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Automated Guided Vehicle Systems

A Guide - With Practical Applications - About The Technology - For Planning

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Günter Ullrich
Voerde, Germany

Thomas Albrecht
Fraunhofer-Institut für Materialfluss und Logistik (IML)
Dortmund, Germany

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Preface

In the 1950s, the automated guided vehicle system (AGV System, AGVS) was invented, which has developed into a proven organisational tool in modern intralogistics to this day. There is practically no industry that does not use automated guided vehicles (AGVs) or at least could do so. From small systems with few or even only one vehicle to systems with well over 100 vehicles, everything is possible and has already been realised. After many years of restraint, companies in the automotive industry are once again the dominant user sector, but many other companies are also using AGVs to optimise their material flows within the framework of Industry 4.0 concepts. This guide illustrates how diverse the applications are and which technological standards are available without claiming to be complete. In addition, we document the new developments that enable innovative application scenarios and open up additional attractive markets. The future has long since begun with the 4th AGVS epoch. . .

Another focus is the holistic planning of such systems, which is described in detail with all planning steps. Here, the reader will not only find a roadmap through the planning process but certainly numerous valuable hints and clues.

The book authors: Thomas Albrecht and Günter Ullrich

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The VDI Technical Committee "Automated Guided Vehicle Systems" has been supporting the industry for over 30 years. Today, it unites about 40 member companies—the European AGV community Forum AGV was created from this strong network, which carries out committed public relations work and, for some years now, has also been providing AGV planning and consultancy with a competent team. We would like to take this opportunity to thank all the members of the Forum AGV, whose contributions have made this primer possible. We would also like to thank Springer Vieweg-Verlag's mechanical engineering department for their kind and understanding support.

The guide is aimed at experts and practitioners in intralogistics who deal with the optimisation of material flows. They are active in almost all branches of industry, in some service companies, or in research and teaching at universities and technical colleges. From our work as planners and consultants, we know that there is a need for a summarising presentation of our topic in practice and in teaching. We have endeavoured to provide an objective view, moderate professional depth, and clear and comprehensible language.

This third edition has been completely revised, is structured slightly differently, and takes into account the rapid developments in technology and markets. For the first time, Dipl.-Ing. Thomas Albrecht is a co-author. He has been working for almost 30 years at the Fraunhofer IML in Dortmund as an AGV specialist and is known in the industry as a reliable and fair-minded authority. May this revised guide contribute to ensuring that automated guided vehicles are used according to their capabilities and become even more efficient in the future.

