Title

Status Of Foreign Advanced Highway Technology

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Status of Foreign Advanced Highway Technology

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California PATH Research Paper

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Program on Advanced Technology for the Highway, PATH

STATUS OF FOREIGN ADVANCED HIGHWAY TECHNOLOGY-OCTOBER, 1987

PURPOSE:

To assess the general status of development work in Europe and Japan that relates to the California PATH, Program on Advanced Technology for the Highway.

APPROACH:

After a library search, trips were arranged and made to Germany and Japan to those organizations directly involved with the planning, funding, conduct and implementation of PATH type technologies. The detailed trip reports are attached. Each contains a short summary of about two pages, however the following is an attempt to highlight the overall impression and state of development.

STATUS:

Much activity is underway worldwide regarding how to cope with increased demand for road travel and the limited road building resources and urban space available for this purpose.

In Europe, a five country, coordinated study called Prometheus is being carried out primarily by fourteen automobile manufacturers. The governments are expected to be directly involved once the initial system definition phase is complete by the end of 1987. Prometheus supporters indicate that the seven year R&D phase to follow will cost about $ 100,000 million/year and will be funded by both government and industry.

In Japan, the efforts of academia, industry and government are being coordinated in a complex organizational manner in which the Ministry of International Trade and Industry is playing a significant role. It appears that Japan is planning for the next high-tech industry - one pertaining to an Intelligent Vehicle System (IVS). The technology planning effort is in progress and if development follows it has been estimated approximately $700,000 over the next 15-25 years.

Other advanced highway work observed included:

- Most industry work has been in navigator development, with many systems about to be marketed. Two major European demonstrations are planned for next year - one in London the other in Berlin. Japan has also developed navigation systems, and has tested a sophisticated experiment called CACS in Tokyo and now is in the second phase of work under the Ministry of Construction. Systems were more advanced than U.S. counterparts, providing detail route instructions.

- Lateral guidance (both mechanical and electronic) have been developed. Systems are operational in Furth and Essen, Germany and Adeline, Australia.

- While there is no work under way on electrified highways, much has been developed (and implemented in some cases> regarding dual mode busses and trucks to address the urban pollution (noise/air) problems. The Tokyo Electric Power Company showed much interest in the PATH electric bus development.

- There appears to be a contrast in management philosophy between the European and Japanese work regarding cooperation. Prometheus is definitely closed to US firms while the Japanese hinted that collaboration might be advisable, since this is a worldwide problem.

TRIP REPORT

Date: August 9, 1987

Travelers: Adib Kanafani
Robert Parsons

Trip: Federal Republic of Germany - June 20-27, 1987

Organizations Visited:
German Aerospace Research Establishment (DFVLR) Cologne, FRG
Essen Transit Authority (der Essener Verkehrs-AC) Essen, FRG
Robert Bosch GmbH, Advanced Engineering Communication Systems, Hildesheim, FRG
Daimler-Benz, Public Transportation Test Facility, Rastatt, FRG
Daimler-Benz, Research Directorate, Stuttgart, FRG
Siemens AG, Ali-Scout Project, Munich, FRG

Coordinated by:
Ministry of Research and Development, Bonn, FRG
German Aerospace Research Establishment, Cologne, FRG
Dornier System, Friedrichshafen, FRG

Purpose :
1. To assess German work in advanced technologies for the highway, specifically automatic lateral guidance and navigation.

2. To describe the U.S. PATH program. .I

Summary

1. European navigator systems, more technologically advanced than the U.S. ETAK system, have been developed and several are waiting near term demonstrations in London and Berlin.

2. Three German automatic lateral guidance concepts have been researched, developed and tested; two of these have been operationally deployed in bus systems in Essen and Furth, Germany and Adelaide, Austral.ia.

3. The newly established PROMETHEUS program, a part of the larger European EUREKA program, is sponsored by14 automobile manufacturers. It is half way through the 1st year program definition phase and appears to have reduction of the 50,000 annual highway deaths as its main goa1. A 7 year research program is to follow this initial definition phase.

4. Foreign subsidiaries of U.S. automobile firms have been purposely excluded from participation in PROMETHEUS, as it was very evident (especially at Daimler-Benz) that this is regarded as a highly competitive venture.

5. There was little interest expressed in the US. non-contact electrified bus project, except as one contact noted, "if if urban highway productivity gains materialize as expected, then non-polluting propulsion systems may be necessary to avoid unacceptable emission levels due to the added traffic in major cities".

6. Apparently EEC member governments have told the private industry to get their act together and decide on the "best" system for future highway automation activities before the public sector considers investing in any new infrastructure.

Individual Contacts:

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Resume' of visits:

NAVIGATOR SYSTEM STATUS:

There are four general classes of automobile navigator systems being marketed or planned in Europe as follows:

1. Autonomous dead reckoning
2. Deadreckoningwithmapreading
3. Radio and beacon signal navigation
4. Adaptive navigation responsive to radio/beacon-corrmunicated real-time conditions

In addition there are route planning systems that provide a printout of travel directions prior to taking the trip.

Two of the major Continental navigator systems being developed, the Bosch/Blaupunkt EVA (type 2) and Siemens Ali-Scout (type 41, were examined and test evaluated. Both are judged to be more technologically advanced and useful to a driver than the U.S. ETAK system (type 21, especially since they provide continuous, easy to read, route guidance (to destination) information. ETAK shows one's present location on a scrolling map display (synchronized with the speed and direction of vehicle movement).

Human factor considerations were evident in both designs, K. Krell of the German Federal Highway Commission has focused attention on this topic and stressed that navigator systems' input and output should be designed to ease driver workload and that hardware should be designed to minimize the diversion of the drivers attention from traffic situations. Both systems appear well suited in this regard and provide an audible notification to the driver when one should glance at the display for turning instructions. The EVA test system provided this information verbally so that the driver need not look at the display. The displays are to be eventually placed into the normal instrument clusters (in R&D models they are dash mounted), the design is clean and care has been taken to keep information displays simple, mostly diagrammatic.

Both use map reading to automatically recalibrate their dead reckoning systems whenever a significant (believed to be approximately 90") curve is negotiated. The dead reckoning systems use odometer input and a magnetic compass (EVA also employs differential wheel sensing detection) to calculate bearing.

In the Ali-Scout system, the driver uses an infrared remote control keyboard to put in the destination information. It can operate in an unsupported mode using only the dead reckoning system or it can be used in the beacon assisted mode to provide fixed details on individual routes (e.g. number of lanes, or information on real time traffic conditions). There is no map storage in ROM. Another feature provides a continuous distance to destination reading. The detailed information provided in the beacon assisted mode is excellent. Instructions are supplied at variable distances from intersections, depending up-on the anticipated traffic levels, sufficient to provide time for adequate lane changing maneuvers. A shrinking bar chart is used to graphically portray the distance from a recommended turn.

EVA features a compact disc storage media, which could also provide other amenities (sound system) to the automobile. Thus, it has large map storage capability and can operate with very good accuracy (due to the automatic recalibration with stored maps) over a wide geographic area, perhaps the entire U.S. On the test run the stored detail was impressive. Not only were the number of lanes shown, but the recommended lanes were more prominently displayed (darker/heavier arrows).

The upcoming Berlin Ali-Scout demonstration was discussed and Siemens has already started the production packaging of their equipment- The on-board processor unit is compact, approximately l"x6"x6" and we were told it should cost around $300/350 in production quantities. The beacon assembly and components seemed very simple, rugged and appeared low cost. Standard Siemens traffic light hardware casings are employed and the transmitter and receiver circuits were all miniaturized for mess production. We were told a typical road based beacon unit would cost about $500 (in quantity) and would require only one extra lead from the traffic light to the control unit,

The Berlin Ali-Scout experiment, estimated to cost 15 million D marks, was initiated in 1985 and the final evaluation should be completed by mid 1989. Latest plans call for use of 200 taxis as "floaters" in order to determine if data received from this mini-fleet could replace the more expensive loop sensor approach, common to central traffic control systems. Approximately 1000 vehicles will be involved and drivers will not be given navigation advice for the first three months of the experiment in order that "normal driver behavior" can be collected and analyzed. This will serve as a reference for the experiments.

Prime objectives are to determine:

1. driver acceptance of the concept
2. technical feasibility/reliability of the equipment
3. impact of the system on traffic safety
4. cost/benefits to various groups

As a sidelight to the trip, a major decision was made regarding navigator communication links during the visit. The British and Germans have agreed to use the Ali-Scout infrared system.

LATERAL GUIDANCE SYSTEM STATUS:

In the late 1970's, the German Ministry of Research and Technology initiated a new technology bus R&D program to address the disadvantages and problems of the heavily used bus systems in major cities. According to a German association of public transit authorities, more than 75% of the operational transit vehicles were buses, which accounted for more than 70% of the vehicle mileage and almost 60% of all passenger miles carried by transit. However, even with these impressive statistics, German bus operations were losing money. As ridership was also slipping it was decided to undertake a vigorous R&D effort to improve bus performance and public acceptability.

One of the more unique projects, called 0-Bahn, attempted to combine the best features of rail and road transit into a dual-mode system that could provide a 1) flexible, 2) adaptable and 3) easily expandable system that affords better social interface with congested German city centers. For example, these systems would require less space, produce less noise and pollution, yet could be flexible in operation to adapt to changing urban demographics. Like in the U.S., there are population shifts as industry reforms (shifts from heavy to light industries and service organizations) are occurring.

New small diameter tunneling advances led to an opportunity to provide better city center rail service, but required that buses be laterally guided if they too were to use these tunnels.

Several cities now have operational bus systems that incorporate aspects of the 0-Bahn developnent that have a direct, Mate interest to PATH management. Review of the lateral guidance system performance is important since we plan to incorporate such a concept on the electric bus to be tested and evaluated at the University's Richmond Field Station next year in order to improve the efficiency of the inductive couple subsystem.

A sketch showing highlights of the mechanical and electronic lateral guided systems is shown in Figure 1. The system of prime **PATH** interest is the electronic wire follower approach, which responds to a buried cable embedded in the street paving. An on-board antenna registers deviations from the cable and processes instructions to the steering actuators to automatically steer the bus along the desired route.

During the trip we were able to ride and observe operation of both the Daimler-Benz mechanical and electronic guidance systems. Both visitors found that the mechanical system afforded a smoother ride, but the electronic system ride was judged adequate for the Richmond Field Station experiment.

