller is proposed for the design of control systems. In the design of a high-level controller all the performance specifications are taken into consideration and the control input is a control force or a moment. The designed control force (moment) is a required force (moment), which must be created by a hydraulic actuator. The required force is tracked by a lower-level controller by setting the valve of the actuator. The advantage of this method is that the controller for the physical actuator and the control tasks are handled in independent control design steps.

The qualitative features of the developed integrated control methods and the appropriation of the theoretical methods have been analyzed in several simulation case studies constructed in Matlab/Simulink. The integrated control design has also been analyzed on real-life applications. The vehicle featured several control components such as active steering and active braking.

## 4. INTELLIGENT ACTUATORS

The development of electronics and increase of comfort, environmental and safety expectations on vehicles requires individually operable 'intelligent' actuators that act as part of a larger, more complex system. The background of the program's goals is formed by the present development and development demand of automotive electronics. The relevant international R&D work is very complex and, in addition to the automotive industry's players, also involves universities and research institutes in the work that requires great experience. Partial tasks defined in the program focus on 4 areas of vehicle systems: engine, drive-train, braking system and steering system.

The comprehensive goal of the project is to establish a knowledge base and infrastructure necessary for developing intelligent actuators. The program includes R&D tasks in the field of system modelling, control technique, mechanics, electronics and communications that are necessary for developing autonomous vehicle control systems.

### 4.2. Steering system realizing additional steering angle

In the project 4.2 the Department of Control Engineering and Information Technology, Department of Road Vehicles at BME and TÜV Nord Ltd. has been assisted during the year 2008.

This year's goals were test of steering algorithms in vehicle simulation, test of steering algorithms in prototype vehicle, preliminary safety qualification, software executed on prototype electrical control unit, vehicle safety tests.

The steering algorithms developed in the last years of the project are tested in the VeDyna vehicle simulation environment first. This environment allowed – with small modifications, by adopting the by TKP Hungary already used models – the investigation of the system. After the first pilot measurements, the final manoeuvre catalogue has been worked out, These manoeuvres are able to provide us the desired, useful and comparable results. TKP Hungary provided not only the VeDyna software but also the – internal developed and built - simulator which is used for similar simulation tests at the company.

In the next phase the tests defined for Vedyna were tried under real conditions. The separation of these two phases had two reasons. One is, that the validation of the VeDyna models was extremely important, to allow the development of a cheap but close-to-the-reality simulation environment. The second reason was that only those tests shall be executed in the prototype vehicle, which has already

brought reasonable and comparable results in the simulation. To perform the tests, a prototype vehicle has been built up with the support of TKP Presta another company of ThyssenKrupp Technologies. The flexible architecture of the prototype fulfils all requirements of functional software development regarding architecture, electrical and mechanical design.



Contrary to the previous years, a new electrical control unit, with a completely different architecture is used. With the supporting help of the employees of TKP Hungary, the software integration into the control unit was performed easily. The implemented functionalities remained. It is very important to mention, that the current electrical control unit is very close to the serial production, the planned changes to start of production are marginal. This allowed the software development, testing to work under conditions very close to the real application. This allowed also the preliminary safety qualification tests to rely

on hardware architecture very close to the serial design. This fact is very important because of the reusability of the test and measurement results. In our case, the results of the preliminary tests are valid for the final qualification.

The tests and measurements needed for the preliminary qualification of the system were developed by the employees of TÜV NORD-KTI Kft. The base was the UN ECE 79/03 (2008 79/03) standard. On this base the planned measurements are developed, with the goal to qualify the vehicles basic mechanical steerability, controllability, immunity against disturbance factors (electric, electromagnetic, mechanical) and reactions. The planned measurements do not refer to and base on the IEC 61508 and ISO 26262, and

the functional safety of the system. The measurements are not performed till this time, so the results are not available yet.





Continuing previous researches, the last step of the hypothetical model development was done by the BME-KAT. They have examined the effect of different types of driver's behaviour on the traffic flow considering measurement experiences. Driver's behaviour is highly affected by the circumstances (tired driver, weather) and traffic conditions, and based on them it can be relative quickly changed. Therefore, previous years work was based on the investigation of the effect of drivers behaviour models integrated in macroscopic road traffic simulations. Its last step, the extension of the simulation model was done this year by the BME KAT, preceded by sensitivity analysis of the driver dependent parameters.

As a result, based on the 2008 results it was able to develop and implement time and traffic velocity dependent driver models. Consequently, the final goal of the project, a traffic feedback simulation model was created. This means that the traffic velocity affects the driver behaviour and vice versa. The simulation results are in strong correlation with real traffic situations and can be well connected to the measurements done by BME-IIT. Therefore, a possible further work can be concentrated on this field even after the end of this project.

### **5.3. Development and release process, reliability analyses of mechatronic components**

The main goal of project 5.3 is the methodology characterization, reliability analysis and prototyping of the development and the evaluation of mechatronic vehicle components. The participants of the consortium are the following: Knorr-Bremse, TÜV NORD, BME Department of Transport Automation, BME Department of Road Vehicles, BME Department of Mechatronics, Optics and Instrumentation Technology.

During the first two years of the project (2005-2006) we have considered, determined and categorized the mechatronic vehicle components. We have explored and revised the available and applied test methods and the standard procedures of the vehicle industry. Based on these documents we have defined the parameters and conditions how to set up the requirements of the design, prototyping and manufacturing of mechatronic vehicle components.