Voerde, Germany — Günter Ullrich
Dortmund, Germany — Thomas Albrecht
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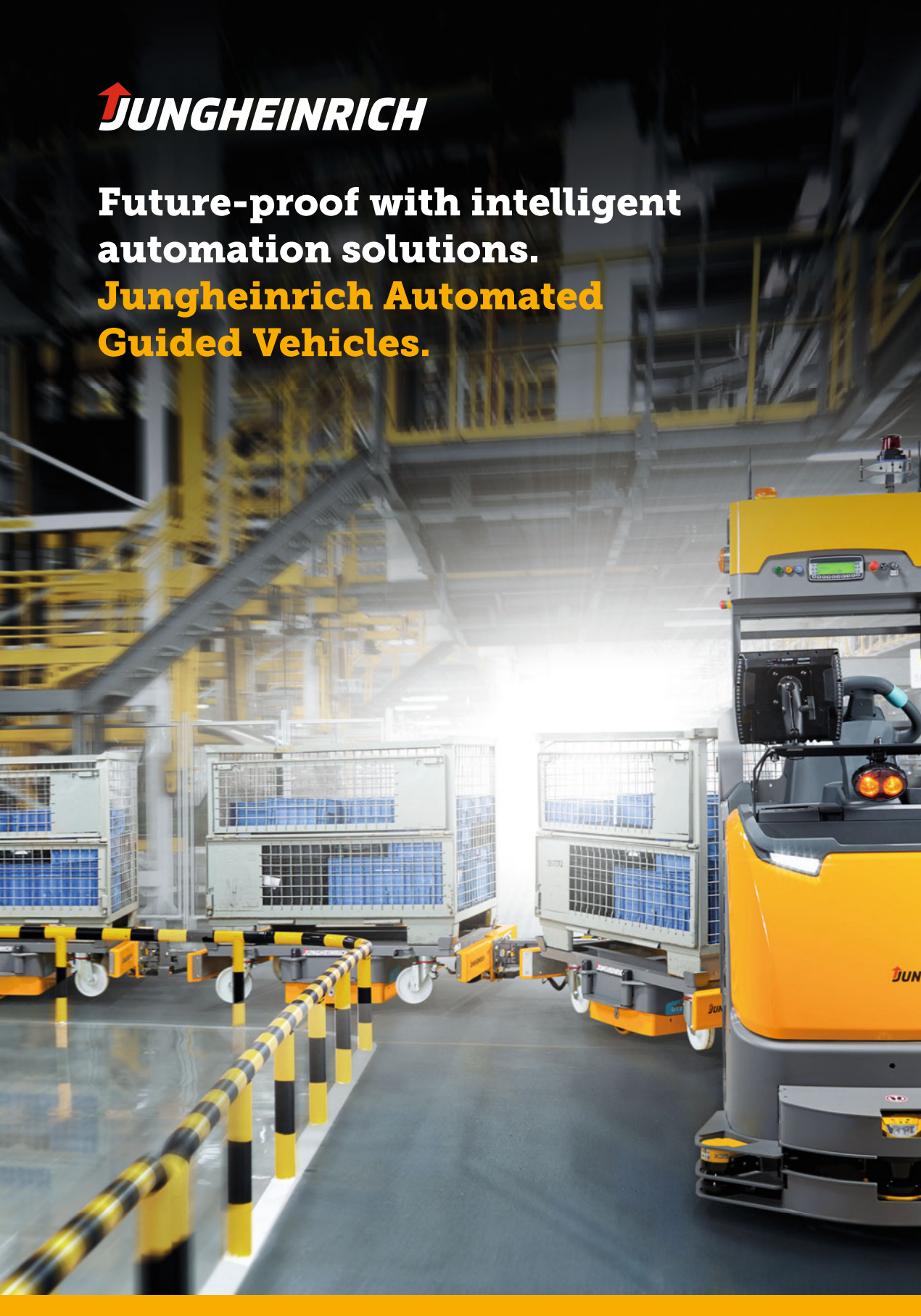

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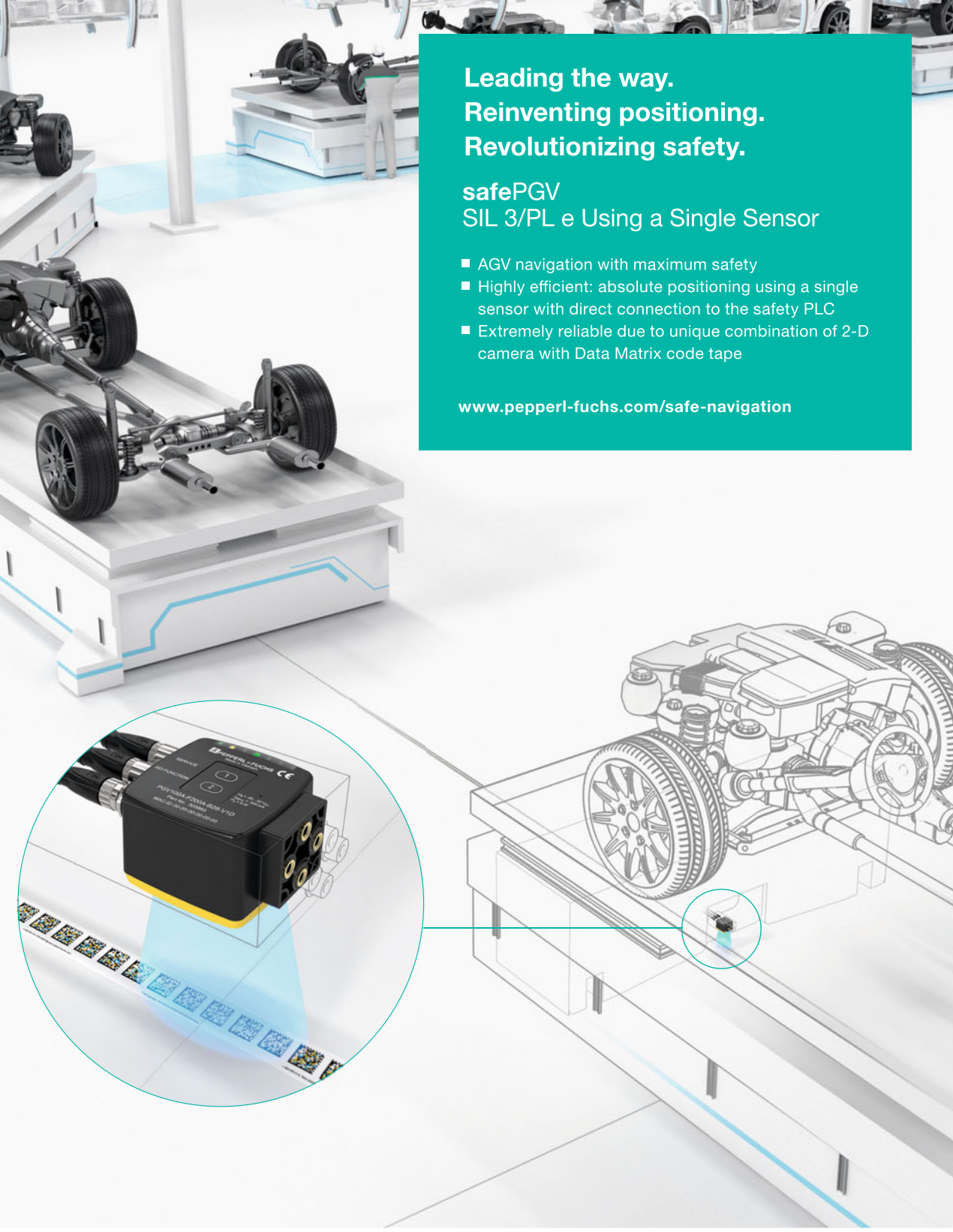

