TRACKS

Project Programme of Brite Euram: BE-S2-5466
Contract BRST-CT98-5372

FOR PUBLICATION

European Cooperative Research - CRAFT: BRITE - EURAM
"An integrated system for on-line inspections of railway tracks"

TRACKS

- SYNTHESIS REPORT -
(from 1st November 1998 to 31st October 2000)

Start date of the project: 1st November 1998
Duration: 24 months
Date of issue of the report: 31st December 2000

Project coordinator: Tecnogamma
Other contractors: Nelrow, Raind, Vitronic
RTD Performers: Consorzio Padova Ricerche, University of Erlangen, Politecnico di Milano
End Users: A.T.M. Metropolitana Milano and T.M.B. Ferro Carril Metropolità de Barcelona

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1. SUMMARY

1.1 Keywords

1. Railways safety
2. Laser measurement system
3. Railway maintenance costs reduction
4. Rail profile measurement
5. Rail wear measurement

1.2 Results and benefits of the project

TRACKS project developed an innovative laser measuring system which could effectively respond in a reliable way to railways demand for tracks quality control. The system measures in real time the whole rail profile, detecting wear, defects or anomalies along the line.

The requirement to control tracks quality on-line and in real time is becoming more and more urgent for all the railway transport companies and considering the role of rail transport in Europe a big matter for European transport system. This need is due to the following factors:

- railway traffic increase due to policies that encourage railway transport
- speed increase in railway transport due to promotion of high speed projects
- security and comfort standard increase

All this requires more and more frequent maintenance interventions at higher and higher costs.

TRACKS system is the innovative solution. No more special trains are necessary, since the new system could be installed on every kind of train. In this way railway network could be monitored by everyday railway vehicles at every hours of the day without creating any traffic congestion. All these aspects ensure at the same time a continuous and precise rail inspection and a thick costs saving for railway companies.

A prototype, implemented during the project, was tested in different rail contexts: railways, tramways and subways. The results of the field tests have demonstrated the achievement of the objectives laid down in the proposal:

- high precision measurement
- surface rail conditions do not influence on the whole the measurement
- external light conditions do not influence on the whole the measurement
- vibration do not influence on the whole the measurement

Railway Companies are considered by the involved SMEs to have the biggest potentiality of growth applying the new measuring system the TRACKS project developed. However, it is important to highlight that the results the research has carried out, could be further implemented for other applications. Using the know-how acquired during TRACKS project and the technology of optical triangulation, characterised by high speed and precision without contact, it will be possible to study and develop other railway systems able to answer to other measurement requirements.

2. THE CONSORTIUM

2.1 Partner organization

- **TECNOGAMMA SPA – First proposer and co-ordinator –**
  Address: Vicolo Ongarie, 13 31050 MORGANO (TV), Italy
  Contact person: Mr E. Casagrande, President
  Tel. ++39-0422-8391
  Fax. ++39-0422-839200
  e-mail office@tecnoeurope.it

- **RAIND SRL – Sme proposer -**
  Address: Via Vignola, 4 47030 Sogliano al Rubicone (FO), Italy
  Contact person: Mr G. Fondriest, Managing Director
  Tel. ++39-0541-948428
  Fax. ++39-0541-948002
  e-mail raind@glomanet.com

- **NELROW – Sme proposer -**
  Address: Z.I. Ste Agathe - Rue Lavoisier 57192 Florange, France
  Contact person: Mr C. Rowdo, Managing Director
  Tel. ++33-383-826222
  Fax. ++33-472-492772
  e-mail claude_rowdo@yahoo.fr

- **VITRONIC Gmbh – Sme proposer -**
  Address: Hasengartenstrasse, 14a 65189 Wiesbaden, Germany
  Contact person: Mr B. Minge, R&S Director
  Tel. ++49-611-7152130
  Fax. ++49-611-7152133
  e-mail bm@vitronic.de

- **AZIENDA TRASPORTI MILANESI – End User -**
  Address: Foro Buonaparte, 61 20121 Milano, Italy
  Contact person: Mr A. Meazzini
  Tel. ++39-02-875424
  Fax. ++39-02-48031455

- **FERRO CARRIL METROPOLITÀ DE BARCELONA – End User –**
  Address: Avda. del Metro s/n l'Hospitalet de Llobregat, 08092 Barcelona, Spain
  Contact person: Mr R. Mir
  Tel. ++34-93-2148369
  Fax. ++34-93-2148390
  e-mail rmir@tmb.net

- **CONSORZIO PADOVA RICERCHE – RTD-Performer -**
  Address: Corso Spagna, 12 35127 Padova, Italy
  Contact person: Prof. G. Clemente, Director
  Tel. ++39-049-8703310
  Fax. ++39-049-8703255
  e-mail gio@padova.ccr.it

- **POLITECNICO DI MILANO, Department of Electronics and Computer Science – RTD-Performer -**
  Address: P.zza Leonardo da Vinci, 32 20133 Milano, Italy
  Contact person: Prof. V. Piuri
  Tel. ++39-02-23993606
  Fax. ++39-02-23993411
  e-mail piuri@elet.polimi.it

- **FRIEDRICH ALEXANDER UNIVERSITÄT , Erlangen – RTD-Performer -**
  Address: Staudtstr. 7 b2 91058 Erlangen, Germany
  Contact person: Prof. G. Haeusler
  Tel. ++49-9131-8528382
  Fax. ++49-9131-13508
  e-mail haeusler@physik.uni-erlangen.de

2.2 Consortium description

Tecnogamma Spa , Italy

Tecnogamma has many years reliable experience in the design, development and production of dimensional control systems using optoelectronic technology. In the specific sector of railway transport Tecnogamma has already carried out many systems, among them:

- Dimensional check system of rails, installed on testing lines by Acciaierie di Piombino (IT)
- Dimensional check system for train wheels at hot temperature,
  - installed by Lovere siderurgica, Italy
  - installed by Valdunes Dunkerque, France
  - installed by Standard Steel, Pennsylvania USA
- Prototype for feasibility study of measurement of rail wear, installed by ATM Milan, Italy

The technicians of Tecnogamma are experienced in two main sectors: hardware and software development. The laboratory is equipped with excellent level instruments.

Since the very beginning the vocation of the company has been to focalize the activity on some particularly innovative fields and to develop constantly the technological level. In particular, research in the sector of optoelectronic technologies have been encouraged with applications in the field of quality and dimensional control.

In 1986 a particular measurement technology based on optic triangulation principle has been completed. This technology uses a collimated laser beam and a high resolution linear camera. The development of this technology has allowed the company to undertake technical and commercial collaborations in very important industrial sectors such as steel industry and railway transport.