During the third year of the project (2007) we have developed specific development processes based on the previous basic research activities and

we have implemented them into practical applications. Our aim was to primarily focus on the mechatronic vehicle components that are included in the present development trends of the car manufacturers and that can significantly increase efficiency.

Among our projects we had some exceptional ones such as the development of vehicles with hybrid drive, traffic lights development and testing, servo drive development, examining running stability of vehicles and development of traffic signal devices.

In the first three years of project 5.3 we have worked out several measurement and test methods that have been supporting the basic research and development.

During the year 2008 (fourth year of the project) our goal was to fulfil the missing segments in the research and development and we worked on the implementation of the results into practice. These project details can be categorized in the following way:

1. Conducting basic mechatronic tests and analyses those are applicable in the examination and development of vehicles on the component level.
2. Integration of the project results in a uniquely developed vehicle using mechatronic components.
3. The mechatronic development in the vehicle industry does not only comprise technical content. Vehicles supported by mechatronic solutions are generally machines controlled by humans. Therefore during the development phase the human-machine relation's psychophysical and ergonomic aspects should be also considered.

As the results of these tasks we can summarize the following achievements:

1. During the practical analysis of the mechatronic vehicle components we have developed novel measurement and test methods for the investigation of the fundamental mechatronic vehicle components. We have created testing and analysis stations and we conducted checks on sensors and actuators such as DC servomotors, stepping motors, control technology analysis of different systems (e.g. PID), optical sensors, force sensors, displacement sensors and basic electronics analysis.
2. Combining the mechatronic vehicle components in a complex way we have created a one man, three wheel test vehicle using pneumatics. The power supply was using air compression transformed to mechanical power by pneumatic cylinders controlled by an electro-pneumatic system. The ve-

hicle is equipped with several functional and safety systems such as wheels, breaks, etc and can be used in two operational state that are also appearing in the development phase of today's vehicles. That is with the slight changing of the control and drive parameters of the vehicle either economic or high performance operations can be realized.



3. In order to test mechatronical vehicle components we have built a simulation tool that can analyze the human effect of some components such as break lights or driving aid equipments. The computer controlled simulation environment and the test method provides the possibility to examine the human aspects of mechatronical vehicle components in use and to apply the analysis results during the development phase.

#### **5.4. Fault tolerant system architectures for vehicles**

Quality and functional assurance of today vehicle technologies is increasingly relied on the application of software enabled, distributed, embedded control systems and fault tolerant communication networks. These systems raise a number of new requirements to the design and realization of safety critical vehicle control systems. This project puts the most recent technologies available for the synthesis of complex, networked vehicle control systems in a single framework. It is shown that the key idea behind the fulfilment of the ever increasing safety and functional requirements is based on specific structure of the control system as well as in the architecture of the communication network.

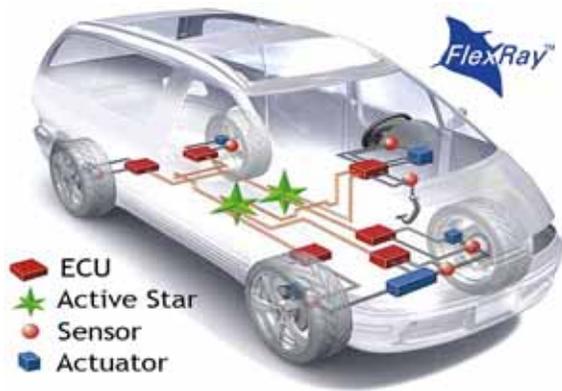
The project No. 5.4 of the Knowledge Center is aimed to be an integration project which is based on the close collaboration of the partners i.e., MTA

SZTAKI, three departments of the Budapest University of Technology and Economics (GJT, KAT, IIT), Knorr-Bremse Hungary LLC, ThyssenKrupp Nothelfer LLC, and TÜV Hungary LLC. Participants work together in an attempt to integrate the individual project achievements of the knowledge center in a common operational platform. The broad subject of the project has been the research, analysis and synthesis of dependability issues of complex vehicle systems with special focus on the structure and architecture of on-board vehicle control systems. This includes the methodology of conceptual design of complex vehicle systems and their detailed functional specification, the preparation of prototypes and production planning as well as verification and validation of the entire design process.

As the number of powered systems in cars increases, so does the requirement for reliability and fault-tolerant operation. Special attention is being focused on failsafe and fault-tolerant systems design. Electronic control is replacing mechanical controls in Drive-by-Wire applications. The same factors that drove the Fly-By-Wire breakthrough in the aerospace industry are now propelling the adoption of different X-By-Wire technology in the automotive industry. A key element in facilitating Drive-by-Wire is the in-vehicle network and fault tolerance must be built in for safety critical vehicle dynamic control. Drive-by-Wire systems are demanding more distributed network architecture and are leading to a greater interaction between vehicle sub-systems. As one of the most important changes witnessed in automotive industries during the last two years has been the new time-dependent communication technology FlexRay has gained strength by altering vehicle production technologies and conceptual design methods, significantly.

Results of this project have shown that the key to the success of fault tolerant vehicle systems lies in the application of a specific design methodology applied in the course of the whole product development process including the functional specification and target design of the control systems, and a very specific structure (architecture) of the on-board vehicle communication system, i.e., the construction of the FlexRay network. Time controlled communication technologies, such as FlexRay, however, are demanding in terms of design complexity. One of the biggest challenges is the complex time dependence of the possibly big number of ECU's included in the

network. 50-100 ECU's is quite common in a middle range car, recently. Because the performance properties (i.e., stability, robustness and efficiency of the data processing methods) provided by the network, depend on the time-varying parameters the performance should be kept under control, yet in design time.