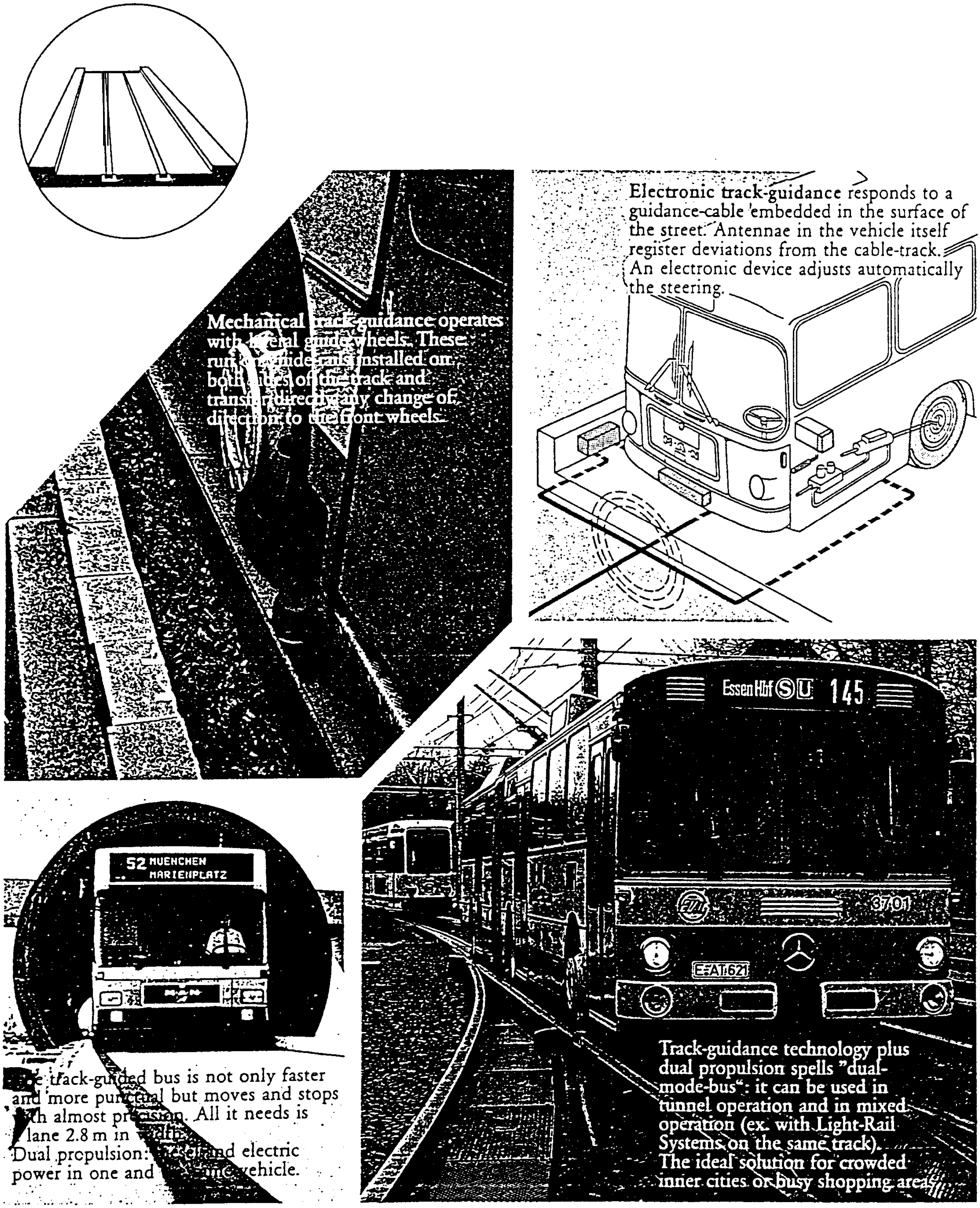
We reviewed the hardware and found that the electronic equipment was mounted on a removable shelf (about 2'X4') and required **8"** to 10" of vertical clearance. There were two parallel systems to provide redundancy. In discussion with Dr. Niemannwe mentioned that our systems contractor. (Systems Control Technology, Inc.) for the electric bus testing would be contacting him to see if the Daimler-Benz gear could be used with minimum retrofit in the U.C. test bus. We plan to examine U.S. and foreign bus equipment to find a compatible system and to determine whether a collaborative effort might be arranged with the developer.

LATERAL GUIDANCE IMPLEMENTATION CONSIDERATIONS:

The visit to Essen provided valuable insights on the problems of implementing a new fixed route system having some similarities to the non-contact pick-up electric bus being tested and evaluated at the University's Richmond Field Station.

In the Essen *Bahn installations, the implementation strategy appeared to use the "fixed' 0-Bahn infrastructure along bus routes where there were known "bottlenecks" in order to smooth flow (congested areas). Another key factor appeared to be a desire to limit the number of new variables into the system in any one "add-on link" to the routes. For example, the first link of fixed guideway was to prove the lateral guidance concept and fail safe control system. The second installation addressed

[1] similar systems have been developed by MAN Nutzfabrzeuge QnbH of Munich



Mechanical track-guidance operates with lateral guide wheels. These run on guide rails installed on both sides of the track and transfer directly any change of direction to the front wheels.
Electronic track-guidance responds to a guidance-cable embedded in the surface of the street. Antennae in the vehicle itself register deviations from the cable-track. An electronic device adjusts automatically the steering.
52 MUENCHEN MARIENPLATZ
The track-guided bus is not only faster and more punctual but moves and stops with almost precision. All it needs is a lane 2.8 m in width.
Dual propulsion: diesel and electric power in one and the same vehicle.
EssenHbf S U 145
3701
E-AT 621
Track-guidance technology plus dual propulsion spells "dual-mode-bus": it can be used in tunnel operation and in mixed operation (ex. with Light-Rail Systems on the same track). The ideal solution for crowded inner cities or busy shopping areas.

Figure I

the concept of dual-mode operation with trolley vehicles on a common guideway. The third will determine the commuter acceptability to the idea of having diesel buses operate in the long tunnels under the Essen downtown area. Noise and pollution (mainly odor) will probably determine the public acceptance

This incremental implementation approach, which the **PATH** management plan states as an explicit goal appears to be the key to quick and enthusiastic acceptance of the 0-Bahn in Essen. The transit officials seemed delighted with this new transit concept, particularly since its operational flexibility and ridership has also been good.

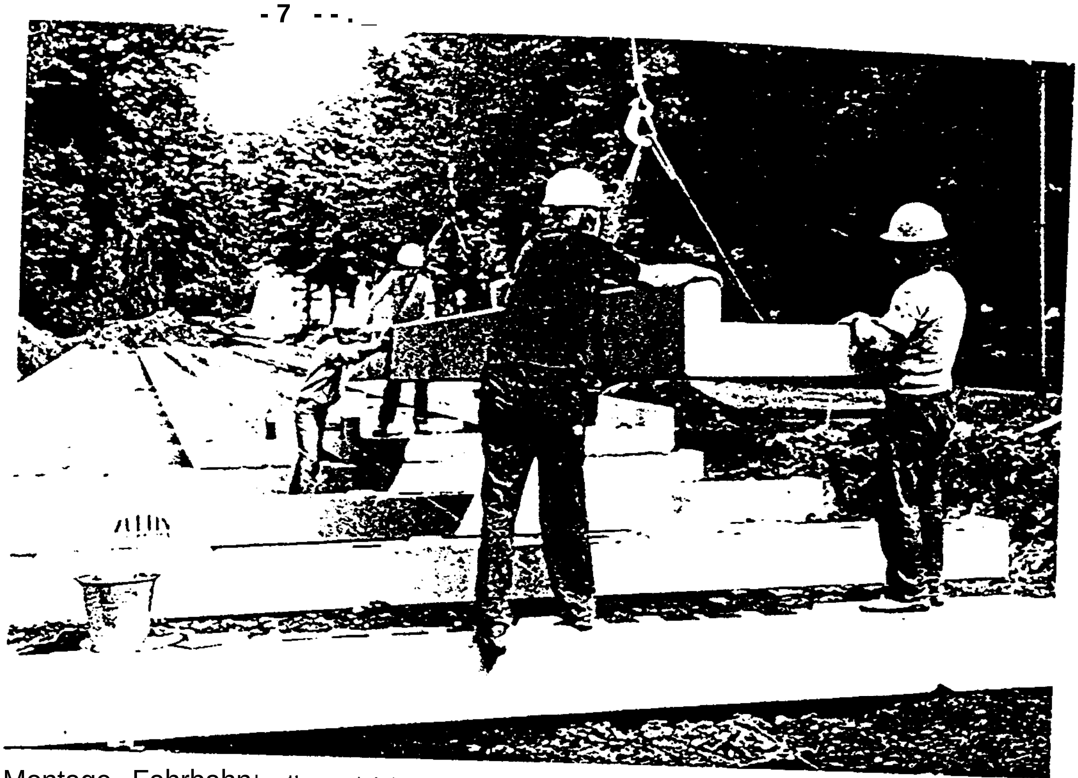
Other implementation related items noted included the attention devoted to minimize installation costs while at the same time providing design features aimed at quick, easy deployment with minimum interruption to existing commuter traffic. For example, guideway sections of several alternative designs were installed in the operation segments of the route to gain operational/maintenance experience. The Germans carry parallel developTlent concepts all the way through initial operation before one preferred concept is selected. They apparently place such importance on public and transit authority acceptance of new systems that they are willing to double or even triple the early R&D and testing investment in order to find the optimal final system

With regard to the above mentioned redundancy, pre-cast concrete, wood and steel guideway designs were noticed in different parts of the system. The most widely used pre-cast concrete sections resemble railway design. Figure 2, shms a section being installed an the completed track before top soil has been replaced. One will note that the 10 meter long road slabs act like rails and rest upon large concrete "ties" that in turn bear upon two piles. In other installations these "ties" sit on conventional rail ballast.

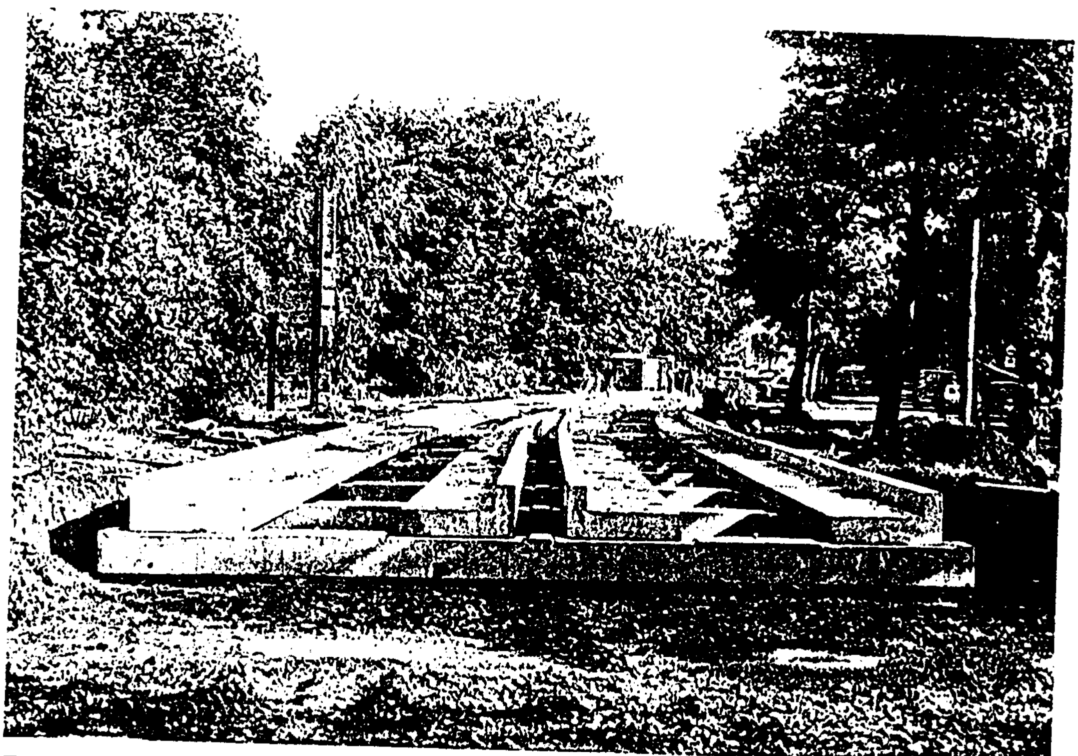
Another interesting concept involved the mixed bus/trolley operation. Here, Figures 3 and 4, the slab designs are such to provide running surface for single or dual bus wheels and to be compatible with both standard and narrow gage trolley track.