Tecnogamma has many collaborations with Electronics, Mechanics and Mathematics departments of various Italian and foreign universities.

From the very beginning Tecnogamma has promoted a new and original company policy, that aims at overcoming the narrow company frontiers, opening its doors to the outside world. This means that collaboration between structures and people from different environments and culture is welcomed, and free circulation of ideas, that enhances the competencies of the single and amplify his potentialities, is pursued.

In TRACKS project, Tecnogamma was involved in every task as general management and scientific co-ordinator. From a scientific point of view, its activities focused in particular on laser techniques, electronics, vision system, prototype assembling and tests.

Raind Srl, Italy

Raind is specialised in the design and planning of electronics systems for the measurement of forces and deformations. They have developed and patented in collaboration with Italian railway transport company a measurement system of traction and deformation forces of railway tracks, caused by the transit of vehicles and thermal expansion.

The company has a well-established experience in the problems linked to railway track and to its control.

In TRACKS project, Raind focused its activities in particular on the hardware and mechanical aspects of the system.

Vitronic (core group proposer)

Vitronic has a well-established experience in the sector of optoelectronic technology, in particular artificial vision. They design and carry out three dimensional systems for the detection of complex shapes, that use the principle of illumination with fringe lights and telecamera detection. They have a great experience in the field of image elaboration and in the field of complex profile calculus with vision systems. Vitronic operates in collaboration with UNIER (RTD performer).

In TRACKS project, Vitronic focused in particular on the optics design and tests.

Nelrow , France

Nelrow works within the Technologic Innovation Centre in Florange (France) and is specialised in optoelectronic technologies and in particular in laser telemetry systems. Nelrow has a good experience in dimensional control field, using laser technology. In their applications, they use both the interferometric and triangulation principle.

In TRACKS project, Nelrow was especially involved on the research aspects regarding physics.

Azienda trasporti Milanesi, ATM , Italy

ATM is the public transportation firm of the Municipality of Milan; it manages the urban and extra urban transport of Milan: the ATM service covers a total of 3 million inhabitants. It uses three metro lines covering 140 km of tracks and 18 tram lines for a total length of 250 km of tracks.

Its metro fleet, composed by 590 vehicles, which transports every day 1,1 million people, covers a total of 51 millions km per year.
Its tram fleet, composed of 480 vehicles, which transports every day 570.000 people, covers a total of 23 million km per year.

ATM has planned many investments to improve the efficiency and safety of transport on railway transport.

In TRACKS project, ATM was very active at the beginning of the project, defining the technical specifications and requirements and at the end of the project, verifying the research outcomes on its railway lines. ATM was also involved for all aspects regarding marketing

Ferrocarril Metropolità de Barcelona S.A. TMB, Spain

TMB manages the urban and extra urban rail transport of Barcelona in Spain. Its service covers a total of 2,2 million inhabitants. It uses two underground lines and 11 surface lines for a total of 200 km of rail.

On its lines 200 vehicles run, which transport every day 200.000 people for a total of 16 millions km per year.

The company has planned a programme of investments to expand rail transport, to improve the efficiency and increase safety.

TMB role in the project was:

- advice for technical specification and requirements as for market analysis and industrialisation phase,
- making their infrastructure and the required personnel available for testing,
- involvement in the activities of spreading and promotion.

As potential end user of the project results, like ATM, TMB was very active at the beginning of TRACKS, defining the technical specifications and requirements and at the end of the project, verifying the research outcomes on its railway lines. TMB was involved for all aspects regarding marketing, too.

Consorzio Padova Ricerche, CPR, Italy

CPR is strictly linked to Padua University and in particular to the Faculty of Electronics and Informatics. They develop an intense activity of research in the field of architecture of hardware systems, in the field of micro electronics and high calculus power information systems. They are an important connection between the industrial and academic environment, as they search the right balance between theoretic research and applied one.

In TRACKS project, CPR focused the research activities on all aspects regarding hardware and software.

Politecnico di Milano, POLIMI, Italy

The Department of Electronics and Informatics of POLIMI collaborated within the project aiming at developing and verifying a mathematical model for the analysis of data coming from a vision system to check the rail profile. The research entailed the use of algorithms containing conventional processing and neural networks, that allowed the analysis of a large number of data in a very short time. The Department of Electronics and Informatics of POLIMI gave a decisive contribute to TRACK project.

In the TRACKS project, POLIMI was involved in the research and development of new algorithms able to reconstruct the track profile, as seen by the cameras, with a subpixel accuracy. The suggested processing chain, which encompasses modular processing based on traditional image processing and training-based models is capable of dealing with strong perturbations such as external noise. The suggested algorithm solves the compromise between computational complexity -fundamental issue in a strict real time computation- and accuracy by adding -or removing- as required by the application, the processing modules constituting the final complex and robust algorithm.

Friedrich Alexander Universität – Erlangen, UNIER

The Chair for Optics of this university carried out research about optoelectronics technologies and optical metrology. This department contributed to the project about the design of the sensor, to make it work at the physical limit.

The contributions of UNIER concerned questions of the optical and geometrical design of the measurement system in order to optimise its accuracy as well as its reliability. UNIER also provided an algorithm for the calibration of the system.

3 TECHNICAL ACHIEVEMENTS

The TRACKS project aimed at developing innovative technologies in the field of railway maintenance. The proposed measurement device is based on an optoelectronic system equipped with a set of laser triangulation apparatus. Although this kind of technology is well known in many application fields, its feasibility in railway wear control is under investigation and represents a challenging inquiry from a technical and scientific point of view.
The results of the activities performed by the RT&D partners in the TRACKS projects can be summarised into the following main topics: new software methods and algorithms in the field of image processing and data filtering have been studied, original hardware technologies have been designed and experimented, finally the system components have been tested both in laboratory and on a prototype.