In this project year the objective was to extend the results of the analysis, achieved in previous years, to real network implementations by taking the newest industrial trends, design methods, real applications and recently appeared system components into consideration. The experimental FlexRay cluster, built in the past project periods, served useful for this experimental work. An experimental scenario, aiming the design and implementation of a four wheel drive car model where the wheels were driven by independently controlled electric motors, governed over FlexRay network, has also been studied. The results of this experimentation work can be directly utilized in the real automotive practice.

### 5.5. Research and development process and the related project management system

In realizing this partial programme, our objective was to lay out and shape up a research and development project management system in the field of manufacturing motor vehicles and parts of such vehicles. The aim of the partial programme is to shape up a method and compile a professional publication that are capable to define and store research & development information and parameters related to the manufacturer's pre-development activities as well as to follow-up and produce documents on the necessary duties, tasks and steps from the assessment of the purchasers' and clients' requirements, through the early-stage strategic experiments and including

the approval of technology search and feasibility certificate.

In the first years of the partial programme, the primary objective was the assessment and description of the outlines, demands and expectations and their transition into such a complete and exact requirement that allows both control and functional accountability during the later development process.

The described requirement specification as well as the repeated redrafting and supplementing of the system plan justify the high-level professionalism that appeared during the realization of the program, since the main aim was always the permanent actuality and maximum compliance with the demands from the current era and the profession.

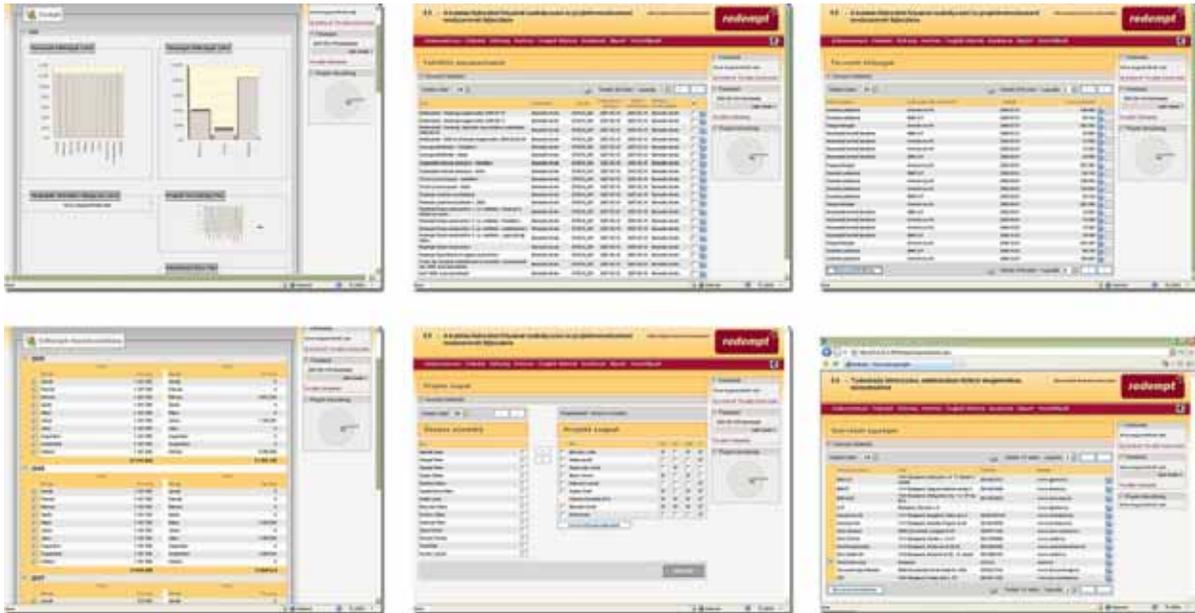
Following the specification, the development was launched, which, although not simple and smooth, has still confirmed the appropriateness of the basic objectives and the correctness of the underlying ideas.

We succeeded in establishing a system that introduces a new approach in the organisations' project execution practice and follow-up method.

In the last year of the partial programme, our aim was to finish the system's development, testing, and publication in a closing status that makes installation, creation of backup copies, etc. trouble-free. In order to achieve this, the ultimate correction of errors and the preparation of a system documentation have become necessary both at hardware and software level. It was equally essential to put together a users' manual and an introductory presentation so that future users can start utilizing the system as early as possible.

The partial program was built fundamentally on the past two years' work, as this was the period during which we had to create the software, which the knowledge centre can utilize in its day-to-day work for monitoring and following-up the results of certain task parts.

The first quarter in 2008 for the 5.5 partial programme was spent for the development and improving of the Redempt project management system; it is because first, the problems that were discovered during previous tests must have been corrected and second, modules and functionalities that were still to be built in must have been made operational (administrator interface: deletion, approval, central management, password processes, logging).



These innovations and developments were necessary mainly to the management of the system and the performance of administrator tasks. The new modules were published on the servers of EJJT; thus, testing became possible and data of pilot projects could have been uploaded.

All the necessary modules had been built in during the second and the third quarter; however, the testing has not yet been completed.

It is inevitable that the testing, which has grown into a successful routine during the development phase, be continued until putting the system into general use and the programme's final closing in order that all possible operational problems can be identified in real processes and be resolved timely.