Two switch types were noted: the lifting lateral rail and the bending lateral rail types.

Another feature is the added ease of passenger access and egress to and from the bus. The design provides for raised platforms, since the steering is precise, that are level with the first step of the bus, Figure 5 . It appears well suited for slightly handicapped, aged and children use, but this was the extent of handicap accessibility devices noted on the system during the visit. No provisions for wheel chair use were observed.

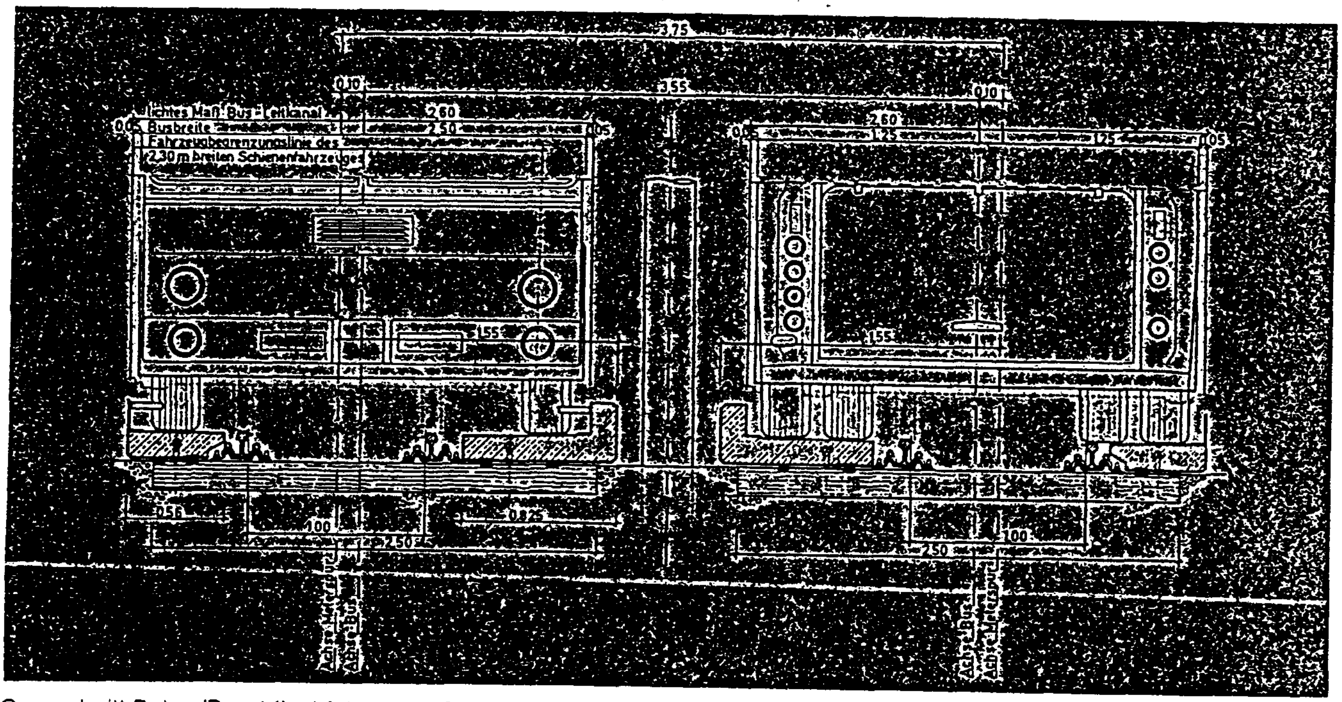


Montage Fahrbahnbalken / *Mounting of guideway elements*



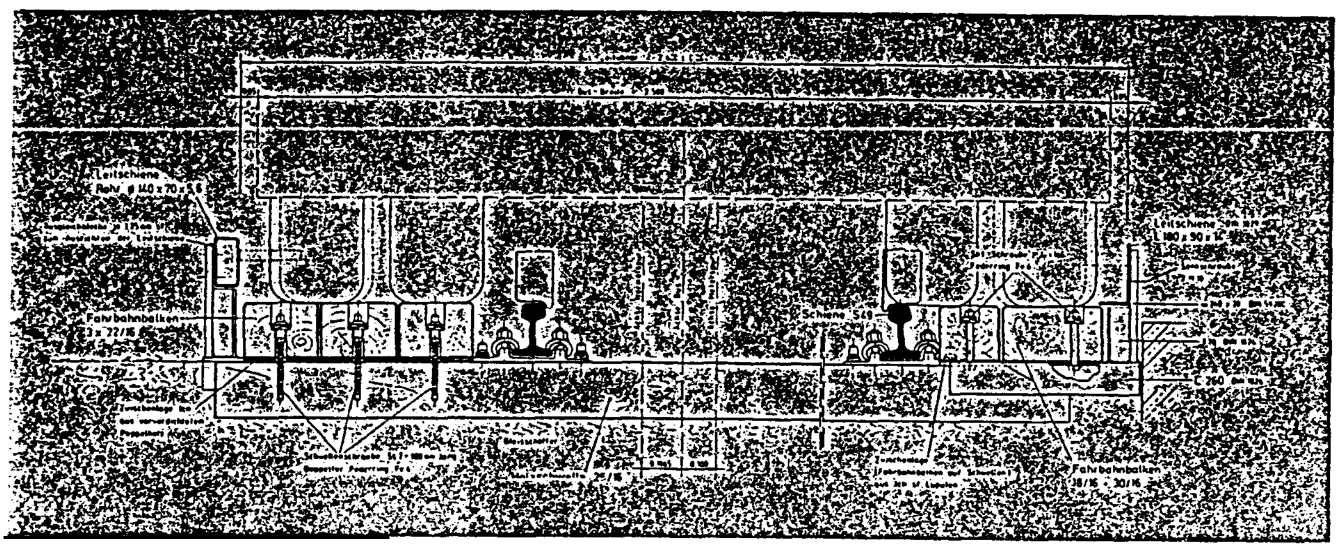
Fertiger Fahrbahnabschnitt / *Completed track section*

Figure 2



Querschnitt Bahn-/Bus-Mischfahrweg / *Cross section of tram/bus joint guideway*

Figure 3



Querschnitt Bahn-/Spurbus-Mischfahrweg (System Richtberg)
Cross section *tram/bus joint guideway (Richtberg system)*

Figure 4

Figure 5

Many Essen buses also feature a dual-mode propulsion system. Both the standard bus diesel engine and a traction motor are coupled to the transmission via a clutch arrangement that permits only one power drive at any time. The infrastructure philosophy again appears to use the fixed propulsion (electrical) selectively to maximize the cost benefits of the system and provide flexibility to change outer portions of the route as demographic changes warrant. Peer pick-up is by overhead trolleys and an automatic system is used to raise and engage the trolleys. This permits an accurate and speedy transfer from one propulsion n-ode to the other, see Figure 6.

RATSTATT TEST FACILITY:

The Daimler-Benz commercial transit R&D group has established a test and evaluation facility in Rastatt, which is located in the outskirts of Stuttgart. The center is well laid out, clean and functional, but conservatively constructed. For example, major road conditions/elements are included (curves, grades, tunnel, bridge, etc.) but only single lane guideways are provided. A gravel access road was used during construction and for emergency assistance and maintenance vehicle use. The tunnel section is simply a length of the narrow concrete pipe used in the O-Bahn installations. There are no signs of gold plating in facility layout.

The maintenance building serves dual purpose with a second floor conference/visitor center (about 50-60 chairs) and office space. An overview of the Rastatt facility is shown in Figure 7.

PROMETHEUS - A JOINT EUROPEAN ROAD/TRAFFIC R&D VENTURE:

The Prometheus program, Program_ for a European Traffic with Highest Efficiency Unprecendted safety, has the stated goals of making road traffic safer, more efficient and better adapted to human abilities. It is premised on foreseeable technologies of micro-electronics, information processing and artificial intelligence.

Prometheus is a subset of the larger pan European concentration of research efforts to be undertaken by scientific institutes and industry, named EUREKA. It was described by one contact as the European "Star Wars" program to organize and advance research and technology, but the type aimed at commercial markets.

The Prometheus program is of 8 years duration, with the first year of program definition about half complete. A report is expected at year end. Annual funding of the R&D portion of the program is estimated at about $100 million.

'Das Stromabnehmer-system

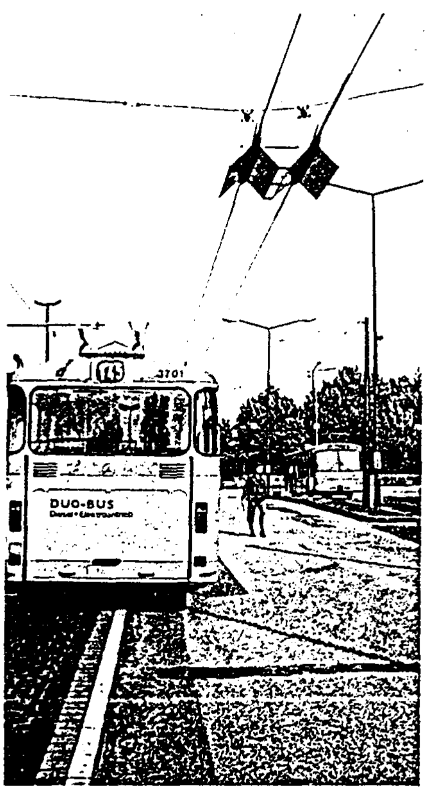
The power collection system

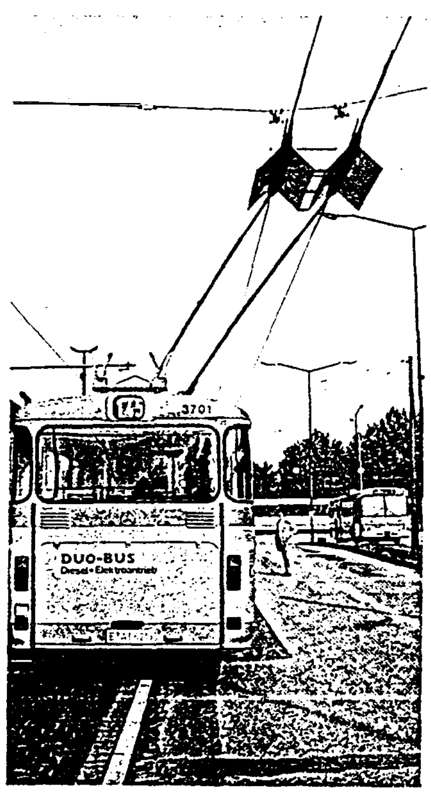
Im Fahrbetrieb muss der zugige ubergang von Diesel- auf elektrischen Antrieb und umgekehrt gewahrleistet sein. Die Duo-Busse wurden deshalb mit zwei nebeneinander liegenden Stangenstromabnehmern der Firma Dornier ausgerustet, die vom Fahrerplatz steuerbar sind und uber selbstandige Anlege- und Abzugsvorrichtungen verfugen.