3.1 Software algorithms

The research activities, focused on a set of algorithmic aspects, have led to the identification of a composite system able to reconstruct the profile of the track by processing the images coming from the acquisition module. The tasks carried out with respect to the data processing module yielded a final system, which encompasses traditional and neural-inspired processing submodules. During the research activity, solutions have been identified by integrating several high level constraints such as computational complexity (a low computational burden must be associated with the system), robustness (the algorithm must be able to deal with different environmental conditions), modularity and reusability (the different parts of the composite system must be intended as modular independent routines so that the algorithm can be easily customised and the routines reused). The final whole solution has, therefore, solved the compromise between performance (track profile reconstruction accuracy) and the above mentioned constraints.
In particular, the TRACKS system has pushed the research activity towards the satisfaction of the following issues: decomposition of the data processing task in elementary sub-modules for supporting the modularity and the reusability constraints, optimisation of the performances for matching the computational complexity requirements. This has led to the definition of a minimal computational chain able to solve the problem in a low noise environment as well as to a set of submodules which enrich the minimal algorithm and make it more robust. The submodules are fully parameterised to support an easy system upgrade. Concerning the high level analysis, the followed approach was based on techniques in the field of soft computing. The off-line experiments allowed to identify a robust computational chain to extract the profile, also under many intense noisy operating conditions.
Results obtained in the optic design and the PMI’s experience achieved on the field during the project allowed to simplify the robust computational chain and to create a minimal computational chain. This solution is able to operate very effectively in the largest majority of the noisy cases, with a higher efficiency due to the lower computational complexity. Another very important issue concerns the problem related to the camera system calibration. This problem arises every time image coordinates must be mapped into real world coordinates. A peculiar research activity was devoted to find a suitable image to world transformation method and to realize an original and practical procedure to calibrate the optical triangulation system.

The research activities performed by the RTD’s partners faced also the problem of data compression and recording. As a matter of fact, the rail profiles measured on the left and right rails together with the train position have to be recorded on disk storage to allow further off-line analysis.

The main objective of this task was to minimise the quantity of memory necessary to contain the profiles, and maintaining, at the same time, the algorithm feasible from a computational point of view.
Starting from the kind of images to be compressed, an incremental coding algorithm was taken into account. The implemented algorithm is a version of the Freeman coding, arranged for the problem at hand, able to exploit the a priori knowledge on the input image.
In particular, an exhaustive set of tests demonstrated an average compression rate of about 88% on typical distribution of data, while in the worst cases the algorithm shows a behaviour similar to other techniques already used in similar applications.
A lot of work has been devoted to an efficient implementation of the processing software to a DSP board in order to achieve the goal of real time capabilities.

Starting from the algorithms previously developed on standard PC platform, an implementation on a DSP board architecture was obtained. The main algorithms concerning the extraction from the raw images of the rail profile have been arranged in order to fully exploit the DSP capabilities. The modules was verified on a set of real world images acquired with the measurement head. Both the requirement of accuracy and time complexity was matched by the implementation.
From a computational point of view, a frame rate of 80 frames per second for six sensors is easily achievable using the solution based on DSP board.

3.2 Optic system

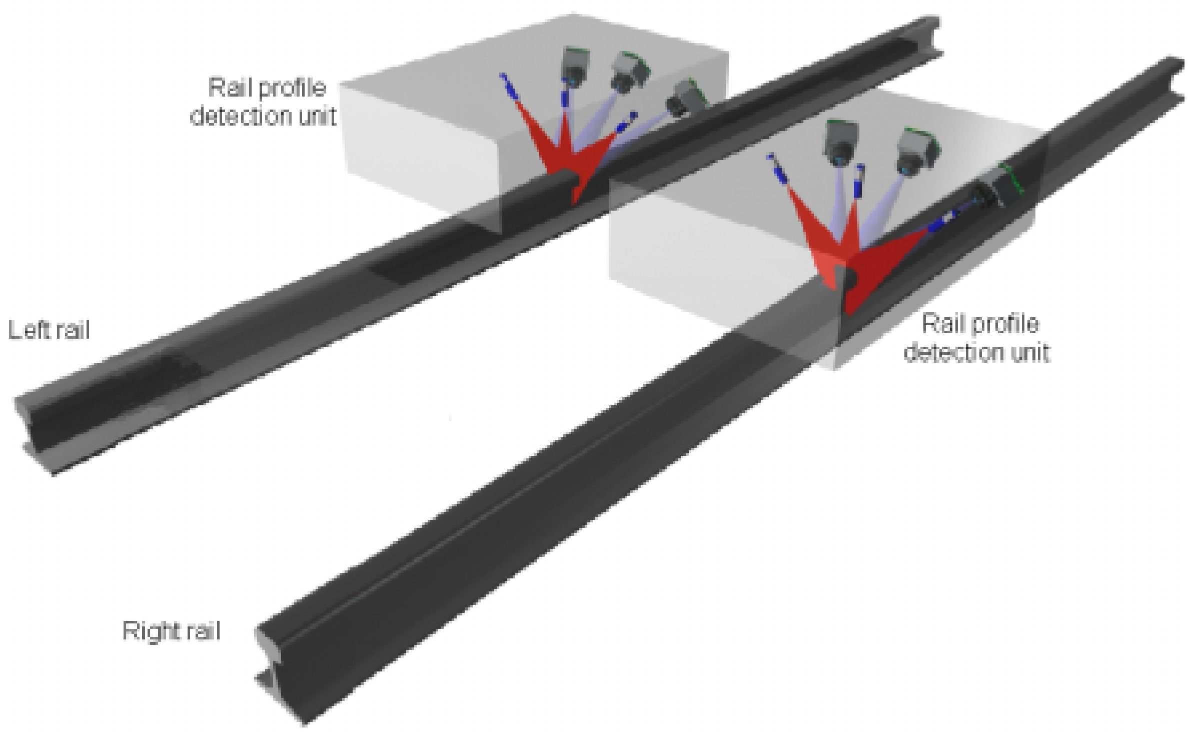
The TRACKS system is based on the method of active optical triangulation for the acquisition of rail images. The method consists of a laser beam focused on an object surface. The reflected spot is imaged by a lens on a optical sensor. The axis of illumination and the axis of observation define the so called triangulation angle. From this geometry it follows that a distance difference in the object position causes a lateral shift in the image plane.
Starting from the principle, some choices have to be made in order to define the configuration of the optical system. For the TRACKS system, the requests were to place the optical sensors so as to observe the whole rail profile, select the position of the laser plane in order to minimize the maximum lateral shift, maximize the triangulation angle, select the viewing and the illumination angles so as to optimize the intensity of the reflected light as seen from the optical sensors, obtain a high measurement accuracy along the whole rail profile.
More than one configuration was proposed, compared and tested in terms of resolution and precision of the system. In particular, an optimal configuration which uses four 2D optical sensors for each rail can be arranged to enhance the resolution concerning the measurement of the upper part of the rail. In this case two optical sensors are used to observe two contiguous parts of the upper surface of the rail and the others two to observe the lower part of the rail. By using such a type of equipment the achievable theoretical precision was estimated to be smaller than 0.1 mm. An alternative solution was realised using three optical sensors. Albeit this simplified configuration decreases the system precision, the obtained results showed that optical sensors with 512x512 pixels and a laser plane with width of about 1.5 mm are sufficient to match the end user requirements.
The modularity of the system does not bar the possibility to modify the geometry configuration in order to choose the suitable one respect to the application scenario and the kind of rail under control.