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About the Authors

Günter Ullrich was born in Oberhausen in 1959 and studied general mechanical engineering at the University of Duisburg. There he worked first as a student and then as a scientific assistant in the department of production engineering[1] of Prof. Dr.-Ing. Dietrich Elbracht, who brought with him the subject of AGVs and robotics from his former employer, Jungheinrich AG. During his time at university, Dr. Ullrich dealt scientifically with AGVs and mobile robots. In 1986, Prof. Elbracht founded the VDI Technical Committee for AGVS; Dr. Ullrich was a founding member and has headed the group since 1996.

After his time at the university, Dr. Ullrich was managing director of two companies that planned and sold AGVs and conveyor systems worldwide.

Since 2002, Dr. Ullrich has been an independent AGV planner and consultant in intralogistics. He heads the VDI Technical Committee for AGVS and founded the Forum AGV in 2006. Today, the Forum AGV is known as a constant in the AGV world and, as a community of interests in the AGV sector, is committed to an honest image of the AGV and successful AGV projects. With five competent colleagues, the Forum AGV works very successfully in planning and consulting, primarily for AGV users, but also for companies that (want to) act as suppliers of systems, components, or services in the AGV sector.

Dr. Ullrich wrote about 150 technical papers on the subject of AGVS/mobile robotics.

Thomas Albrecht was born in 1964 in Soest and studied electrical engineering at the TU Dortmund University, specialising in communications engineering. Already during his studies, he worked as a student assistant at the Fraunhofer Institute for Material Flow and Logistics IML (which was then still called Fraunhofer Institute for Transportation Technology and Goods Distribution ITW) on tasks in automation technology and on robot controls. After completing his studies, he became a research assistant at the Fraunhofer IML in 1990 and has been working on all aspects of automated guided vehicle systems

[1] Jungheinrich AG was one of the first AGV manufacturers in Europe, and they were also suppliers of industrial robots.

since then: first in software development for vehicle control and tools for driving course programming, then in the development of navigation systems for AGVs, and later as project manager in numerous AGV development projects, as planner and consultant in AGV projects in Germany and abroad, as speaker at conferences and trade fairs, as long-standing active member of the VDI Technical Committee on AGVS, and last but not least as organiser of the AGVS conference, which has been held at Fraunhofer IML in Dortmund since 2012.

Thomas Albrecht is the author of numerous technical publications and co-owner of several patents on navigation procedures and other innovative solutions in the field of AGVs.