Die Stromabnehmer lassen einen Versatz zur Fahrleitung bis zu 3 m nach links und rechts zu. Dadurch kann such im nicht-spurgefuhrten Bereich die Antriebsart jederzert bei Bedarf gewechselt werden.

Zwer aus Aluminium bestehende Ruten mrt jeweils einem Steuergerat. einem Antrieb und einer Verriegelung auf dem Wagendach bilden, zusammen mit einem gemeinsamen Bedienteil, das Stromabnehmersystem.

Das Ein- bzw. Ausdrahien erfolgt zweckmassigerweise an Haltestellen, da der Bus warhrend dieses Betriebs-





Automatisches Ein- und Ausdrahten
Automatically attachment and disconnection

A rapid change over from diesel to electricmode, and vice versa, is essential in operation. For this purpose, Duo-buses are *equipped with two pole-formed power collectors developed by Dornier which lie side-by-side, are operable from the drivers console and are furnished with se/f-operating attachment and disconnection devices.*

The power collector poles permit lateral movement from the power transmission lines of up to 3 m to either the left or right. In this way the mode of propulsion can be changed if required at any time and not solely in guided sections *of the route.*

The power collection system consists of two aluminium rods, each with a *drive unit, a control device and the interlock device on the vehicle roof, together with an operating element for both rods.*

Attachment to or disconnection from the overhead wires is effected, for prac*tical reasons, at bus stops. During this* process, *the bus may not be* in a driving

Figure 6

O-Bahn test and demonstration facilities at Rastatt

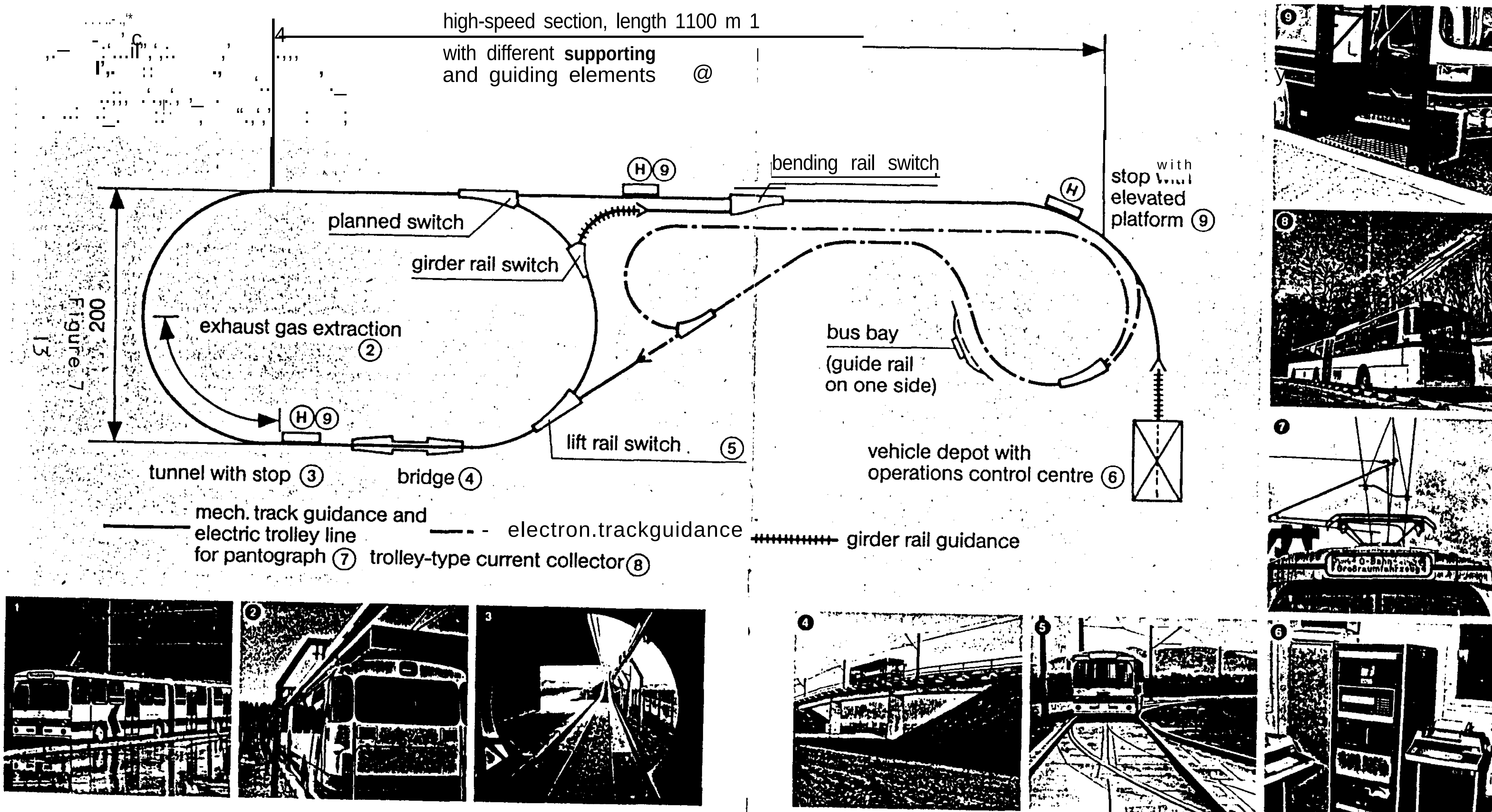


Figure 7

Fourteen automobile manufacturers have pooled resources and are cooperating in this program. The governmental bodies are following the progress but industry has the lead role. The firms involved are:

Great Britain: BL, Rolls Royce
France: Matra, Peugeot S.A., Reanalt
Germany: BMW, Daimler-Benz, Porshe, Volkswagen/Audi
Italy: Alfa Romeo, Fiat
Sweden: Saab Scania, Volvo

Projects have been established in seven categories, three address industrial research and four address basic building block technology (cross cutting). Each project has a multinational team and individual countries are assigned as project leaders for this first year's definition phase. Figure 8 illustrates this organization and shows the lead roles.

In Germany, Daimler-Benz appears to have the coordination role. In our discussion with top Daimler-Benz personnel we were told that they treat Prometheus as a highly competitive venture and not even German subsidiaries of Ford and G.M. are given insight into what is going on. A few observations gathered in this environment were:

- Work status is highly guarded - a mid year review was held but apparently those in attendance were told to keep quiet.

- The prime goal is to address the increasing death rate, now at about 50,000 fatalities/year.

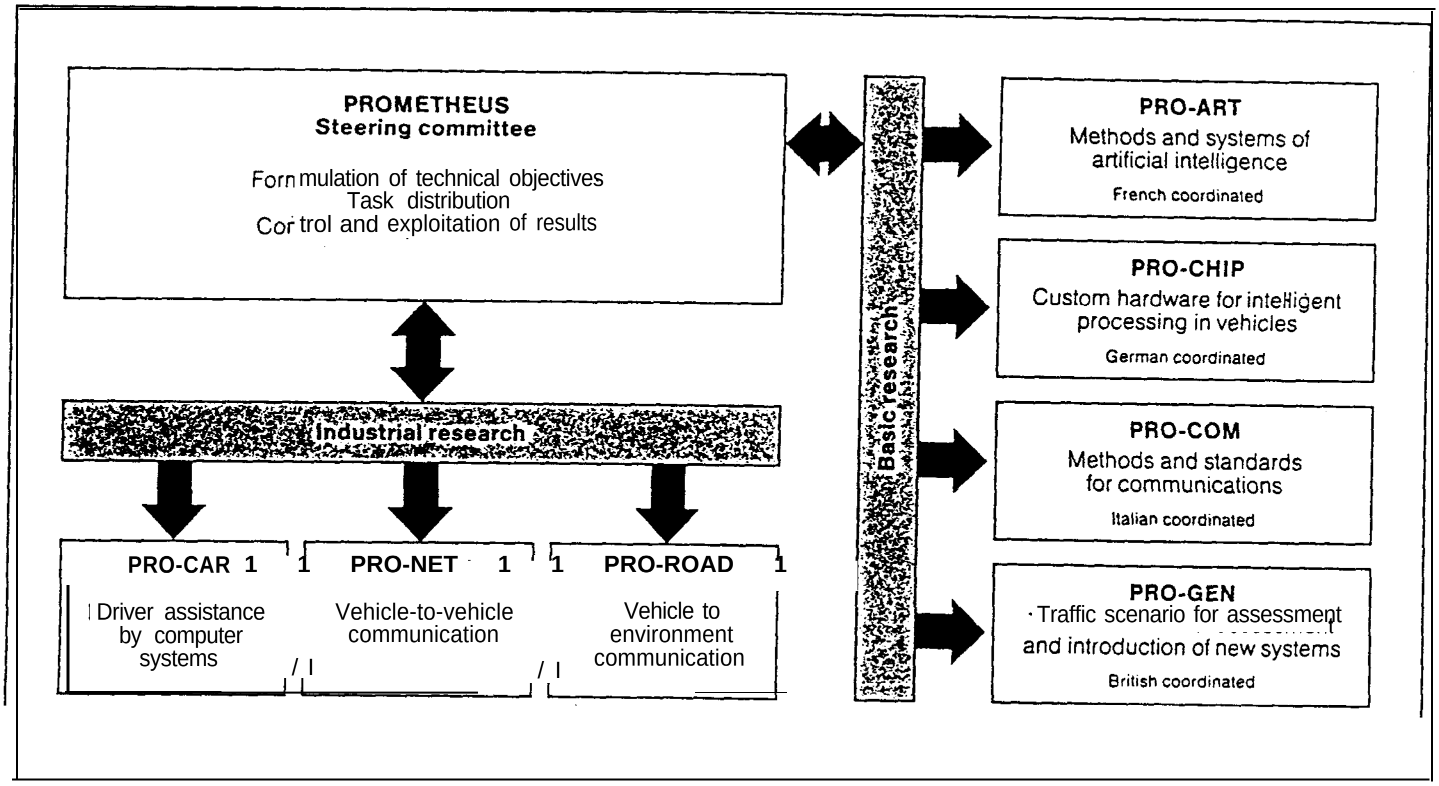
- There was little evidence of cost benefit studies, perhaps they are underway during this first year.