3.3 Digital hardware components

The results of the research activities have directly led to application in designing an original technological hardware component. In general, an image acquisition device is made of an imaging sensor and a A/D converter. In the TRACKS system a single board device composed by a CCD sensor a set of A/D converter and an logic unit was designed and realised. The processing capabilities of the logic unit are performed by an FPGA device mounted close to the imaging sensors. This architectural solution allowed to implement preprocessing algorithms (filtering and definition of region of interest) and significantly reduce the data transfer rate. Moreover, the data coming from the sensors are then given in input to a controller for data serialization and then sent to the PCI Bus Interface through a set of fiber optic transceivers.

3.4 System prototype

The system prototype has been designed and implemented to demonstrate the basic ideas of the project. Its functionalities, architecture and implementation have been derived from the results achieved in the research and from SMEs experience acquired during the project.
The results of the research led to solutions which largely satisfy the needs of the end users in the immediate future, providing enough capabilities to support further enhancements to deal with more critical operating conditions.
The system prototype (Picture 1) therefore incorporates simplified versions of the results obtained by the research. The performances and accuracy of the implemented solutions are satisfying to the end users.



Picture 1: representation of the TRACKS measuring system.

3.5 Field Tests

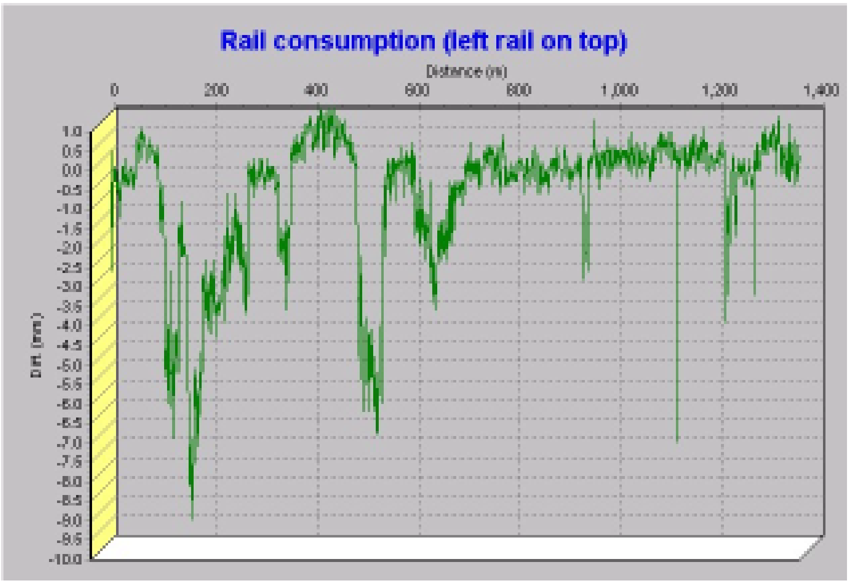
This section summarises the tests carried out by TRACKS consortium. The main goal of this testing phase was the validation of the global system performances as seen by the end user: in particular, the capability of the system to measure the wear of the rail, defined as the variance of the rail profile from the model with an accuracy of 0.1mm, coping with the real environmental conditions. The tests aimed at verify the measurements repeatability, their accuracy and estimate the measurement noise. Moreover, the test were carried out in three different railway environments: TMB underground, ATM underground and on FS-Italian Railways high speed lines, aiming to demonstrate the feasibility of the TRACKS system for different speeds.

The tests were executed **on TMB underground** line 5 between the stations of *Collblanc* and *Placa de Sants*. The total railway length was of about 1300 meters. The train with the system prototype repeated for ten times the same run..

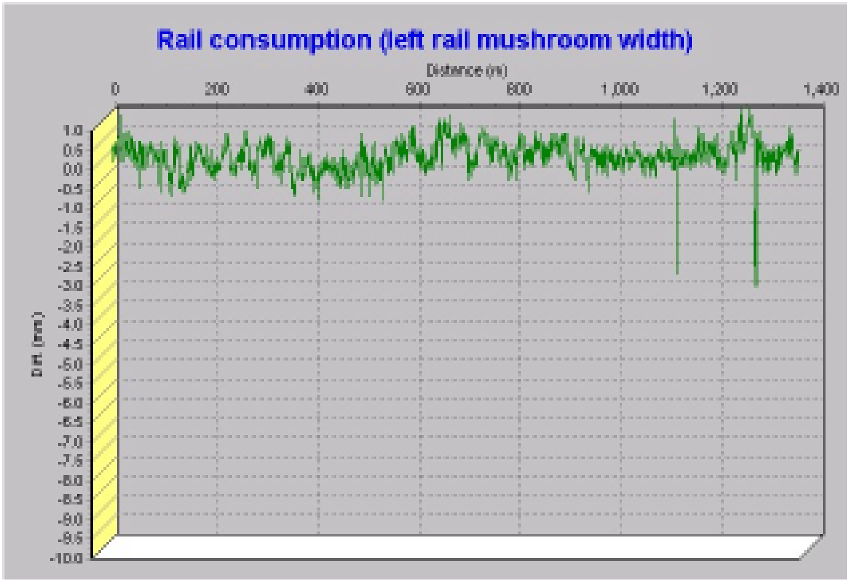
The average speed during the trails was of about 30Km/h, whilst the maximum speed was of 50Km/h.

The system frame rate (the number of extracted profiles for second) was equal to 50 frames/s, that corresponds to a sample each 0.3m along the railway path.

The following figures represent the computed rail consumption for a complete trip. The first figure concerns the consumption of the left rail in the pointer *A*. The second figure reports the rail consumption in terms of difference from expected and measured head rail width.