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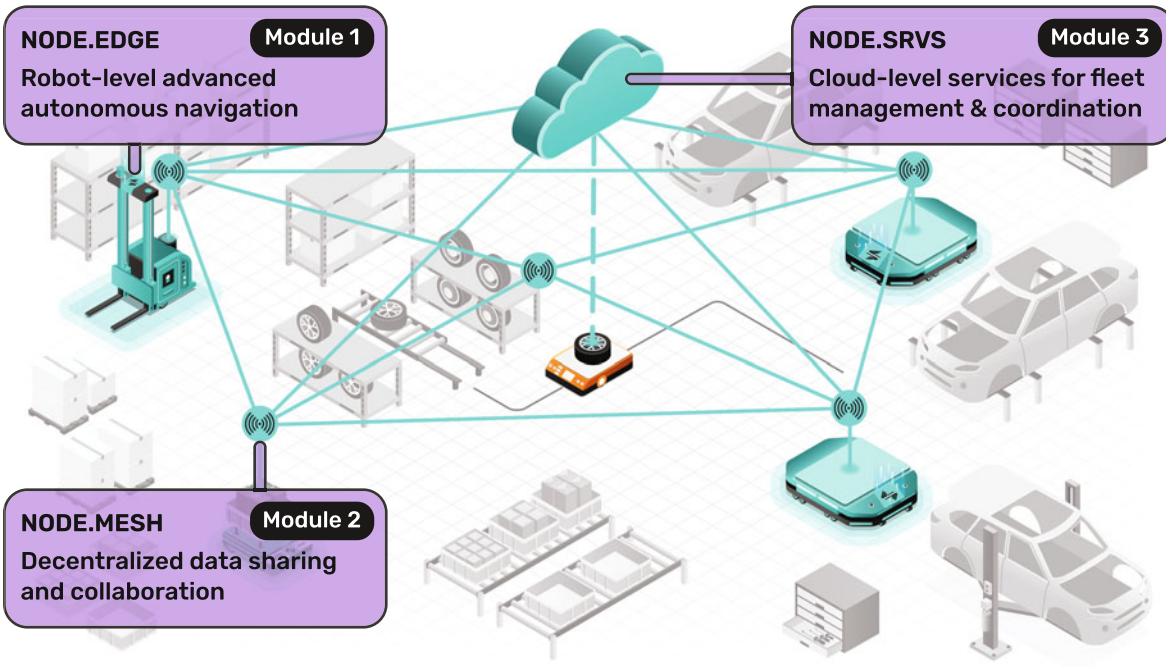

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History of Automated Guided Vehicle Systems

1

Summary
Automated Guided Vehicle Systems (AGVS) are an important component of intralogistics. The technological standard and the experience with this automation technology that is now available have led to AGVS finding their way into almost all industries and production areas. The history of AGVS began in the USA in the mid 1950s.

When production started up again after the Second World War and the global economy boomed, automatically moving transport vehicles were part of mankind's dream of making its own work done by machines. The rapid development of sensor and control technology and originally of microelectronics paved the way for AGV systems.

At this point we would like to pay tribute to the invention of the AGV in America, but then concentrate exclusively on the European market. So far there have been few successful American attempts to enter the European market. The opposite approach has been more successful: there are a number of European AGV manufacturers who are carrying out projects in America. The Asian market has had virtually no overlap with Europe in the past, neither in one direction nor the other.

For about 5 years now, China has been experiencing a huge AGV boom, both on the user and, in particular, on the supplier side: in just 2 years (since 2016) the number of Chinese AGV manufacturers has risen from under 10 to over 40. These companies rely both on technology developed in-house and on solutions licensed from European or American suppliers. At present, however, vehicles from Chinese production have not yet appeared on the European market.

The 60 AGV years to date can be divided into four epochs. These are characterised by the technology available and the emotional attitude towards the systems. These epochs can

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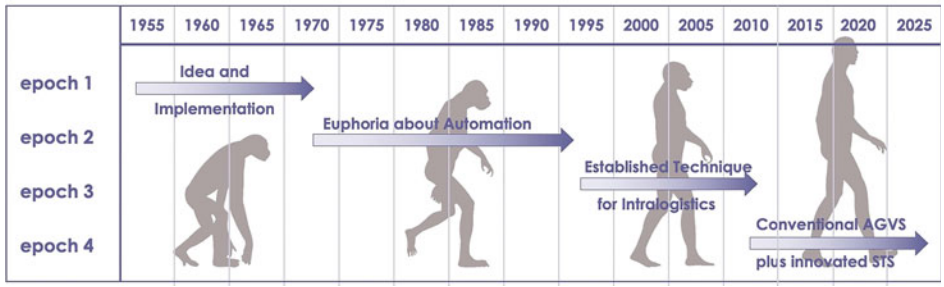

Fig. 1.1 Automatic Guided Vehicle Systems develop in and on evolutionary stages (epochs)

also be understood as stages of evolution, during which there were only limited technical developments and which then merged rather abruptly (Fig. 1.1).