The newly developed project management system was installed on the servers of EJJT and runs appropriately; support is resolved via continuous correction of errors. Therefore, the system may be put into general use with pilot and real data, respectively.

What the 5.5 partial programmes brought as result is a software that satisfies the special requirements of several different partners at the desired level and in the prescribed way.

Managements can supervise common projects effectively by using Redempt. The knowledge centre of Redempt preserves the experience accumulated from projects finished earlier ensuring thereby a more rapid, more effective and cheaper way to the success of future projects regardless of the changes in human resources and technical conditions.

By applying the software successfully, participating partners can unify their knowledge and resources, since Redempt delivers a single, common space for joint and prosperous collaboration to organizations, companies and institutions having the most diverse profiles.

The project management system is capable to support, process, harmonize and follow-up projects managed by the given partner. It satisfies these functionalities according to the specification and the system plans and in line with the preliminary motivations; therefore, the success of the partial program is beyond any doubt.

### 5.6. Database and its management for the knowledge center

The objective of this partial programme is to shape up a uniform system relating to both motor vehicle manufacturing and to the knowledge centre itself; a professional database that is capable to collect, store, uniformly share and ensure access to the parameters, technical specifications, documents and information of research & development projects. Our task was to design, specify and coordinate the development of a knowledge centre that introduces and manages the joint research & development activities relating to the manufacturing of motor vehicles and motor vehicle parts; in addition, this knowledge centre had to be put into application in the field of manufacturing electronic motor vehicles and that of electronic motor vehicle control systems.

The requirements that were formulated in the course of designing the knowledge centre have brought in the forefront the cooperation with project management system to be specified and developed within the framework of the partial programme 5.5. The close cooperation is also justified by the fact that the "knowledge" that is created during the realization of the individual task parts and projects has to form part of the project management procedure that is aimed at making the individual project realization phases retrievable in standardized form with adequate storing and tracking solutions. In order to store, systematize and retrieve effectively the professional works, documents and publications that are to be produced in the realization phase, it is also essential to have a document management system (knowledge centre).

In the starting phase of the development, the primary goal was the specification and establishment of an independent system which can ensure cooperation with the project organizing and tracing system. With the expiry of the design and specification period, the conception has changed due to more and more reasons justifying and necessitating the cooperation (uniform appearance) with the project management system. Today it seems that the decision was correct; it is because inquiries as well as storage and future search of documents have been made possible through a single platform and within the given task part or project.

The redefined conception has altered the ideas in their appearance and not in their fundamentals; thus compliance and performance have been rebalanced and received different emphasis.

The development and implementation process have been broken down into four, well distinguishable parts in order create a system which is well traceable and tolerates the necessary interventions and amendments.

The first year was all about specification; in this period, we defined the demands, i.e. what do we intend to create and in which format. We attribute an exceptional importance to this specification phase, since those topics and suggestions that were raised before only at a level of brainstorming have turned into exact points and accurate requirements in this phase.

In the following phase of the development, the primary aim was to design, to create the basic elements of, and to implement a specified system; all of

which have been successfully completed. The original conception has changed in this phase as follows: due to the reasons explained above, the system to be developed will not be independent; instead, the "knowledge" and the "experience" will appear as parts of an integrated system.

In the next phase, the completed system was tested as well as supplemented and fine-tuned on the basis of information and ideas collected in the meantime in order to apply both user-friendly and professionally correct solutions.

In the last phase of the development process, the key goal was to put into general use the system in the form as it was specified, developed and tested earlier.

Through the system we have contemplated the operation of such pilot projects whose documentary system and information database are smaller and can be circumscribed and defined rather exactly.

As a result of testing and operation with pilot data the general use of the system has also started, since documentary systems and "knowledge" in projects and task parts in operation at the EJJT have been uploaded and appeared in an integrated form. Errors that have been generated by the continuous use have been corrected ensuring thereby the safe and permanent operation as the normal course of business.

The knowledge centre and the project management system in their full functionality have been published only during the second and third quarter; accordingly, uploading the knowledge centre with real documents and materials has started in this period.

In line with the original ideas and objectives, it has become possible to label, search and define the access rights to the uploaded knowledge base.

The development process may be closed by accessing to the documents, professional works and reminders (uploaded in the final phase of the partial programme) appearing in structured and searchable form.

It is important to note, however, that a knowledge centre with its current uploads may never be considered as complete and final. The value of its professional content decreases day by day and the centre becomes obsolete by losing its innovative value over time; therefore, the project of building a knowledge centre can be regarded successful, only if the concerned employees and partners use it each

day, not only for carrying out their chores described in the house rules, but also for exploiting their own potential.

### **5.7. Development of the international regulation for vehicle dynamic control systems (UN-ECE WP 29 GRRF subcommittee)**

Hungary has initiated the elaboration of a new UN-ECE Regulation on Electronic Vehicle Stability Control Systems (EVSC) within the framework of the 1958 Geneva Agreement in 2004. The background of this initiative is the joint interest of the Hungarian government to improve traffic safety and of the Hungarian industry, which has a worldwide significant share in the development of these systems.

The proposal was accepted by the World Forum for Harmonisation of Vehicle Regulations (WP.29) and the work done under Hungarian chairmanship and under the Secretary in the EVSC ad-hoc group of the regular Expert Group for Brakes and Running Gear (GRRF).