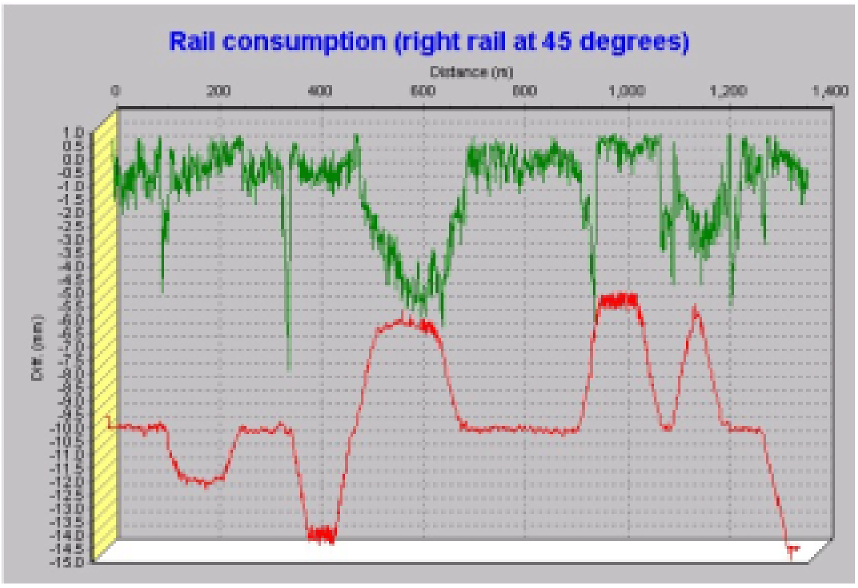


Picture 2 : *The difference between the measured and the expected rail in correspondence of pointer A for the left rail.*



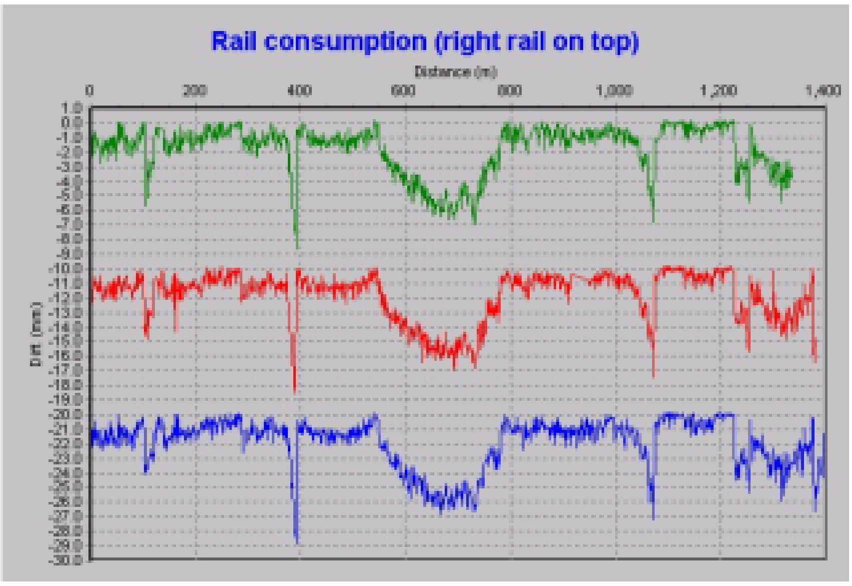
Picture 3: *The difference between the measured and the expected head rail width.*

The next figure reports the rail consumption for the right rail on the same trip, and it is superimposed with the signal coming from the inclinometer (lower graph). To avoid the superimposition of the two graphs, the inclinometer signal is shifted from zero to –10: the values are reported in millimeters and represent the elevation of one rail respect to the other. It is relevant the correlation between the wear of the rail and the presence of superelevation showed by the inclinometer data.

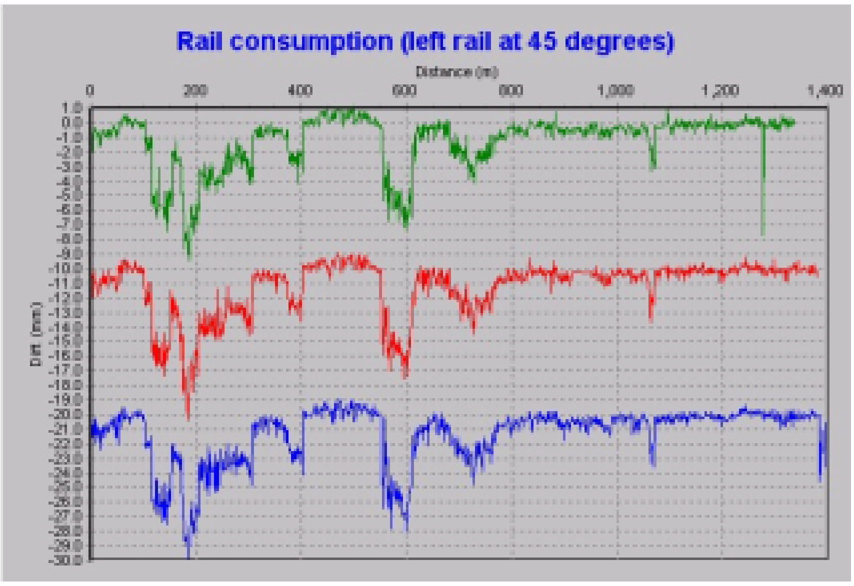


Picture 4: *The rail consumption and the corresponding inclinometer data. This data is shifted from zero to –10: the values are reported in millimeters and represent the elevation of one rail respect to the other.*

Pictures 5 and 6 report three trials on the same underground line. As before, the tests were executed on the underground line 5 between the stations of *Collblanc* and *Placa de Sants*.
The reported graphs show with evidence the repeatability of the given measures.

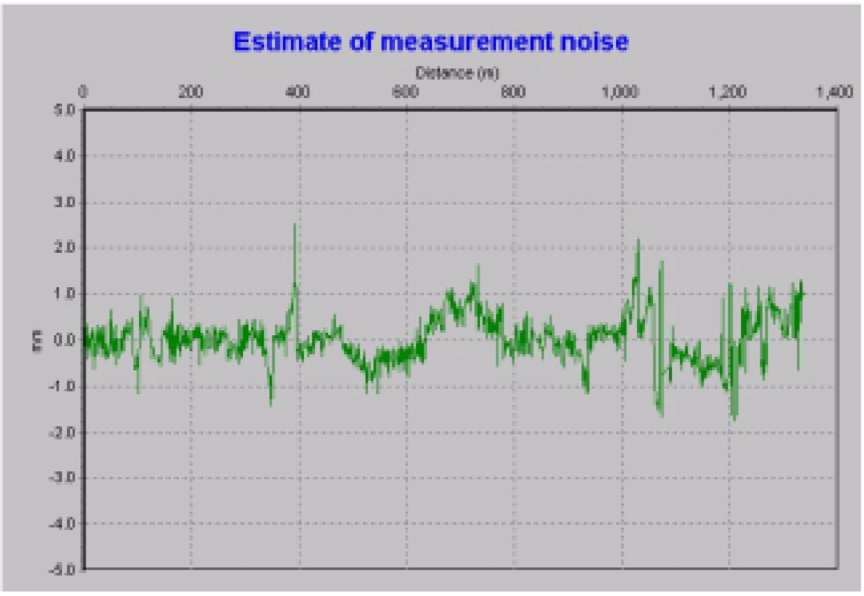


Picture 5: *The rail consumption on the top of the right rail for three consecutive runs on the same path. The second and third graphs are shifted respectively of 10 and 20 mm, in order to simplify a visual comparison between the three data sets.*



Picture 6: *The left rail consumption in the position of pointer B for three consecutive runs on the same path. The second and third graphs are shifted respectively of 10 and 20 mm, in order to simplify a visual comparison between the data sets.*

Note the conspicuous wear detected in range between 600m and 800m, about 5mm, in correspondence of two consecutive curves along the path. In particular the wear detected on the left rail before the 600meters correspond to a right curve, while the wear detected on the right rail after the 600meters correspond to a left curve.