1.1 The First AGVS Epoch: Idea and Implementation

The first epoch began in America in 1953 with the invention of automated transport vehicles and in Europe a few years later. It lasted almost 20 years. Technologically, the first systems were characterised by the simplest track guidance techniques and tactile sensors, such as bumpers or emergency stop bars for workers' protection and safety, with mechanical switches.

At the beginning of the 1950s, an American inventor had the idea of replacing the human being on a towing wagon used to transport goods with an automatic machine.

This idea was implemented by the Barrett-Cravens of Northbrook, Illinois (now Savant Automation Inc., Michigan). In 1954, the Mercury Motor Freight Company in Columbia, South Carolina, installed the first AGV system as a towing train application for recurring consolidated transport over long distances (Fig. 1.2).

The previously rail-guided vehicles now followed an alternating current conductor which was laid in the ground. We know this principle today as inductive track guidance or wire guidance, a vehicle using such technology is called wire guided AGV. The first vehicle thus oriented itself during its journey without a driver by means of an antenna that detected and evaluated the field surrounding the current-carrying conductor with the help of two small coils. The stations at which loads (goods) were to be transferred were coded by magnets embedded in the ground, which were detected by sensors in the vehicle. The coding itself resulted from a specific arrangement of north/south pole oriented magnets.

At that time, the simple control system was based on tube electronics, which had only limited development potential.

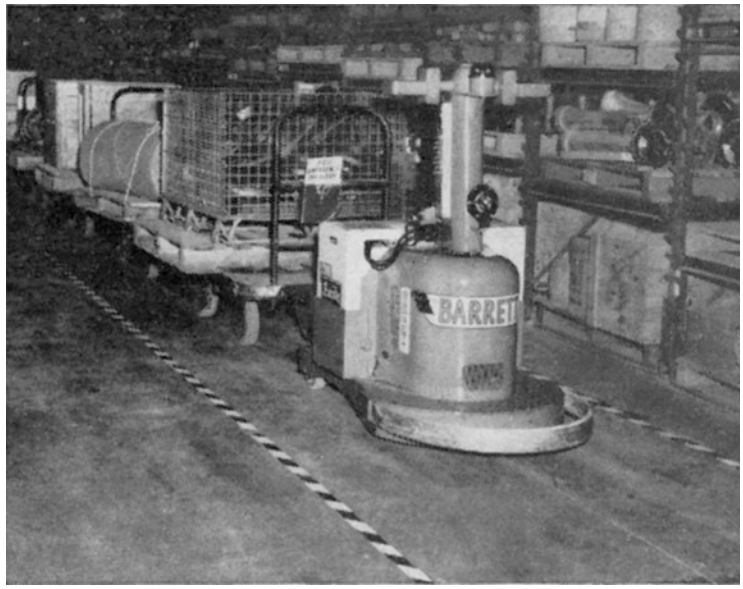

Fig. 1.2 One of the first American AGV, built from 1954 as a tractor for five trailers. (Source: Barrett-Cravens/Savant Automation, 1958)

1.1.1 First European Companies

In England the company EMI entered the market in 1956. The vehicles followed a colour stripe on the floor, which was detected by an optical sensor and provided the corresponding control and steering signals. From the 1960s the first transistor-based electronics were used, which increased the options of guidance and control.

In Germany, the companies Jungheinrich, Hamburg, and Wagner, Reutlingen, started the development of AGVs in the early 1960s. They automated the forklift and platform trucks originally designed for manual operation.

The mechanical engineering company Jungheinrich was founded in 1953 and started selling the electric four-wheel forklift truck "Ameise 55" on the market. Then, just a few years later, in 1962, the first automatically controlled, inductively guided stacker "Teletrak" was presented. Optical track guidance was also used here (Fig. 1.3).

The company Wagner Fördertechnik began marketing AGVs for use in automobile production and trade in 1963.