- Cooperation seems excellent, not only between countries in the establishment of the ground rules (during our trip the infrared approach was selected as the link for beacon to vehicle -cation, but between companies. Siemens and Blaupunkt-Bosch, two electronic competitors are working closely together on the Ali-Scout demonstration.

- University personnel are also involved in this early phase as are several non-profit research establishments like WV Rhineland.

- There appeared to be relatively little concern over U.S. technology as compared to the concern over that of Japan.

ORGANISATION



PROMETHEUS is a joint research project of several European automotive companies.

With this project the automotive industry intends to supplement and support government traffic research programmes in vehicle and traffic developments.

The project is divided into seven fields corresponding to the focal points of the-work. -

During the first year the automotive industry and the research institutes will specify the numerous tasks in order to prepare the basis for an invitation to the European high-technology industries to join in this project.

Figure 8

TRIP REPORT

DATE: June 10, 1987

FOR: Howard R. Ross

TRIP: Tokyo, Japan - May 10-22, 1987

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University of Tokyo; trip coordinator
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Mitsubishi Research Institute (MRI)
Ministry of Construction
Public Works Research-Institute
Central Research Institute of Electrical Power Industry (CRIEPI)
University of Tokyo
Institute of Industrial Science
Nagoya University
Technova
Tokyo Electric Power Company (TEPOO)
Japan Electric Vehicle Association (JEVA)
Japan Traffic Management and Technology Association

AJRPOSE:

1. To assess Japanese work on advanced technologies for the highway.

2. T0 describe U.S. program in the same area.

3. To open the door for future U.S.-Japanese collaboration in this field.

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I met with 12 organizations and 31 individuals in a 13 day trip to Japan in what appeared to be a relatively free exchange of information, and I gained the following impressions about Japanese developments in the fields that interest us.

SUMMARY:

1) A national program of research and development on the Intelligent Vehicle System (IVS) is being studied in Japan under the general guidance of the Ministry of International Trade and Industry where the study team, headed by a Japanese professor, embraces representatives of the major Japanese universities, the federal government, the automotive industry and the heavy electrical/electronics industry. A 15 - 25 year effort of 100 billion yen (-$700 million) is envisaged. At present this effort, which is rather small scale, is aimed at understanding the problem, defining the major technological elements, and gaining consensus as to whether to proceed. However it is well-organized and will probably serve as a nucleus for any major program that does merge.

2) The technical concept for an IVS is based on dramatic advances in on-board technology such as image recognition, ultrasonic and electronic sensors, image processors, gyroscopes, four-wheel steering, obstacle detection, parallel processing computers, autonomous vehicle navigation, and automatic braking. The Japanese approach appears to rely much less on the intelligent highway and it appears, although this could not be confirmed, that it represents as much a conscious commercial development strategy to bring in to being the next generation automobile as it does a response to social necessity. Although accidents are cited as a reason for the program, the underlying basis seems to be the need to carry out very advanced technology development for a basic export industry that cannot or is unwilling to do the work itself because it is too long range.

3) At present, the Japanese are relatively open about the work they are doing, or appear to be so. A report "Intelligent Vehicle System Research Report" of March 1986 was provided and we have had the summary trans1ated, which includes the index of the complete 176 page report. However, if our assessment of the commercial motives for the development are correct and in such matter the Japanese government and industry function as partners, not adversaries, then the United States could find itself in an international competition with the Japanese in this fundamentally important area. However, it appears unlikely that any decision along these lines will be made for at least a couple years and the emergence of a strong U.S. program could have an effect on what the Japanese do.

4) There has been extensive work on various types of navigation systems in Japan, which include communiations and other driver aids to facilitate driving. These around the Ministry of Construction, MITI, the Japanese Toll Road Authority and the National Police Agency. It includes a wide range of things from automatic vehicle identification on up to sophisticated experimentation on in-vehicle route guidance such as CACS. Some of the reports on this work are now available in the TIS file. It appears that some of the work is competing, for example, that between the Police Agency and MOC.

5) There is no work underway in Japan on the electrified highway. However, the strongest interest evinced in Japan was in the U.S. efforts in this field, in one case because of its implications for highway tunnels (from the University of Tokyo), and in another from the Tokyo Electric Power Company (TEPOO), because of its implications for future energy use. Liquid fuel is extaordinarily expensive in Japan, over $3.OO/gallon and, although electric power is also high, the ratio is quite favor able to electric vehicles. There are also compelling environmental and geopolitical reasons for a shift from petroleum based fuels. Although advanced battery work continues, there is at present no strong battery electric vehicle program. However,subsequent comnunication with TEPCO and the University of Tokyo suggests that a development program in electrified roadways might be considered and we have left the door open to collaboration.

6) The Ministry of Construction has experimented with both electric buses and electric trucks using a conductive power transfer principle. the power transfer technique includes lateral guidance of the vehicle. The former work, which is called a "dual mode" bus, continues, whereas the latter has been discontinued. Experiments were carried out with full-scale vehicles, both buses and trucks, the objective being to reduce the required width of highways by about 20 percent, resulting insignificant cost savings in tunnels and on aerial

structures. This savings results from the guidance feature, not electrification, although the latter is important to tunnel operation. The electric bus work is analogous to current development work at ITS using conductive rather than inductive energy transfer technology, although in the case of Japan there is no opportunity to translate the results into an electric autmobile.

DISCUSSION OF MEETINGS

Mitsubishi Heavy Industries (MHI)

MHI was one of my hosts in Japan and virtually all of my meetings were set up by MHI in consultation with the University of Tokyo representatives. I had had previous associations with both groups on prior trips to Japan and introductions from such organizations are essential to a successful trip.

In this meeting, as in all subsequent meetings, I was introduced by the MHI or University of Tokyo representative, and I made a brief statement as to my purpose. This was followed by a slide briefing and then a discussion period in which attempted to satisfy my own questions and answer theirs. The persons present and referred to are listed in a previous section of this report under Organizations and Individuals.

I went through a battery of questions which Maeda had thoughtfully translated into Japanese. Is there any effort in Japan on the electrified highway? The consensus seems to be that there is none. As Maeda said atone point, "unfortunately, no". Is there a concerted effort to develop the automated highway? Here the feeling seemed to be that there was some effort along these lines, certainly in related areas. What about wayside or onboard energy storage technology? Well, this could be affected by superconductivity, and Kase expressed the interest of the utility company **in this particular** problem. There seems to be very little work on the battery electric vehicle. There is some work on the guided bus, but this uses physical guidance.

Afterward Tsukio said that there were at least 5 efforts in Japan that related to what we are doing. I made notes so that I could reconstruct this later.

1) The Ministry of Construction, which seems to roll into one the functions of the highway departments of the United States and the transit districts, since it builds rail transit lines, as well as highways, has planning underway on a road communication system that can provide a multidimensional flaw of information to the driver. This appears to include a variety of things such as in-vehicle route guidance, electronic route guidance, vehicle location monitoring, map display concepts, and vehicle identification. This work is centered in the Public Works Research Institute, with whom I met May 13. The man I met is named Shibata. This is in Tskuba City, about 60 miles from Tokyo.

2) The National Police Agency, which is far more than a police organization, since it includes what we in the United States would see as traffic engineering and part of the functions of the public works departments in US cities; it provides control over traffic signals, for example. It appears that this organization has underway certain studies that are independent of those of MOC, and in some sense competing. It will use, perhaps, a different approach, although I got the impression that the system proposed is very similar. There seems to be some conflict between this agency and the MOC group, but no one seems to be upset about this. The National Police Agency seems to be responsible for the 1620 communications band to all vehicles in the Tokyo area. As I rode around in taxis during my visit I could see the signs above the highway with "1620" and then a bunch of Japanese characters I didn't understand. I was able to meet with these people.

3) MITI: Association of Electronic Technology for Automobile Traffic and Driving. MITI, the Ministry of International Trade and Industry, has a central role in all of this, as I full well expected. It is the link between the government and the private sector, and seems to be able to assemble project teams to do things that are multidisciplinary and multi-industrial.. I met with a Mr. Fujii on this on the 12th of May.

4) MITI: Fund for Social and Mechanical System. This awkward translation illustrates the problem in going from one language to another. This is where Tsukio is involved, and it is where there is an embryonic program on the automated & highway. Tsukio is from **Nagoya** University, but somehow he has been involved with these advance technology ideas for the past 3 years or more. In this activity the Intelligent Vehicle System" (IVS) is being considered. Funding is very small, Tsukio said, but being considered is 100 billion yen for a long-range effort, or the equivalent of $700 million.

5) Japanese Toll Road Authority. In this organization there is something called "Highway 2000" which no one seemed to know a great deal about. My notes have a notation "premature." I also show that Iguchi is an advisor again. It appears that the Toll Road Authority has a keen interest in automatic vehicle identification that would permit them to collect tolls without having human beings in the business of collecting coins. I cited the Caltrans in San Diego as an example of AVI in the United States.

University of Tokyo

My most senior contact at the University of Tokyo was Dr. Masakazu Iguchi, who had helped to arrange my meetings. In Japan, many of the senior professors at the University are very influential in Japanese affairs external to the University and Iguchi is one. In effect, they have a high level of authority over projects that may involve many millions of dollars, such as the Computer-controlled Vehicle System (CVS) that was developed in Japan in the 1970's.

I observed to Iguchi that it was interesting to me that in Japan the university people like himself seemed to have such an influential role in policy direction and technical direction in advanced technology. He laughed and made some remark to downplay his influence. But it is true. The whole CVS program was conceived, I think, and certainly had the principal intellectual leadership provided by Ishii, Koshi and Iguchi, and they were very proprietary about the system even tho' all the money was coming from the heavies of the Japanese industrial-government axis like MITI, Nippon Steel, Fujitsu, Mitsubishi Heavy Industry and Toyo Kogyu (Mazda). So they do indeed swing a lot of weight around, which is as it should be I believe, although1 know of no similar U.S. role for university professors. In certain big research efforts like SLAC, yes, but in applied technology, no.

It was Iguchi who clarified that the MOC and National Police Agency efforts are competing and in some sense in-conflict efforts, and that our admiration for things Japanese should be tempered by a realization that there are big disagreements in Japan on large matters too. Not everythiq is perfectly well-oiled collaboration.

Maeda had told me that Tsukio was Ishii's protege. Asked about the MITI guided effort that Tsukio is involved with Iguchi said that Tsukio is trying to promote this, thus I gained the impression that there was still quite a bit of consensus building necessary before the national effort would actually get underway. I said that, well, about the currents and evaluation, is its thrust? Is it to determine "how", or "whether"? This is a subtle point. It seems, from Iguchi's response, that there is some of both, but the emphasis may be on the "how", i.e., how should they go about doing this thing?