Picture 7: *The estimate of the measurement noise along the trip obtained as the measurement deviation from the average.*

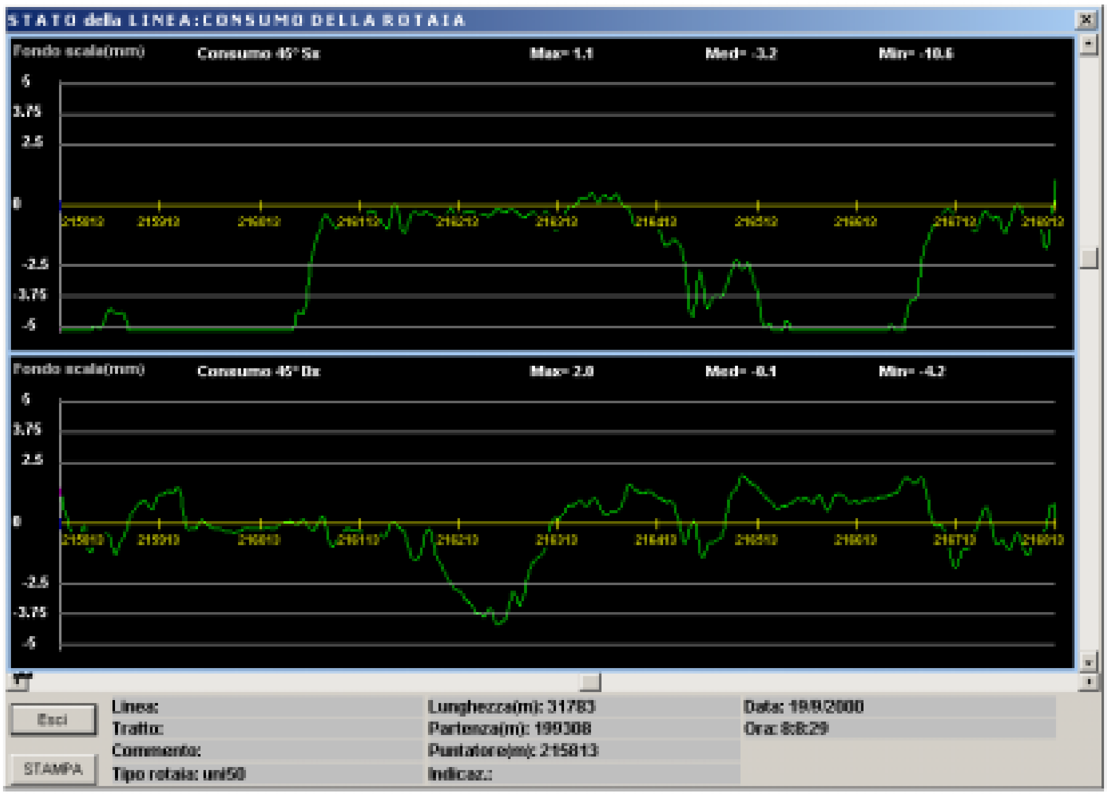
Picture 7 shows the estimate of the measurement noise computed as the data deviation from the average obtained on ten different trials. In this case the measurement noise is used as statistic estimate of the measure repeatability. From the graph it is evident that, apart few outliers, the noise is almost independent from the measures, and can be estimated of about 0.5mm. Note that the result has to be considered sufficiently good because the statistic used to estimate the noise is affected by an uncertainty due to the indetermination in the samples position. In fact, in different acquisition runs the extracted profiles correspond to points that can be shifted of about 0.5m.
As expected from a theoretical point of view, and before obtained in laboratory, the data acquired by the system on the field show an accuracy of about 0.1 mm.

3.6 Further tests

Though the extensive tests for the TRACKS system have been made on the TMB (a partner of the TRACKS consortium) underground in Barcelona (see section 3.5), the technologies that are at the basis of the TRACKS prototype have been tested also in different railways environments.

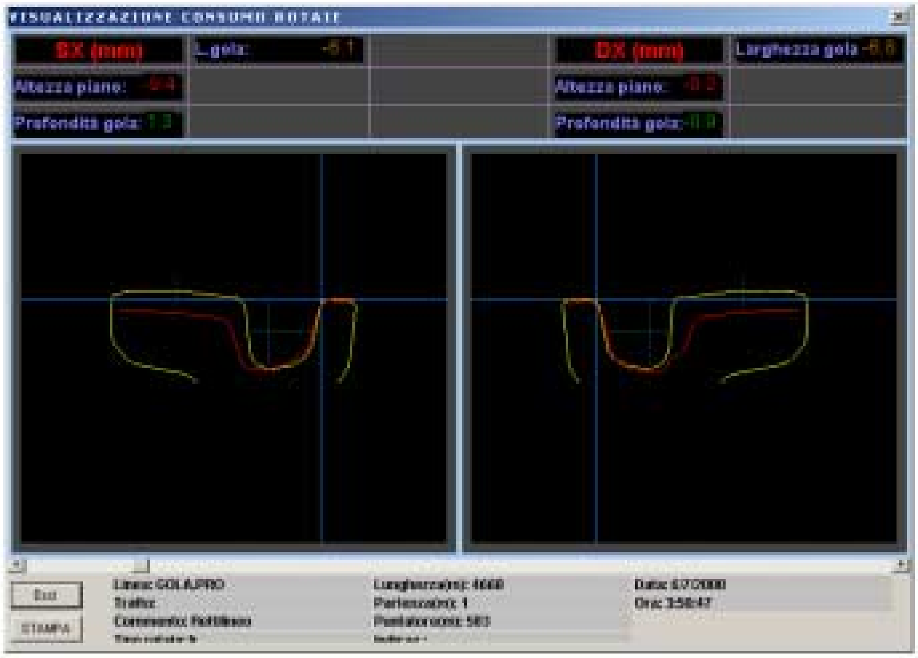
Two different testing phases were carried out respectively on the railway between Rome and Naples and at the Milan underground. They are significant and can complete the field tests made in Barcelona, since they are obtained in very different environmental conditions.