1.1.2 Early Technology and Tasks

Even the first systems, developed and built in the USA, England, Germany and other countries, had elementary features which are still part of an AGV system today: the master

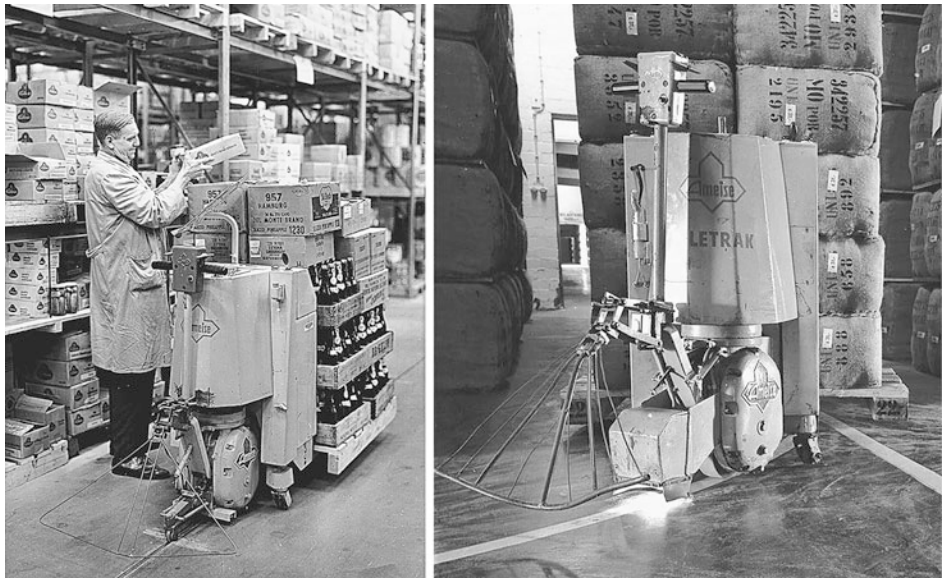

Fig. 1.3 "Ant"/teletrack. (Source: E&K 1965)

control system, the vehicle with control computer, the safety system, and the track guidance system.

The environment in which the first Automated Guided Vehicles were operated was a normal factory or warehouse. Where workers used to use their (towing) vehicles to transport goods through the hall areas, the environment has now been adapted step by step to the requirements of a system that dispensed with human escort. Markings, road ways free of obstacles and passive and active protective measures were to reduce the risks. There is said to have been resistance to the new technology in the USA: trade unions feared that jobs would be lost. But who calculated at the time the gain in new jobs in the developing manufacturing and supply market?

From the mid-1960s onwards, the first individual transport applications and transport as part of the "linking" of workstations were found, and the first systems were used in order picking in the food industry. The variety of vehicles was limited to tractors, forklift trucks and platform trucks (Fig. 1.4).

The master control system was simple, more precise: there wasn't any. The vehicles drove predetermined roadways from station to station, started on demand and stopped after recognizing the stop markers. A simple electrical system and a magnetic sensor system made this possible in a reliable manner. The operation did not allow any flexibility; the transport bridged farther distances, the stations were approached one after the other, there was practically only one direction—forward.

The AGV had been developed based on a manually operated towing vehicle, i.e. it had the same steering and drive as a normal vehicle, and it had additional safety devices. Its size

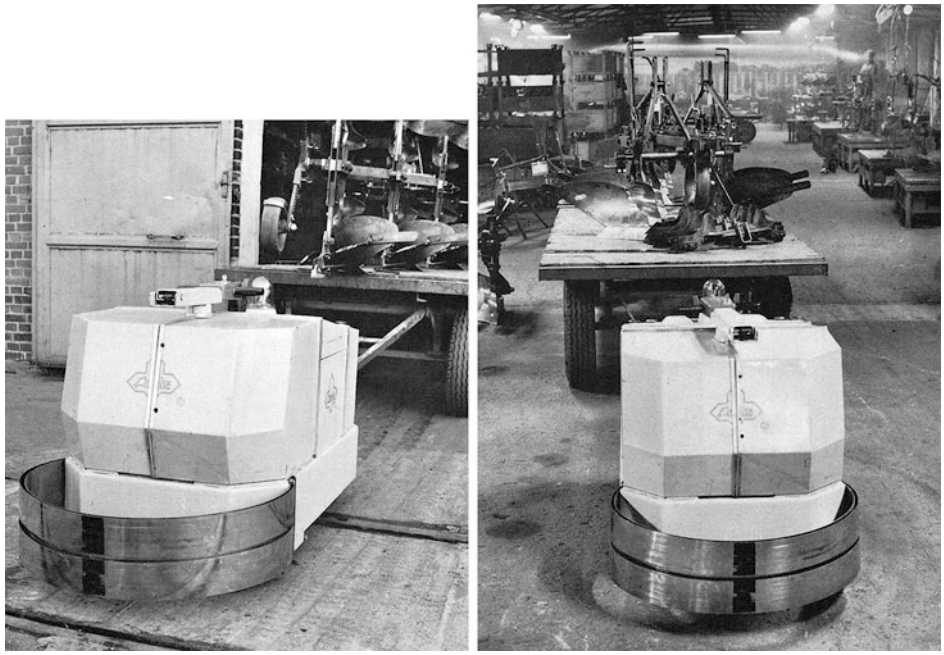

Fig. 1.4 Ant/teletrak with trailers. (Source: E&K)