The project demanded the participation of the Hungarian stakeholders (including the representative of Hungary) in the meetings of the mentioned groups and also the activity of the contributors (BME GJT, BME MOM, KB, TKN, in the frame of the EJJT 5.7 project.) whose advisory contribution and background research was indispensable to the activity, which appears on international scene in the form of the final UN-ECE Regulation on Electronic Vehicle Stability Control Systems (EVSC).

As the future international regulation shall play an essential role in supporting industry to develop, mass produce and sell worldwide quality EVSC products without commercial barriers, and defending customers from poor products a large number of proposals were discussed in the meetings. (Meeting in London, 11. October 2005, Meeting in Paris, 12. December 2005, Meeting in Munich, 27. January 2006 )

Between the meetings the main stakeholders fulfilled lot of test to find the best method acceptable from all points of view of the technique, law and practical aspects.

Large efforts were made to solution using simulation without losing the close connection with the real situations on the road. In the frame of EJJT 5.7 a lot of tests and simulations were made by the members (BME GJT, BME MOM, KB, TKN,) to give a solid support for the Hungarian opinion and proposals.

Having finished with the debated items, the group has looked over the whole draft text for necessary rewording. The rewording job was done and the final text is ready and is waiting for the official signature and for release. The outcome is the official document ECE/TRANS/WP.29/GRRF/2006/34, to be discussed in the 60th session of the GRRF.

The last version of the official document was accepted in 2007. This is the final outcome of the joint activity of the EVSC group. The job of the EJJT 5.7 project is fulfilled. The project is closed successfully. We annex it to this report. All of the documents of the group are to be found in the Internet.

### **5.8. Homologation of complex electronic systems**

One of most important objects of 5.8 project in this year was the overview the requirements of the complex electronic systems.

During the whole project term there was no any important modification in the requirements. An automotive standard which is equivalent with the generalised standard IEC 61508 still not published. The series 11 of ECE R13 came in to force, which contains the functional requirements and the frame of the testing of electronic controlled stability systems.



In the frame of the project we tested the applicability of the standard of safety critical electronic systems (IEC 61508) in case of an electronically controlled braking system. The regulation of ECE R13 as a special requirement of the vehicle sector prejudices the application of IEC standard in case of the several function of the braking system. We analysed the aspects of partial or full changing of the control functions from the pneumatic to the electronic one in

case of a current pneumatic braking system. We carried out same analysis of the required safety integrity level (SIL) for the whole braking system and separately for the main functions as well. Based on standard of IEC 61508-as the service experiences can be taken into account at the evaluation of the reliability.

We reviewed some test reports and manufacturers information documentation of complex systems. Based on its experiences the main part of the testing practice emphasizes the functional safety of systems. Design requirements, continuous documentation of development process, risk analysis and determination of SIL levels don't belong to the test.

The reliability test of an electronic/pneumatic foot brake module was continued. In this frame we reviewed the weighting factors depending on the manufacturer and service parameters (temperature, vibration, power utilization) of the electronic parts. The analysis was extended with the case of electronic redundancy.

Perhaps the most important complex system is the electronically controlled vehicle stability system which acts on the brake and/or steering system. The regulation of ECE R13 gives the testing possibilities by real vehicle measurement and/or by simulation. The simulation method shall be validated by vehicle tests. Our aim was to try some possible testing manoeuvres, and to carry out some test for determination the vehicle characteristics (suspension parame-

ters, torsion stiffness of suspensions and of the chassis...) during the resonance test and tilt test which are usable in the simulation model.

We made many testing measurement with the trailer EBS CAN tester (test HW, 01.023.01.013 version test SW) equipment developed in the frames of the project of 5.8. These tests were quite successful. The system is a proper tool for the testing of the trailer CAN communication (conformity, functional tests both on tractor and trailer side). We specified the final version of the HW which gives a possibility for the tractor test with trailer simulation and trailer test with tractor simulation or the listen mode between the tractor and trailer.



# STRUCTURE AND MANAGEMENT

## ADVISORY BOARD



**Dr. Károly Molnár**  
Minister without portfolio responsible for research and development  
President of Advisory Board