In the railway between Rome and Naples, the train has reached a maximum speed of 180 Km/h, and the system demonstrated satisfying performances since it was able to successfully cope with the new conditions. Taking into account the effects due to vibrations increase, which can depend on the state of the line, the rail model and so on, the obtained data appears comparable in accuracy and precision but at a lower sampling rate respect to those reported in the previous paragraph. In Picture 8, a graph is reported with the computed railway consumption for a test of one kilometre. The data refer to the rail consumption on the pointer at 45 degrees for the left and right rail.



Picture 8: *The left and right rail consumption for a test of one kilometer.*

The tests made on the **Milan underground** presents different aspects since the rail model under inspection was the grooved rail (see Picture 9).
The results obtained are completely equivalent to those obtained in Barcelona, but these tests are really important because they confirm the modularity of the TRACKS hardware and software. From an hardware point of view, slight changes on the geometrical architecture of the detection unit allows to cope with the new rail model without others modifications. Moreover, from a software point of view, the user interface allows the operator to easily exchange not only the rail model under inspection, but also to redefined the measurement points. In correspondence of these user defined points the rail wear profile is computed and then compared with the expected one.
Nevertheless the final prototype was a simplified version of all the activities carried out by the TRACKS consortium, the tests so far made have demonstrated its feasibility even in different application scenarios.



Picture 9: *The rail model under inspection in the tests carried out in Milan.*

3.7 EMC compatibility tests

EMC compatibility tests have been accomplished on the final prototype. The results of these tests demonstrate that the system successfully meets the following EMC specific norms:
EN 5501, EN 61000-4-2, EN 6100-4-3, ENV 50204, EN 61000-4-4, EN 61000-4-5, EN61000-4-6.
The tests were performed at ELETTRA 80 EMC Laboratory (Via Colonna, 14 S. Maria del Piave – Treviso - Italy).

3.8 Mechanical vibrations tests

Mechanical vibrations tests have been accomplished at the Mechanical Department of Politecnico di Milano aiming at testing the robustness of the system to mechanical and vibration stresses simulating the heaviest working conditions on board of the train (RMS acceleration of 0.5 m/s^2 and maximum harmonic frequency of 40 Hz).

The RMS accelerating value reached during the tests was of 1.5 m/s^2, while vibrations frequency reached values of 50 Hz. Further random frequency spectrum vibrations were applied to the prototype aiming at simulating real working conditions. At the end of the tests the mechanical and optical settings of the prototype were evaluated. Since there were not significantly off-settings, the system demonstrated a good mechanical robustness.

3.9 Updating on field tests (on 02/04/2001)

At the moment, the most significant tests are those on the FS- Italian Railways lines. The system prototype, installed on a FS vehicle, began to detect FS lines on May 2000. At the moment, it has been working for 10 months, making 1000 km a week. Considering that it works 5 days a week and it did not work on August, it already checked 40.000 km of lines. The vehicle runs at a speed

between 80Km/h and 180 Km/h, depending on the line condition. The average speed is around 120 km/h with peaks of 180 Km/h.
It already worked in all environmental conditions: summer, winter, day and night, with snow and ice, with temperature from –10° C to +40° C.
Tecnogamma technicians are always in touch with FS managers responsible of that diagnostic vehicle, they go on the diagnostic train every two weeks to verify data and the state of the system.

Regarding vibrations: nowadays, we do not have recorded any problems at all regarding vibrations, since the equipment is installed under the vehicle body which is amortised. TRACKS Partners and RTD-performers had overestimated the vibration problem. During the last 10 months, our technicians removed the measuring unit three times, but the inside components had no damages.

Regarding dimming: this kind of problem was on the contrary underestimated. The problem arose during the wet days. This obliged the operator to remove and clean the windows of the system. To solve the question, we firstly used electrified resistances to warm the windows glasses but they did not always overcome the problem. The windows definitively stopped to mist on March 2001, thanks to another innovative solution: a special kind of glass, already used in the aeronautics industry for the flight deck window. That window is composed by two pasted glass layers, between which a special film is placed. To this film a voltage is applied that uniformly warms all the glasses. The system, equipped with this new window has been working for 1 month, during this period the whether has been quite wet and at the moment the problem seems to be solved.

3.10 Future development

The functionality, architecture and implementation of the TRACKS system have led to a solution that satisfy, as so far discussed, the needs of the end users for what concerns the rail wear measurement, but also provide the basic blocks to support further enhancements.
The demand for the future will be probably focused not only in having more accuracy and robustness in the existing measurement systems, but also in obtaining new measurement parameters from the railway suitable for the control of the railway condition.

In this sense, a first enhancement for TRACKS system will be the use of more than one measurement head for each rail. This can lead to the use of other two heads, made of two triangulation systems. The whole resulting system will be composed by four detection unit for a total of ten sensors. The central detection units are standard units for the profile reconstruction, one for each rail, they implement the optical system discussed in the previous paragraphs. The data coming from these units can be merged together with data coming from the other two units placed in front and behind the carriage. In such a way the system can be updated in order to control more relevant geometrical parameters.

For instance, the two new units can contain in a single assembly two triangulation systems arranged in such a way as to measure only a portion of each rail corresponding to the superior internal part.

The extracted data will then be used for the extraction and estimation of some geometrical features like the horizontal and vertical railway alignment; the superelevation of one rail respect to the other, the distance between the two rails and so on.

4. EXPLOITATION PLAN AND FOLLOW UP ACTIONS

4.1 Marketing plan

An effective exploitation plan was planned the last semester of the project and an intensive marketing activity has been planned for the first semester after project completion.
Some of the following activities are currently in progress:

- The project final meeting organization. It is going to be scheduled for the middle of March 2001. It is required among partners, EC officers and potential end users of the developed systems to explain and show the reliability of the innovative measuring system. A demonstration of the potentiality of the system will be directly performed on one of the TMB's lines, by Barcelona underground, providing a train, with the prototype of the new measuring system.
- The establishment of a commercial consortium, constituted by the four SMEs with a partecipation share proportional to the role performed during the project. The consortium will be the owner of the project results and of the related patents. The use of the project results or their related patents will involve the payment of a royalty, whose amount will be around 10%. The proceeds of the royalties will be shared among SMEs on the basis of the consortium participation percentage.
- The industrialization of the system. The prototype realized with the TRACKS project is at a good level of industrialization, but it will be better developed in order to produce it easier for the foreseen quantities, about 10 pieces a lot.
- It will be established a sales network at world-wide level constituted by commercial collaborators and salesmen with many contacts and shared among different geographical areas. The sales network will be used not only to commercialize the TRACKS project but also for other projects currently in progress or in preparation stage.
- An intense marketing strategy has been developing both at European and world-wide level, locating the geographical areas of main interest and defining the opportune commercial actions. The communication strategy aims at informing all the potential customers about the new tracks monitoring system, what is useful for and also how it works in principle, not arguing of technical details but on the contrary explaining the working principle that is the basis of the innovation, developed thanks to the project.