was determined by the application requirements. If the driver was removed, then a combination of mechanics, electrics and "electronic intelligence" had to take over his tasks. Human perception—through the driver's eyes—was thus replaced by sensor technology, albeit only in a rudimentary form. In order to ensure safety in operational traffic, not only the equipment had to be protected, but above all the people working in the company.

Initially, the vehicles' control system was still based on tube technology, then there were those with relays and step switching mechanisms, and from the late 1960s on, semiconductor technology (TTL logic) came up.

Personal safety for forward direction was realised with a "bumper" or a safety edge, i.e. in any case with a tactile sensor.

The track guidance was provided by current-carrying conductors in the floor or by optical guidance lines on the floor.

At the end of the 1960s the first tractors with automatic couplings were designed: they could pull one or more trailers and park them (= automatically uncouple them) where they were needed. However, coupling and reversing was still done manually by an operator using the fold-down drawbar. The following picture shows such a tractor, interesting here is also how unsecured the attached trailer was (Fig. 1.5).

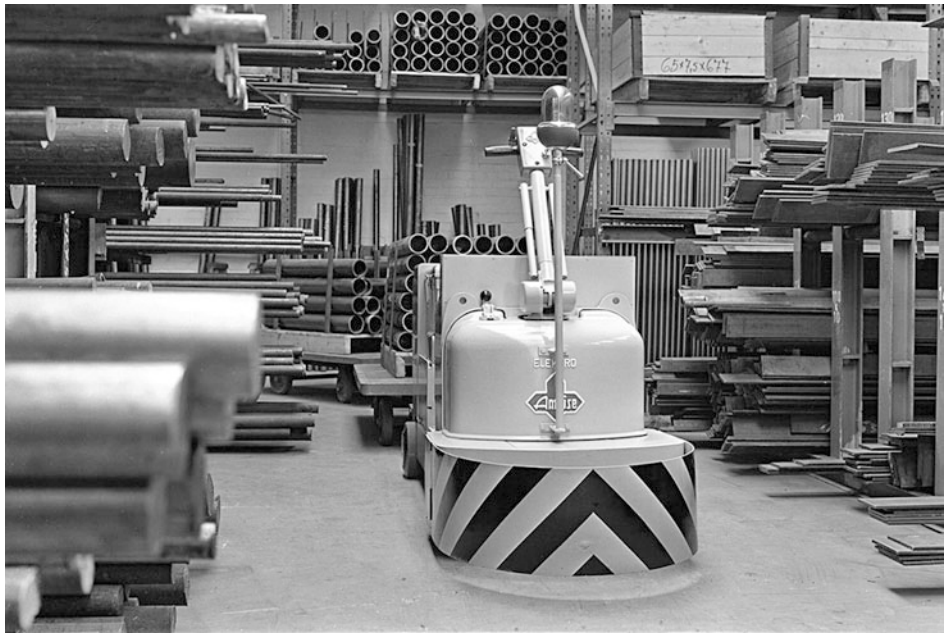

Fig. 1.5 AGV as towing tractor. (Source: E&K approx. 1965)

1.2 The Second Epoch: Euphoria About Automation

The second epoch lasted through the 1970s and 1980s and ended in the early 1990s. The electronics arrived in the form of simple on-board computers and large control cabinets for the block section control of the plant. Active inductive guidance by means of a wire in the ground became commonplace, and data transmission was either via the same wire, infrared or even already by radio.

In the 1970s, the typical AGV was finally created. As production efficiency increased and manually operated transport systems were used, the demand for a higher degree of automation developed, which should reduce production costs in the long term.

1.2.1 Progress in Technology

Market demand, driven by user expectations, could only be satisfied by constantly improving technology.

A growing number of manufacturers and component developers increased the flexibility of the application possibilities and improved the system capabilities. Even at this early stage, the manufacturers recognised that they could take advantage of the rapid

developments in electronics and sensor technology. However, a special supplier market did not develop; the overall market volume was too small for this. Developers and manufacturers of components were driven by other markets, e.g. by the needs of manufacturers of traditionally manned transport vehicles.