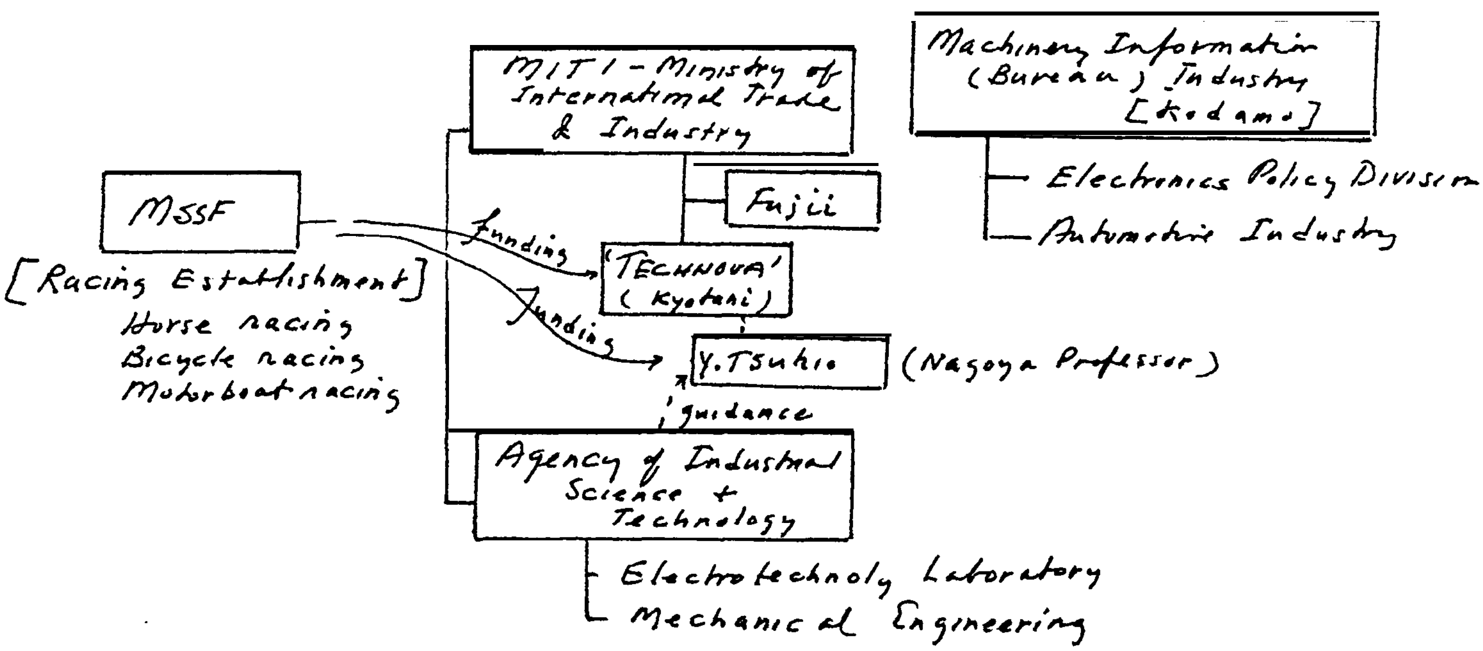
It appears that interest in the IVS was stimulated by US efforts by Martin Marietta and others on the automatically controlled all-terrain vehicle, which I was aware of. It is a military vehicle, and uses artificial intelligence to direct itself around obstacles and find its Way to an objective. I have seen a paper on this vehicle and a photograph.

Iguchi knows of no Work in Japan on electrified roadways. Most of the work on battery electric vehicles has ceased, although some interest remains. He, like the others queried, seemed to be unwilling to speculate as to the effect of superconductivity on the electric vehicle, although he agreed it could be profound. He pointed out that high current densities had not been achieved. However, even since this conversation the high densities have been achieved by IBM.

Iguchi said, and I believe this, that the Japanese efforts are nowhere nearly so well coordinated as the Western press would lead us to believe. There is conflict between agencies. It is not as easy as one might suppose to bring the private sector and public sector together. There are turf problems. There are funding problems. Not everyone agrees on the approach to the automated vehicle. Funding is short just as it is in the United States. Large errors on fundamental matters are made.

MITI: Association of Electronic Technology for Automobile Traffic and Driving

This association is primarily concerned with the utilization of commununication and other driver aids for navigation. I met with a Mr. Haruki Fujii. This meeting was valuable primarily in gaining a bit of understanding as to how MTTI functions. It is important to understand that MTTI has no exact counterpart in U.S. society, and indeed in the way it functions to serve the needs of Japanese industry and government it is also unlike anything we have. Mr. Fujii sketched the following diagram.



The diagram that Fujii drew is only slightly less complicated than the design of a chip with integrated circuits. It somehow seems **to permit** MITI to organize teams of people from government, the private sector, and the universities to accomplish what it wants to.

There are these big "bureaus" in MITI, and then on a lower level the divisions. MSSF is a private group, which is funding Tsukio's effort that has been going on for 4 years. There are 7 bureaus, Fujii said. So in Tsukio's case MITI "suggests" what is to be done, and it provides institutional weight in forming advisory or technical steering committees, but it is not paying for the work. The guidance in this case is that provided by the Agency drawn in the lower box. MTTI knows what is going on under its aegis, but in many cases no money is changing hands, Maeda said. People from private companies may do a lot of work for MITI without a Contract; they simply get paid by their own institution. Of course many people stay their whole lives with one organization, and this gives them the flexibility of moving people around without ever changing their basic affiliation. Fujii, interestingly enough, was once with Toyota.

The small study that Y. Tsukio is involved with, for example, is somehow under MITI's guidance even though it is not funded directly by MITI. It is, instead, funded by MSSF, which is a Japanese racing organization. It manages the bicycle racing, the motorboat racing and horseracing in Japan and it makes a great deal of money. So it is the private sector that manages to pay for it whereas MITI: benefits from it by setting the rules. Or so it seems. The Technova group that Kyotani is part of maybe funded this way.

There is no electrification work underway that uses the roadway inductive coupling; however the dual mode bus work being directed by the Public Works Research Institute involves a guided bus, i.e., physically guided and capable of picking up power by sliding contact on a "third rail" along the sides of the curbs.

Fujii said that, "...in response to my question, There are thousands of people" who work for MITI. There are these big bureaus, and other divisions, and MITI is somehow involved in setting up ad hoc groups to study or develop something. I know that this was the case with CVS (computer vehicle system) that MITI led about15 years ago, and this activity involved Nippon Steel, Mitsubishi Heavy Industries, Toyo Kogyu, Nippon Consultants [Ken Takagi], and Fujitsu.

Through this meeting with the MITI representative I became aware of the CACS work that was carried out by MITI in its early stages, but now as it proceeds into a second stage of development and testing, it has been handed off to the Ministry of Construction. Fujii gave me two papers on the CACS effort, which are available in the ITS file.

The principal conclusion to be drawn from this meeting is that the Japanese work on navigation systems is extensive and sophisticated, and extends over a long term; any U.S. development or demonstration efforts should take full cognizance of the Japanese work so as to utilize the best technology and not duplicate what has already been tried.

Mitsubishi Research Institute (MRI)

I met with Yoichi Aoki and Ryoichi Nishimiya of MRS.

Mitsubishi Research Institute has about 600 people, said Aoki. The focus is on study efforts rather than hardware development, and doing such things as policy analyses, master planning, feasibility studies, economic evaluation and risk analyses, facility planning, and "information" related studies. Then for the group that Aoki heads called Public and Social System Development there are modal division like highways, ports and airport, railways and rivers.

Aoki said that they have no funding from the Mitsubishi family of companies directly except in cases where they do research for a member company, and about half their research budget comes from these companies. The other half comes from other sources.

Mitsubishi Research Institute is a child of the Mitsubishi "family" of companies. There is Mitsubishi Heavy Industries, which has taken me under its wing in arranging my trip. There is Mitsubishi Electric. There is Mitsubishi Zosen-Jo, which makes ships (and I was a guest at their shipyards 30 years ago when I lived in Japan). There is an aircraft manufacturing group. There is the Mitsubishi Bank, and Mitsubishi International Corporation (MIC), the trading company. Mitsubishi steel, and so on. This was, I recall, all one giant enterprise at onetime, a "daibatsu", but was split up after the defeat of Japan in the war. But these big organizations still function integrally because in Japan tremendous amount of business is done without a single word on paper; there are, ineffect, agreements involving million of dollars that simply rely on honor rather than a written contract. Part of the power of Japan lies in this; part of the failure to understand Japan lies in our lack of understanding of this fact. It is why there are so few lawyers in Japan; only 2% as many lawyers in Japan compared to the United States. It is not that human dispute do not occur; they do, but they are resolved differently. There is a distinctly Japanese concept of honor which I greatly admire but only partially understand, that revolves around the concept of personal honor. This governs so much of the Japanese behavior, and if we don't understand that we don't understand anything. Forget for a moment that the Japanese auto worker is superior in almost everything to his Detroit counterpart in terms of education, discipline, knowledge of his craft, loyalty to his company, willingness to work extra hours if need be, and cultural integrity. More important, perhaps, is the equivalent of this on the level of the Japanese manager or executive, where the university degree is de rigueur, long hours are the norm, technical resources are very great, and there is a cultural wholeness that is not found in the G.M. executive. But on top of this there is this code of behavior that underlies so much of the Japanese culture, namely a respect for the integrity of relationships that is not completely defined by the word honor," but transcends it in so many ways that Americans do not understand.

Public Works Research Institute, Construction, Tsukba City,

The Ministry of Construction has taken over the CACS work referred to previously and has conducted the R&D on the dual mode bus and truck. l. Tsukuba City is about 60 miles from Tokyo, and I was accompanied by Mr. Nishimiya from MRI.

So we rolled through the Japanese countryside outside Tokyo toward Tskuba City. As I noticed on the ride from Narita there are these acoustical barriers that I had never seen before. This is evidently a new highway, as one could see certain intercharges that were still being built. Lot of steel in the construction. These barriers are not the same as in the U.S. - they seem to be quite thin, they are louvered on the traffic side at least, and they appear to be only about 4" thick. Nishimiya was unable to tell me anything about them. Every U.S. acoustical barrier is masonry or wood. But the advantage of the Japanese approach is that these modules can be fabricated in a factory and installed on the concrete pedestals on the site, thereby showing same economic benefits (one would think).

We met with Masao Shibata and H. Kanzaki at the Public Works Research Institute of the Ministry of Construction. Mr. Shibata spoke fairly good English, enough to express himself. I understand that nearly the entire post WWII generation studied English in school- obviously, otherwise there could not be any real membership in the nations of the world. So many scientific papers are published in the world in English that if the Japanese did not read English they would have access to perhaps only 10% of the scientific research, since their own contribution cannot be much more than that, perhaps less. We are fortunate as Americans that English is becoming the world language - if an Indian or Chinese wanted to have his work read by the scientific community he would surely have to have it written in English.