  In particular the following means are used:
  - Participation to at least two important fairs a year at world-wide level. The industrial partners will participate in national and international technical fairs (e.g. TRANSTECH) to present the system and new technologies developed during the project.
  - Preparation of illustrating material, using the techniques of the virtual reality (a demonstrative CD-ROM has been already developed). The knowledge will be disseminated through brochures, leaflets multimedia demos on CD and special training sessions.
  - Preparation of an internet website with a wide technical documentation. Scientific and technical results will be posted at the web site for each company with references to the project.
  - Participation to congresses
  - Organization of technical meetings and workshops.

Tecnogamma submitted at EU Commission a proposal of Accompanying Measure to organize an international workshop on *Virtual and Intelligent Measurement Systems for Railways Transportation VIMS-RT*. The proposal has been positive evaluated and in November 2001 scientific world, industries, potential end users and EU Commission representatives will meet in Paris at the

workshop of the "Tracks Technology". The workshop management sees the technical co-operation of Politecnico di Milano, one of the TRACKS Rtd-partners, the Paris underground (RATP) and the technical sponsorship of the IEEE, Instrumentation and Measurement Society.
The idea to organize this event has been taken considering the revealed Railways requirements and therefore the workshop will see the participation of:
EU Railway companies managers, each one representative of specific characteristics and problems. All the different type of rail networks will be surely represented: big national railway network, underground network (RATP as contractor, TMB, ATM and SNCF as technical cooperators); high speed railway network (FS – Italian railways – and Eurotunnel are expected to participate). All these companies create together an important test field for the workshop success, but they also constitute a formidable launch point for the development, and dissemination stage of other RTD- activities in this field.
Research centres from different European countries, each one involved with a specific role and with a high technological level. Each centre is involved in complementary to the others research field with a deep knowledge of the project issues. These centres/universities give their essential contribution to the workshop success and they represent an important reference of scientific rigour and reliability of the whole project to be used in the next stage of further research and development activities and industrial development.
European SMEs, active in the railway field. A transfer of technology is foreseen in order to create a strong and effective co-operation in terms of technical competencies and commercial opportunities.

4.2 Time to market

A prototype of the system for on-line and real-time monitoring and control of the state of the rail is currently available, as outcome of the research project. Thanks to the strategy for its development and validation, the prototype is at a satisfactory level of industrialisation. Moreover, a reasonably short time-to-market of 8 months is estimated as a consequence of the agreement among the SMEs participating in the project to speed up the technical activities for further validation and demonstration to produce as soon as possible a marketable product.

4.3 Exploitation plan

The final measuring system could be sold by each partner in two different ways, as follows:
- *by own proper name.* The seller company buys the finished system by the producer, obtaining a 10% discount on the market price, then the company sells the system to the final customer with its own name.
- *as intermediary.* The partner companies could act as sale intermediaries, obtaining a 10% commission on sales.

All partners agree on producing the final system in one sole laboratory. A single production laboratory allows economies of scale and homogeneous products. This laboratory must necessary be Tecnogamma's one, since here you can find the know-how and the competencies, which are pre-existing to the project, but part of the final system.

4.4 Dissemination activities and improvement of transnational, technical co-operation

The partners will particularly take care of the dissemination of the results, too.
The partners will promote the exchange of students or permanent researchers and scientists between academic institutions and industrial companies, enhancing then the level of skills of

RTD performer researchers. The European cohesion will be improved through the transfer of scientific and technological information on no-contact and on-line measurement systems.
The outputs of the TRACKS project have many potential applications. In order to achieve the dissemination of the results in the best way, the following measures will be taken at two levels, industry and research:
Industrial dissemination: the industrial partners will participate in national and international technical fairs to present the system and new technologies developed during the project. The knowledge will be disseminated through brochures, leaflets multimedia demos on CD and special training sessions. Scientific and technical results will be posted at the web site for each company with references to the project.
Academic dissemination: Scientific papers will be written in international scientific and technical journals. Partners will attend scientific and technical conferences in the area of the vision systems with the purpose of presenting the results of the work performed in the project. The partners will promote the exchange of students or permanent researchers and scientists between academic institutions and industrial companies. The academic institutions will hire post-graduate and post-doctorate students that will greatly benefit from the international collaboration in terms of knowledge of the industrial environment.

In details, the European technological level will surely progress if European experts could cooperate and their cooperative achievements would be effectively disseminated.

National and international cooperation with parallel and supporting competencies will continue and will be increased with other foreseen conferences and projects in the same research area.

5 COLLABORATION SOUGHT

The SMEs involved in the TRACKS project, particularly the prime proposer Tecnogamma, are strongly committed in a R&D program aiming to develop and to optimise the global quality of products and services. Their strategy and mission are those to realise a range of high technology systems able to give answer to the demand of quality. In particular, the results, the present research project has achieved, respond to the demand for on-line quality assurance risen by the railway companies. Railway companies are more and more requested to supply a high-quality service, such as high speed lines and trains. To achieve this high quality level, new strategies and systems for accurate monitor and control of railroad are necessary.

The consortium would like to find RTD-collaboration at international level to produce innovation and support EU SMEs growth in an emerging field.

The workshop in November 2001 will be an important occasion to meet those companies active in the railway field. The collaboration among participants will produce a branched stream of information and contacts through different countries. Thanks to all this the project will give its own contribute to the economic and social integration among European countries and will provide to the Railways Companies important tools to develop their businesses in an increasingly competitive commercial railways environment.

The transfer of technology will be encouraged also by stimulating participants to give their contribution at the workshop and involving them in new RTD-cooperative projects. The interactive format of the VIMS-RT workshop will be an optimum stimulating tool of technology transfer and new cooperations among SMEs.

An European technological interaction will surely take new ideas to solve the railway needs and the expected RTD-projects and achievements will lead Europe to improve its technological progress.