The experience of AGV manufacturers was increasingly incorporated into improved plant control systems. But the supplier community still had its roots in mechanical engineering.

Technical innovations freed the manufacturers from previous restrictions, and a number of innovations came onto the market in the 1970s:

- Powerful electronics and microprocessors enabled increased computing power and thus more complex application scenarios and plant layouts. Programmable logic controllers (PLC) were used for the first time in plant control. Improved, affordable sensor technology improved precision while driving, navigation (positioning and position recognition) and at the load transfer stations.
- Battery technology became more powerful, although one had to admit in retrospect that it was not fully mastered. Automatic battery charging was also introduced.
- One navigation method became generally accepted: inductive track guidance, also known as wire guidance. An alternating current flowing through a conductor in the ground generates an alternating magnetic field around the conductor, which in turn induces a voltage in a coil, the level of which depends on the position of the coil relative to the conductor. If two coils are arranged below the vehicle in such a way that one is to the left and one to the right of the conductor wire, the differential voltage of the two coils can be used to control the steering motor.
- The master control system was modelled similar to the block control system of railway traffic. Large electrical cabinets using relay technology provided for sequence control and ensured that the vehicles did not collide or block each other.
- Load handling was done more intelligently and increasingly automated. The possibilities for movement of the vehicles increased (reverse travel with load transfer, omni-directional movements); the first outdoor applications were realised.
- The automated vehicles were fully integrated into production processes; for example, the vehicles were used as mobile workbenches (series assembly).
- For data communication, infrared light but also radio systems were used.

1.2.2 Major Projects in Automotive Industry

Market demand was mainly driven by the automotive industry. The large German car manufacturers in particular modernised and automated seemingly limitlessly. The AGV was one of them, it was “in”, especially in the following application areas:

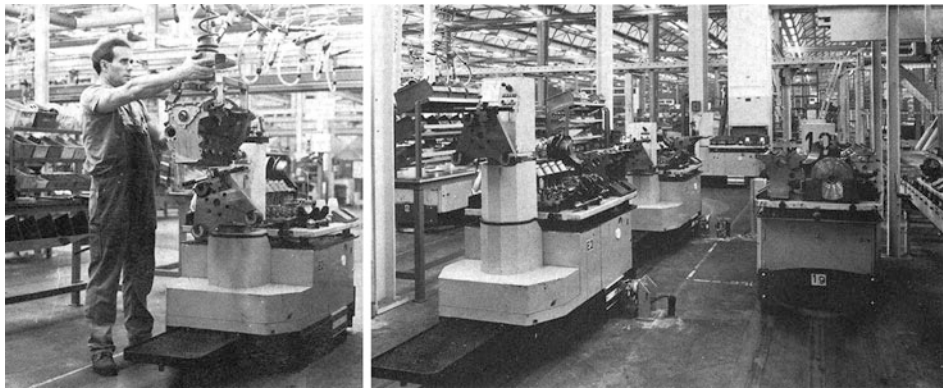

Fig. 1.6 Wire guided assembly platforms for motors at VW in Salzgitter (Source: E&K 1977)

- taxi operation in intralogistic applications,
- AGV as a mobile workstation in the pre-assemblies,
- interlinking of production machines in aggregate manufacturing,
- tractors, piggyback and forklift truck AGVs for assembly belt supply,
- in the warehouse, for picking and material delivery to the lines,
- special devices for integration into production systems.

Many of the major VDI-FML[1] partners in the automotive industry have supplied large systems, often with more than a hundred vehicles. The systems were used in pre-assembly (cockpit, front end, doors, engines, transmissions, drive trains), in final assembly, in buddy shop, but also for logistic tasks (Figs. 1.6, 1.7, and 1.8).

1.2.3 The Big Crash

By the end of the 1980s, the decline was already looming: The economy was hit by a recession and money became scarce. AGVs had the image of being expensive anyway: The flexibility the systems were advertised with even then was not achieved in practice. Small changes in the drive track had to be carried out by the AGV supplier and cost a lot of money. The reliability and availability of the systems left much to be desired.

The German car manufacturers Volkswagen, BMW and Mercedes Benz agreed that something had to be done about the lack of compatibility and economy of the systems. They initiated the foundation of the VDI technical committee[2] "Automated Guided Vehicle Systems", which began in 1987 to develop VDI guidelines on the relevant AGV topics

[1] VDI FML (= Fördertechnik, Materialfluss und Logistik)—German for: Conveying technology, material flow, logistics.

[2] www.vdi.de