**Dr. László Keviczky**  
Academician



**István Lepsényi**  
Managing Director of Knorr-Bremse Brake Systems Ltd.



**Dr. Pál Michelberger**  
Academician

## CENTRAL MANAGEMENT



**Dr. Zsolt Stukovszky**  
Director



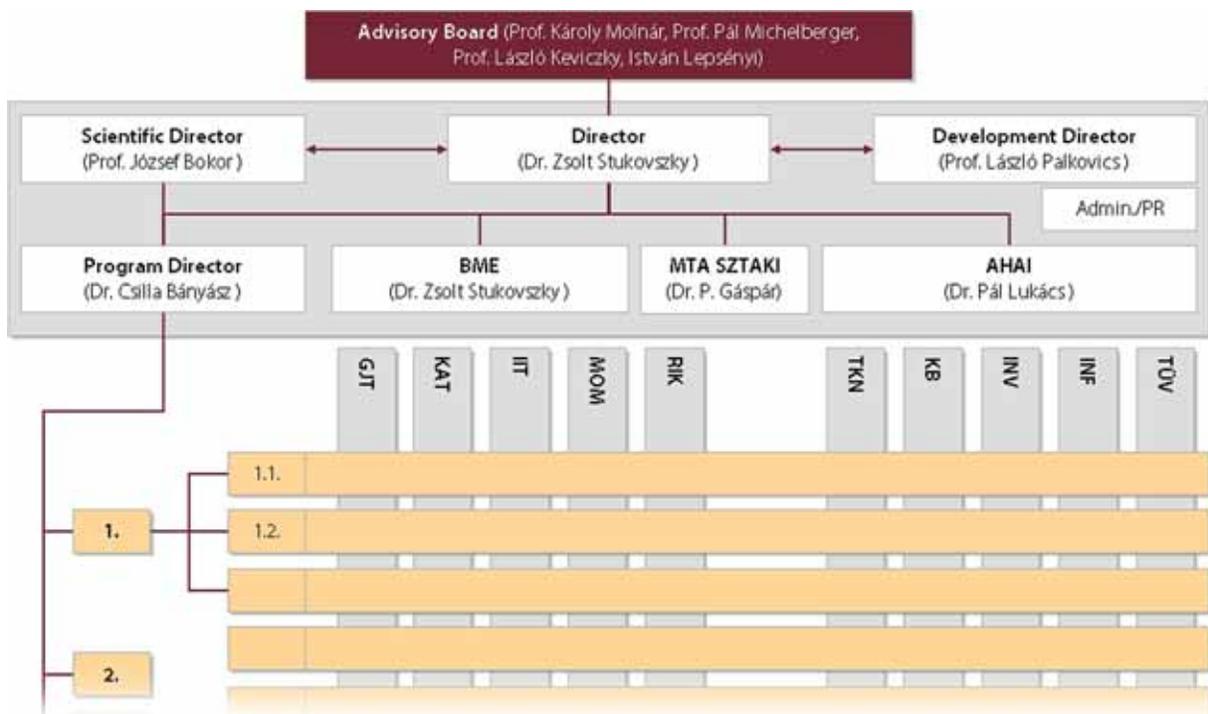
**Dr. József Bokor**  
Scientific Director



**Dr. László Palkovics**  
Development Director



**Dr. Csilla Bányász**  
Program Director



## STAFFING AND ADMINISTRATION

### ADMINISTRATION

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**Mária Csíki**

Administrative Executive

**Dr. László Nádai**

Marketing-Communications Executive

### PROGRAM MANAGERS

---

**Dr. Tamás Péter**

Manager of the 1st Research Program

**István Wahl**

Manager of the 2nd Research Program

**Dr. Péter Gáspár**

Manager of the 3rd Research Program

**István Jánosi**

Manager of the 4th Research Program

**Dr. András Edelmayer**

Manager of the 5th Research Program

### INSTITUTIONAL CONTACT PERSONS

---

**Dr. Tamás Péter**

BME Dept. of Control and Transport Automation

**Dr. Lehel Kádár**

BME Dept. of Automobile Engineering

**Dr. László Vajta**

BME Dept. of Control Eng. and Information Technology

**Dr. György Ábrahám**

BME Dept. of Mechatronics, Optics and Inst. Technology

**Dr. Péter Gáspár**

MTA SZTAKI

**Péter Széll**

Knorr-Bremse Brake Systems Ltd.

**István Wahl**

Thyssen-Krupp Nothelfer Ltd.

**Dr. Zsolt Szalay**

Inventure Ltd.

**Krisztián Kolonics**

Informin.hu Ltd.

**Gábor Brett**

TÜV-Nord KTI Ltd.

### PROJECT MANAGERS

---

**Dr. Tamás Péter**

Research Project No. 1.1.

**Dr. Alexandros Soumelidis**

Research Project No. 1.2.

**Dr. Zsolt Szalay**

Research Project No. 1.3.

**István Wahl**

Research Project No. 2.1.

**Bálint Szabó**

Research Project No. 3.1.

**Dr. István Loványi**

Research Project No. 3.2.

**Dr. Péter Gáspár**

Research Project No. 3.3.

**Péter Koleszár**

Research Project No. 3.4.

**István Jánosi**

Research Project No. 4.2.

**Dr. Huba Németh**

Research Project No. 4.3. and 4.5.

**Géza Szabó**

5.1. kutatási projekt vezetője

**Dr. Zoltán Benyó**

Research Project No. 5.2.

**Dr. György Ábrahám**

Research Project No. 5.3.

**Dr. András Edelmayer**

Research Project No. 5.4.

**Krisztián Kolonics**

Research Project No. 5.5. and 5.6.

**Gábor Brett**

Research Project No. 5.7.

**Ferenc Finszter**

Research Project No. 5.8.

## INDUSTRIAL PARTNERS

### KNORR-BREMSE BRAKE SYSTEMS LTD.



<http://www.knorr-bremse.hu>  
1119. Budapest, Major u. 69.

Knorr-Bremse Group is the world's leading manufacturer of brake, suspension and traveling dynamics systems for trains and trucks. The Vehicle Systems Branch of the Group has 18 premises worldwide. In 2004, turnover exceeded 1.5 billion EUR.

The road vehicle program initiated the Hungarian co-operation with Knorr-Bremse at the beginning of the '70s. This resulted in founding the first East European joint venture of the Munich-based company. The Kecskemét-based Knorr-Bremse Brake Systems Ltd. is now a strategically important manufacturing base of the Group, and has been the centre of the East Central European sales. It is the exclusive manufacturer of certain brake system components such as quadruple-circuit protective valves or leveling valves. These products can be found in trucks and buses of all of the leading vehicle manufacturers such as Daimler Chrysler, MAN, IVECO or SCANIA.