Shibata said that there are two developments that they are involved with that could be of interest. One is the dual mode bus, which is physically guided by guide rails, curbs, along the sides. It also has a third rail power supply and a pickup so it can have an electric drivetrain. They gave me technical descriptions of this system, which the PWRI is developing. They said that the guideway width can be 6.5 to 7.5 m. versus 8.5 - 9.5 m., so that is about 22% reduction in area, which is the determinant of the guideway cost.

The second is the current version of CACS, which was tested at fairly large Scale in 1979 using over 1300 vehicles, in Tokyo. They found that there was perhaps a 15% reduction in travel time possible, but the cost of the wayside equipment was too high, so they are reformulating an approach with more onboard equipment They gave me two papers on the subject. Also, a very informative document called Annual Report of Roads" prepared by the Japan Road Association. It contains data on expenditures by all modes, and travel by all modes. (For example, 44% of all trips (passenger trips) are made by automobile, whereas 12% are by bus, Rail is 23%, plus another 16% by private rail [it is now all private rail, and I wonder how they worked that magic, since the system lost about $20 billion last year. There must be some continuing government subsidy]. So the public transport modes provide 50% of all trips; all road **vehicles**, including buses, provide 56% of all trips. Air is steady at 4%. There is some ship passenger travel, about 1%. The total travel is 520 billion passenger mile - my guess iS that that is much leSs than half the U.S. figure 5 capita, which I will guess to be close to 2 trillion by now. [2 x 10 passenger miles/year].

Central Research Institute of Electric Power (CRIEPI)

I had a letter of introduction from Floyd Culler, President of the Electric Power Research Institute (EPRI). It appears that CRIEPI and EPRI are analogous organizations; the most significant difference being that CRIEPI does almost all of its R&D in-house, whereas EPRI is an R&D management organization and contracts out for its work. But both represent the research interests of their respective industries.

We met with Yasuo Ohba, Rikio Ishikawa and Yoshio Mashida, plus a 4th man who didn't have a card to give out. Mr. Ohba was my host; Dr. Aki, to whom I had written, was ill. He is the same man that Floyd Culler wrote to. Mr. Ohba also seems to be the person who coordinates for CRIEPI in its association with overseas groups like EPRI.

I gave them a set of reports, including the Integrated Work Program, the summary of the SCT report on the Static Test Facility, the economic evaluation in Phase 3B that I did, and SCT used in the final report, and the updated position paper on the overall program. They seemed pleased to have all this, and asked questions about the program. I emphasized that while the Integrated Work Program is funded, the California R&D effort is only about 10% funded, and the national program is simply a planning concept at present. I said that EPRI had put a small amount into the planning of the national effort.

CRIEPI confirmed that there was no known work in Japan on the electrified roadway, and a diminished interest in the battery electric vehicle.

University of Tokyo, Institute of Industrial Science

The Institute of Industrial Science was formed after WWII to help restore Japan's industry and create new industry. It is staffed by professors, at least 100, plus a lot of technicians and graduate students. Every professor seems to have his own laboratory where he can experiment.

I met with Fumio Harashima, a professor of mechanical engineering, who is reputedly important in the robotics area. Our discussion, however, ranged over large number of subjects including the use of superconducting Technology for energy storage rings, possibly for a vehicle system. I described the emerging California plan to create a national program.

He asked Maeda why there was no Japanese program like this. He said he was very interested in what we were doing and our approach. He said that there is no Japanese "project" of this type, that the current evaluations of Dr. Tsukio were very small scale, and only studies, that he was not sure they would result in a project that could be called such.

He understood perfectly the difference between the smart roadway, which was the approach taken by the CVS, and the "smart" vehicle, which the IVS would exemplify. I said that our attitude, at least my **attitude**, is that the optimum does not lie at either end of the spectrum but is probably in-between. He said that I am probably right. It seems obvious, but in reflecting on the impetus behind MITI and Dr. Tsukio I have an increasingly strong feeling that such an approach as he has outlined is motivated more by commercial considerations than social necessity.

Harashima said that even though the ICE vehicle is very reliable, and certainly more reliable than any electric vehicle we can produce in the near term future, we will almost certainly have to go to electricity for transportation after 2000. This is very likely a "social necessity", he said. I said that we were developing the electric vehicle because it might be essential to automation; automation is the real goal, I said, and it would turn out that we cannot get the reliability with the ICE vehicle. We do not know the answer to this, but cannot afford to take the risk that the ICE vehicle will turn out to be too unreliable, hence we will develop the ICE vehicle in parallel with the electric vehicle, each backing the other up.

Harashima said that the motivations for doing things in Japan are different than in the U.S., for one thing Japan does not have a good highway system to convert to automation. It has a huge investment in rail systems. Japan's electrical generating capacity is heavily based on petroleum. According to CRIEPI data, I said, nuclear is about l0%, hydroelectric about 17%, the remaining 66% is "thermal", which includes ING, coal and petroleum. CRIEPI sees 20% nuclear by 2000, or more. There is in Japan, just as in the U.S., some skepticism about nuclear power, but the current momentum will boost the percentage higher in both countries even if no new plants are commissioned. The CRIEPI data seems to suggest that generating capacity of nuclear will almost be doubled with plants now planned or under construction. But that doesn't double the percentage because thermal plants also continue to be installed at the same time.

Harashima was saying that because even electrical power is expensive in Japan shifting to electric transportation doesn't necessarily yield as many gains as in the U.S., because all the fuels have to be imported anyway. However in Japan fuel is also very expensive (gasoline); the CRIEPI people said that a liter of gasoline cost about 90 cents; if my memory serves correctly a gallon (U.S.) is 3.785 liters. So the cost of gasoline in Japan is, if this is correct, $3.40! Or more than 3 times what we are paying. A large amount of this is going for taxes imposed by the government, the rest maybe higher production costs. Like many things for me in Japan it is very difficult to analyze. If electricity is 2 l/2 x U.S. prices, and gasoline is 3 l/2 x U.S. prices, but there is very little petroleum deplacement potential, do you shift to electricity? Well, there would have to be other factors, Harashima said.

Harashima discounted the current Japanese effort. What will happen, he said, is that we will watch the U.S. effort very closely, and then when it becomes clear that the U.S. is going to do it we'll get going ourselves. So that by 2030 we will be equal to what the U.S. is doing, i.e., we'll do the same thing.

The decision-making process in Japan is one that he doesn't like, he said. It is all concentrated in Tokyo under the federal government. There are no equivalents to the U.S. "states", i.e. there are the equivalents of counties, which are called gun, like Tsuba Gun, and then there is a smaller political division called the toshi or shi, hence Tokyo shi, then chome, ku, the districts and neighborhood. Hence Marunouchi 2-Chome is the Marunouchi district in Tokyo, whereas Chiyoda-is the neighborhood. I think. In any case there is nothing like the state level of government in the United States. "We are not a 'united states'", said Harashima. So all the big decisions like this one, he said, like the 5th generation computer [l00 billion Yen, 10 years] are made on the national level.

Harashima took us to his laboratory in the basement - every researcher has his own laboratory, hence there are more than 100 separate laboratories under the Institute. He showed us work on obstacle avoidance by a small vehicle using an optical scan. It can pick up a 3-dimensional. object, and the graduate students who work for Hamshima showed us how it works. In principle, he said, there is nothing to prohibit the detection and avoidance of a moving object such as a pedestrian. But they haven't done that yet. They gave me two papers on these kinds of robotics devices.

My second meeting with the Institute took place on May 21, when I met with Professor Masaki Koshi, whom I had met previously, and Masao Kuwaham, who did his graduate work at ITS.

Koshi confirmed what I had learned before, namely that there is currently no Japanese effort on electrification. Battery electrics are a dubious proposition at best (he had done some work on garbage collection trucks, and there had been some vehicles built). The automation work is still very much a conceptual and planning effort, and no "project" has yet been established. There are elements of communication being developed, but not as part of a cohesive program.

I asked Koshi about CVS. Why didn't it go ahead, I asked? well, for one thing it cost a lot of money, he said. And it was **visually** intrusive with the aerial structure required. It also had a poor cost-effectiveness relationship and the wholly centralized control system may have been a mistake, i.e., the "smart" roadway.

Nagoya University (MITI directed effort)

A second MITI effort is under a group called the Society for the Promotion of Machine (or Mechanical) Systems. An Associate Professor Yoshio Tsukio, whom I had met on a previous visit to Japan, and who was at the MHI meeting, is now in charge of the MITI-guided efforts to plan a program on the Intelligent Vehicle System (IVS). The report referred to previously on this subject was made available as a result of this meeting.

Studies on the "intelligent vehicle systems," or IVS, have been going on for the past 4 years, he said. There have been previous reports. The one of March 1986 is the most recent one. It is not available in English, he said, but he gave me a 19 page summary that I had translated. It provides some analysis of the technical elements, and a comparison of various approaches to providing mobility, including AgT, PRT (CVS), the bus, the rail modes, and for each of these there is some ranking according to how well it satisfies certain criteria. The comparison was, in my view, incomplete because it does not address energy issues, for example. It does not account for the very dramatic dislocation that occurs when the entire provision of mobility shifts from the private to the public sector, as for example with the CVS. It does not take into account the geopolitical consequences of petroleum dependence, which it would seem to me would be of enormous importance to Japan. It does not address air quality or other environmental issues.

I asked Tsukio, in effect, since Japan imports 90 percent of its fuel from overseas, and since this makes Japan terribly vulnerable, why wouldn't it develop an electrified ground transportation system? He gave a curious answer, namely that they were going to be "optimistic" about the energy supply. And then, ironically, he said (later) that the vehicles used initially for experimentation would use battery electric vehicles because they are easier to control!

Their approach to the automatically controlled vehicle is to make it fully autonomous, i.e., a vehicle that can operate safely on any highway without the highway itself contributing to the control function! This is is so difficult that I really doubted that it could succeed. Surely the road should be communicating certain information to the vehicle. They think that it will cost too much for the roadway to be modified. How much would it cost to put a wire on every highway and Street in the United States, he asked? Well, there are 4 million miles, so if it cost $5,00O/mile that is $20 billion spread over, say, 20 years. But in 20 years we will spend a trillion dollars on highways, so it is only 2% of our expenditure. But in 20 years we will spend 600 x 10 x 20 = $12 trillion on all transportation expenditures, so the cost of electrification and automation, even if applied universally, is probably only 2%. The numbers are small, and I don't think they have thought it through. By contrast I can see that equipping 150 million vehicles with several thousand dollars worth of artificial intelligence is terribly expensive - it is over a trillion dollars if one assumes $10,000 vehicle, and that is what it would be bemuse we must have a machine that is a full order of magnitude more reliable than what we field today.