Sales of Knorr-Bremse Brake Systems Ltd. in 2005 increased by 30%, to 22.8 billion HUF compared to the previous year. For 2006, total sales of 25 billion HUF are predicted. In addition to selling its own products, the Company offers the entire Knorr-Bremse product range to the leading truck manufacturers and our parts-market partners in Hungary and Eastern and Southeast Europe.

In Europe, it can also be stated that the largest R&D investor and the industry with the highest innovation potential is the automotive industry. Knorr-Bremse Brake Systems Ltd. started its R&D activity in 1995. In 1999, Knorr-Bremse was the first among multinational enterprises to establish a research institute in Hungary.

Knorr-Bremse Brake Systems Ltd. spent 51% more, about 800 million HUF on investment, development and modernization in 2004. In 2005, almost one billion HUF of investment was realized. The total amount of investments will be as high as one billion HUF in 2006 as well. Production processes will be

modernized, IT will be developed and the SAP enterprise management system will be introduced.

The Kecskemét enterprise, first within the Group, developed a business-to-business e-commerce system. Thanks to this, the commerce of the parts of the company completely takes place via the World Wide Web. Electronic connections with the suppliers and authorities have also been built. In 1998, the company was given the National Quality Award in the medium-sized enterprise category. In 2001, it was awarded the European Business Excellence title. In 2004, Knorr-Bremse's Road Vehicle Systems branch was – first among European automotive company groups – achieved a finalist place at the European Quality Award, in co-operation with the European locations. Both European Knorr-Bremse branches (railway and road systems) were awarded the EQA special prize for great result-orientedness at the 2005 tender of the European Quality Award.

### THYSSENKRUPP PRESTA KFT.



<http://www.thyssenkrupp.hu>  
1111 Budapest, Sztoczek u. 6.

ThyssenKrupp is one of the world's largest steel companies. One of its key goals is to supply the world's automotive industry with various components developed and manufactured by it, such as steering systems for vehicles. ThyssenKrupp's Budapest development centre has been dealing with the development of electronic vehicle steering systems since 1999, in close co-operation with Liechtenstein and German partner companies. The competency centre for management unit electronics, software and sensor development is located in Budapest.

During recent years, we have integrated electronic steering systems into vehicles of various well-known vehicle manufacturers, e.g. Ford, BMW, Audi, Renault, VW, Peugeot, etc. Our employees perform the following tasks: development of system and steering algorithms; designing and stress analysis of steering sys-

tem mechanisms; development of control unit electronics and software; sensor development.

The Institute's activity is in close connection with Hungarian higher education and academic institutes. During recent years, several R&D projects, diploma works, individual lab works, Summer professional practice and TDK research works have been successfully completed with the participation of BME's teachers and students. One goal of the company is to actively participate in higher education and to pass on its industrial experience to the engineers of the future.

Our long-term goal is to build a wide competence in developing electric steering systems in order to ensure a safe and perfect driving experience for the vehicles of the future, using the latest technology.

#### **TÜV NORD-KTI LTD.**

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<http://www.tuvnord.hu>  
1119. Budapest, Thán K. u. 3–5.

The Hannover-based TÜV Hannover/Sachsen-Anhalt e.V. founded a joint venture with Közlekedéstudományi Intézet (today KTI Kht.) for vehicle testing, then system qualification in Hungary, under the name of TÜV Hannover-KTI Kft. Following the founder's strategy, our company continued its business activity under the name of TÜV NORD-KTI Kft. as from November 2003.

From February 2005, TÜV NORD-KTI Kft. has offered its services to its Partners in the professional fields of vehicle and loading-machine testing, work protection, product evaluation and environmental management.

Our Company is an independent expert institution. Our staff has great reputation in their professional fields, both in Hungary and internationally. They bear full responsibility for the quality of their results. This ensures professionalism and objectivity of testing and evaluation.

Our knowledge base is formed by our highly qualified, experienced staff who have several degrees.

We do not pursue any activities that might jeopardize our objectivity (e.g. manufacturing, trade).

#### **INVENTURE AUTOMOTIVE ELECTRONICS R&D LTD.**

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<http://www.inventure.hu>  
1111. Karinthy F. u. 26.

Inventure Automotive Electronics R&D Ltd. was founded in 1997 to develop such gap in the market filling products for Hungarian and international automotive electronic market that satisfy special consumer demands. The exclusively Hungarian-owned company is primarily specialized in individual development and manufacturing of small-series professional automotive electronic measuring instruments. It provides customized solutions by continuous innovation and R&D activity.

The solutions offered are complete with the developed products, the corresponding services (e.g. calibration, evaluation, analysis, and study) and recognized professional knowledge. Inventure Automotive's fields of competence are fleet management systems, CAN bus technology, automotive measurement technology and evaluation of brake systems.

Thanks to our internally developed products, such as the universal acceleration and deceleration measuring instrument family XL Meter™ Pro, the company's name is now internationally known and renowned. Inventure's instruments are among others used by the police, judicial experts, crime scene investigators and the Hungarian Army for brake tests, and Transportation Supervision Authority for regular instrument slowing brake tests.

A key development of the company is the FMS-CDR™ fleet management data collection system. More than 1000 such systems are operating in a satisfactory way in various fleets, e.g. Wáberer's Group (Hungarocamion Rt.). The primary function of the system is the customized vehicle monitoring and monitoring of cost-efficient fuel consumption.

Inventure Automotive's products are, via distributor partners, present in 14 countries of the world, e.g. in Germany, Switzerland, Ukraine and the USA. In ad-

dition to authorities (police forces, transportation supervision authorities), among its customers are public transport and forwarding companies, vehicle manufacturers, and several universities and R&D institutes as well. Regarding foreign markets, it is notable that Volkswagen AG and DaimlerChrysler Corp., both famous for their high quality requirements, are also among its customers.