I was not asked to comment on the validity of the Japanese approach, and without further study it is inappropriate, or at least it is probably premature to reject their approach, and certainly inappropriate to criticize unless asked for advice. So I said nothing critical, except to observe that the optimum system probably involves Some balance between the "smart" roadway and the "smart" vehicle. The CVS was a smart roadway, and in the end a giant failure [about $20 million spent in the early 1970's on a fully automated personal rapid transit system, involving a 5 km test loop at Higashi-Muriyami, 75 passenger and freight vehicles, all tested at headways of l second and lower. What happened to this? It was the most advanced PRT. system in the world, and yet not a single foot of it ever got implemented. It also was the wrong approach. I could see that coming in 1974 when I visited Japan, that implmentation would be impossible on the basis of costs and visual intrusion.]

In their justification for doing the IVS they placed guite a bit of emphasis on the effect it would have in stimulating new technology, for example in terms of image processing, pattern recognition, parallel processing, the 3-D analysis (for example the ability to recognize a shadow and distinguish it from a hole in the ground, and so on.) The idea is that there are social benefits flowing from the technology transfer aspect-to other industries, that is. I agree with him, but at the same time feel that convincing anyone in the U.S. that we ought to develop automated highways bemuse they will spin off technology that can be used elsewhere would be virtually impossible. There are benefits, perhaps very considerable, but I don't know how to reach any constituency for support with this argument.

These are also the elements of technology as they see it, paralleling what I have listed in my own planning document. But the list looks different because their concept is to use the artificial intelligence to do things like follow the center of the lane, for example by sighting on the pavement striping. The Daimler-Benz people have, he said, already tested lane guidance using an optical scheme, at 25 mph. So I asked, well, why use optical sensing when even 30 years ago wire following was shown to be capable of providing a much stronger signal that is completely independent of road surface condition? And it is, moreover, capable of being used at 65 mph already, not just 25? what do you do if the highway has a coating of sand blown over it in the desert, or snow, or a glaze of ice that blanks off the optical system? That's a problem, he said. An optical system must be active, moreover. It cannot just "see" what is there, say the center stripe or the curb, it has to send out its own special light so it doesn't get confused by oncoming headlights, or reflected light, or is shut off by fog. The JPL people discovered this, and the automatic mixed transit vehicle (AMIV) used an active system, i.e. an active optical scanning system.

I asked him what problems they could foresee. One is product liability. Their own automobile companies are skeptical about their liability when failure occurs. Unlike the automobile of today the future vehicle a la Japan would be completely on its own. So if any failure occurred then the liability could go no place but back to the manufacturers. It is inescapable. And an Achilles heel.

The way around the tort liability issue is to insure the <u>system</u> so that it is like the highway system, where the highway department is responsible if a bridge falls into a river, or there is a collapsed highway, or warning signs are missing, or in some sense the driver is not responsible for the accident. Through a diagnostic system, which is a <u>system</u>, not a vehicle responsibility, and through a controlled system deqradation in the case of vehicle problems (a vehicle with low tire pressure is removed from the stream gracefully long before any catastrophic failure. All computational and memory systems are fully redundant, so any failure of one of these subsystems is cause for vehicle removal. And so on. But the system is responsible for these determinations, not the vehicle and by implication not the vehicle manufacturer).

He said that they had calculated the benefits of the fully automated vehicle. For example 8000 lives that are lost today annual1y, which they reckoned at 6.5 <u>trillion</u> yen per year, or about $50 billion. At that rate we should be thinking of $250 billion/year for the 40,000 lives we lose. But in the SCAG study I used about 15% of that. He said that their way of assessing the value of a human life might be different. They estimate 600,000 serious injuries/year, i.e. roughly 100:l; I used 2 million for 50,000 injuries - the ratio **iS** 40:1, so their figure would be consistent if they took into account all injuries requiring care. I used only injuries requiring hospitalization.

Unnecessary driving for trucks: 13 trillion yen, or $10 billion. I had about 8 times that; perhaps he made an error in decimal point. Clearly labor costs in trucks are a huge expenditure in the united States, whereas maybe in Japan a lot of goods move by rail and sea, hence are not amenable to cost savings. I don't know. At least they took it into account.

What will you do with the rail investment if the automated bus makes all the rail modes obsolete in 30 years, I asked? He didn't have an answer. But it would be a very serious issue. Today I reckon roughly the fare cost per mile of providing transportation by their rail modes is $.50/mile - an automated road vehicle ought to do the same job for $.05/passenger mile. The subsidy costs are at least double the fare costs. what do you do then - do you continue to subsidize this huge but obsolete system, with its own enormous work force and its own political strength, or do you phase it out? Can you phase it out, even? He acknowledged this problem too, under the general rubric of "social" dislocation. By contrast we have no huge investment or long-term stake in public transit - it could be phased out over a 10 year period, and every politician in the united States would breathe a sigh of relief. Public transport is a social necessity- hence we should be looking for a way to either greatly reduce its cost, on the one hand, or even shift it entirely to the private sector in the next 25 years, despite UMTA. It all depends on automation.

He said that the third problem is the transition period during which both the automated and non-automated vehicles would have to coexist. Indeed a very big problem. I expect to solve this by the way in which the facilities are phased in, not the vehicles. We will control the introduction of automation by the way in which we equip the highway, not the vehicle. Hence there will be certain lanes that are so designated, then a-whole corridor, such as the San Gabriel Valley in Los Angeles. This is a fundamental concept. By contrast the effort to put vehicles out there, even with extremely sophisticated onboard control, is fraught with enormous difficulties. If there is an accident involving a vehicle that is automated, and one that is not, and there is litigation, would a judge or jury decide whether it was the artificial intelligence that was at fault, or the human intelligence?

I was never critical of their approach in this meeting, although I asked questions about areas where I had some doubts so as to clarify for myself what they are doing. I do have very serious reservations about what they are talking about doing. My thinking about it is that if the Japanese do embark on such a program, and if we succeed in ours, then the two programs will eventually converge. The Japanese vehicle that emerges, while it might have a different level of onboard smarts, will still have to be compatib1e with the U.S. highway system.

Technova

Technova also appears to be a child of MITI, although I was not able to determine its precise provenance or its funding mechanism. I knew Yoshiro Kyotani from a previous visit; he directed the Japanese Maglev work for many years, and is a very respected personage in Japanese technical circles. However, he has now retired; my call was for reasons of professional courtesy. He was interested in our work on inductive coupling power transfer systems, but could shed no light on Japan- work on IVS.

Tokyo Electric Power Company(TEPCO)

There was a TEPCO representative at the MHI meeting the previous week and this second meeting, at their offices, was considerably larger with 5 people present. They had prepared an agenda for my presentation and first showed me a film about the TEPCO organization.

The TEPCO film was really quite good. They are the largest privately owned utility in the world, and servinq the larger Tokyo area they provide electricity to 19 million people. They told me later that the cost per KW-HR is about 23 cents, maybe 25 cents.

I was aware, of course, that their interest would be in electrification, and I emphasized that aspect, saying that during the next phase of work about 40% of our dollars would go to electrification, and that even in the national program it would constitute a substantial fraction. My belief is that automation will double freeway speeds in the next 25 years, and if so the use of **electric** energy for transportation increases commensurately. It won't double, because speeds on streets my be hard to bring up- at present the average speeds are probably 8 mph- could we get 16 mph by automation? Perhaps, but the streets are also used by pedestrians, and so there are limits on what can be done. I am much surer that we can eventually raise the speed son intercity freeways such as I-5 to double what we have today, say going from average speeds of 60 mph to average speeds of 125 mph sometime after 2000. And the same on urban freeways; we only average 30 mph today, and we ought to be able to average 60 mph after 2000.

After I finished my presentation the discussion went on until l2:30. The great interest shown by TEPCO, was a surprising development. Mr.

Ichihara who was the senior person present, and who was sat just to the right of Maeda, said in slow but wholly understandable English, that my visit was quite timely. There had been interest by TEPCO in such development in the past he said, and only recently they had begun to discuss similar matters. He seemed to be suggesting that TEPCO could very well become involved with what we are doing.

In response to a question about ITS I said that it was headed by Dr. Adib Kanafani, who is also a sensei, whereas Bob Parsons, who is the program manager, and myself, are kenkyo-in: we do not teach. Could a person from TEPCO, say Mr. Kase, hypothetically, work on the project for ITS, they asked? Well, yes, I said, I thought so. If the person were thereto simply learn about it then we would have to expect him to pay his own way; if they were to be able to make a substantial technical contribution some other arrangement would be made. I wanted to leave the door open to this, but at the same time I didn't want to seem to make any kind of commitment because I don't know exactly what the position would be of the University.

I did emphasize, again in response to a question, that I had no proprietary position relative to the electrification work; i.e. no patents, no licenses, no inventions. Are you looking at contacting kinds of power collection, they asked? I said that in principle we didn't rule out any approach to transferring energy to a moving vehicle. However for the Santa Barbara work we were obliged to use the induction coupling idea: it is moreover, the only technology that we know about that can do the job. For the type of application envisioned for Santa Barbara we cannot use a contacting type power transfer because it must not be hazardous to pedestrians.

Frequency. I said that initial tests had been limited to up to 400 Hertz, whereas a higher frequency up to about 1000 Hertz looked to be desirable. There would be 4 factors affecting the future design: frequency, probably tending to be higher; material choice in the core materials; gap control, which would go to an automatic approach for the future automobile; and in lateral centering of the vehicle on the lane. All should tend to a smaller unit. They were asking why the vehicle is so heavy, and I am in truth embarrassed. The coupling unit weighs a ton, the battery pack 3 tons. We ought to be able to reduce the size and weight of the coupling, I said, and the approach on the battery is wholly conventional lead-acid Exide, which could also be reduced.

Japan Electric Vehicle Association (JEVA)

There is a diminished interest in battery electric vehicle in Japan, but I wanted to confirm this by meeting with the group that has been involved with promotion of the idea. I met with Yutaka Akikawa, the Executive Director and a Mr. Saito. The decline in interest in battery electric vehicles in Japan appears to have paralleled the U.S. situation.

Japan Traffic Management and Technology Association (National Police Agency)

Maeda and I walked to the office of the Japan Traffic Management and Technology Association, where we met With Hiroyuki Okamoto, an older man who heads this association. This group is developing certain technology on which they've spent a couple of million dollars. The general approach parallels the CACS idea. He showed us diagram of techniques for reading license plates - this is made more difficult by the fact that the Japanese license plates include not only digits, but also a few kanhji characters. So one problem to incorporate pattern recognition in the license reading scheme. The cameras are placed above the lanes on structures. It appears that this technique has also been used to apprehend speeders.

Mr. Okamoto evinced a surprising amount of interest in what we are doing, but I sensed that it is more of a personal interest than an institutional one. He was amazed by the fact that we are developing a roadway powered vehicle.

Although he had initially told Maeda that he had nothing in English, various brochures like pieces began to appear that described in adequate detail what they are doing. The foundation is not heavily funded- this was another one of those situation I encountered in Japan where the institutional arrangement was not entirely clear. The Foundation seems to do its work under the national Police Agency of Japan, it seems to get its funding thereby, but it is not so far as I would determine a branch of the national agency.