The company's products are competitive mainly for their price / quality / performance ratio and the wide customer support, which, after sales, provides a guarantee to act with the utmost consideration of the customer's expectations and individual requirements.

Inventure Automotive regularly publishes articles in Hungarian and foreign specialist newspapers and is invited to a number of Hungarian and European professional conferences and scientific meetings – through its managing director, it is member of ISO WG6 working group to establish standards for brake system testing and of Hungary's EU UN-ECE co-ordination office.

#### **INFORMIN.HU IT CONSULTING AND SERVICE LTD.**

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<http://www.informinkft.hu>  
1111. Budapest, Budafoki ú. 59.

Informin.Hu IT Consulting and Service Ltd. was founded in 2002 by Hungarian private individuals. Its

goal was to become a long-term counseling and provider organization, equally experienced in IT and technical fields. The organization actually started operation in 2004 with technical counseling and project co-ordination activities.

During the previous years, the forming and operation of a project management, organizational development, enterprise management building and IT counseling organization was defined, making use of the employees' and partners' relevant experience.

We want to extend the sphere of our services beyond IT and IT systems towards information protection, project management and knowledge management, since enterprise systems require this to an ever greater extent.

Our consortial participation had two goals. On the one hand, in order to establish a consciously and systematically formed project management application to systematize R&D activities. On the other, in order to systematize and unify knowledge accumulated over a period of years and decades in the university and industrial R&D.

Our participation in the KC focuses on project management and IT support of the individual projects. Our goal is to successfully operate a cooperative Knowledge Centre that is beneficial to both Hungarian vehicle and vehicle part development and manufacturing, and – in a wider interpretation – to the whole of automotive society. We use up-to-date equipment for fulfilling our duties. Our staff and partners are experts highly experienced in both project management and software development.

## ISO 9001:2001 CERTIFICATION

**CERTIFICATE**



BP Tanúsító Kft. Certifies that the company

**Budapesti Műszaki és Gazdaságtudományi Egyetem  
Elektronikus Jármű és Járműirányítási Tudásközpont**  
H-1111 Budapest, Stoczek u. 6.

has established a  
quality system  
in conformity with

**MSZ EN ISO 9001:2001**

The Certificate is valid for:

**Research and development in the automotive  
engineering, innovation, product  
industrialization, technical engineering and  
expert activities, consulting, education**

Date of the first Certificate:  
2006-07-19

This Certificate is valid until:  
2009-07-31

Certificate-Registration-No.:  
CERT-25131-2006-QMS

Győr, 2006-07-19



János Papp  
Managing Director



**NAT**  
MIR TANÚSÍTÓ  
NAT-4-0070/2005

## CONTACT

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Dr. Csilla Bányász

*Program Director*

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### **Advanced Vehicles and Vehicle Control Knowledge Center**

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Fax: +36 1 463 3255

Web: <http://www.ejtt.bme.hu>

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*Administrative Executive*

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Dr. László Nádai

*Marketing-Communications Executive*

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Building J of BME

## FINANCIAL HIGHLIGHTS

<b>Project number and title</b>	<b>Total costs</b>	Founding	Internal	Income
<b>Research program 1</b>				
1.1. Modeling and control of traffic systems .....	<b>18588</b>	18044	544	
1.2. Control of traffic systems by communication networks, cooperative control technologies of fleet management .....	<b>37173</b>	31619	5554	
	<b>55761</b>	49663	6098	
<b>Research program 2</b>				
2.1. Autonomous vehicle control .....	<b>22356</b>	12860	9496	
<b>Research program 3</b>				
3.2. Scalable hardware platform of the vehicle on-board electronics .....	<b>11557</b>	9874	1683	
3.3. Methodology and software tools for integrated braking, steering and suspension. Control in distributed real-time systems .....	<b>25245</b>	21409	3836	
	<b>36802</b>	31283	5519	
<b>Research program 4</b>				
4.2. Steering system realizing additional steering angle .....	<b>30516</b>	16356	14160	
<b>Research program 5</b>				
5.1. Determination of Safety Integrity Level of vehicle systems, function specification .....	<b>11141</b>	9044	2097	
5.2. Behavior of the driver in controlled vehicles .....	<b>11030</b>	11030	0	
5.3. Development and release process, reliability analyses of vehicle mechatronic components .....	<b>12953</b>	11894	1059	
5.4. Fault tolerant system architectures .....	<b>20080</b>	19114	966	
5.5. Research and development process and the related project management system .....	<b>2741</b>	1628	1113	
5.6. Database and its management for the knowledge center .....	<b>3660</b>	1830	1830	
5.7. Development of the international regulation for vehicle dynamic control systems (UN-ECE WP.29 GRRF subcommittee) .....	<b>9523</b>	6306	3217	
5.8. Homologation of complex electronic systems .....	<b>11072</b>	5991	5081	
	<b>82200</b>	66837	15363	
<b>Knowledge Center Office</b> .....	<b>60782</b>	60782	0	54320
<b>Total</b> .....	<b>288417</b>	237781	50636	54320

Financial statements contained in this Annual Report are rough estimates. The exact financial data are included in the audited balance-sheets of consortium members.



**ADVANCED VEHICLES AND VEHICLE CONTROL KNOWLEDGE CENTER**

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