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DESIGN OF SMART TRANSPORTATION SYSTEMS USING ARTIFICIAL INTELLIGENCE. (Development of Integrated Technical Systems Using AI-Enabled Computer-Aided Design Software)

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Abstract

This article examines the development of integrated technical systems using computer-aided design software incorporating elements of artificial intelligence.

To design specialized technological equipment complexes that meet modern requirements while preserving the applicability of the Theory and Algorithm of Inventive Problem Solving, it is necessary, at a minimum, to analyze the definitions and laws governing the evolution of technical systems in conjunction with AI-enabled computer-aided design systems.

The system under consideration is a higher-level integrated technical system comprising a number of technical systems interconnected through a common technological cycle and functioning as dual parallel local supersystems. Each supersystem includes two lines: a chemical line and a mechanical line incorporating electroplating operations.

Accordingly, each dual parallel local supersystem consists of multiple local technical systems, or subsystems, connected through local programmable processors to the central processor of the higher-level integrated technical system.

Keywords: *integrated technical system; dual parallel local supersystems; higher-level integrated technical system processor; law of technical system evolution; classical technical system; automated robotic production and assembly complex*

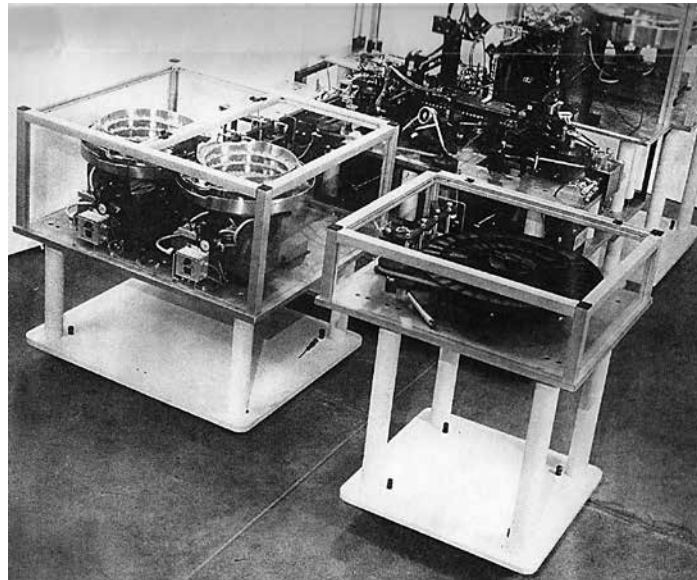
Introduction

The structure and interaction of local technical solutions within each subsystem are fundamentally determined by the laws of technical system evolution formulated within the Theory of Inventive Problem Solving (TRIZ).

For a more detailed analytical examination, it is appropriate to return to examples

of specific contemporary developments, taking into account the above comments on the laws of technical system evolution, as well as certain modifications to TRIZ definitions and classifications proposed in the well-known publications of Mykhailo Korobko.

Figure 1. *The figure shows the technological modules of an automated robotic production and assembly complex designed for the autonomous manufacture of contact blocks for telephone lines. As can be seen in the image, the complex contains four principal technological modules. Three of these modules prepare parts and components for assembly and are arranged around the assembly conveyor module*

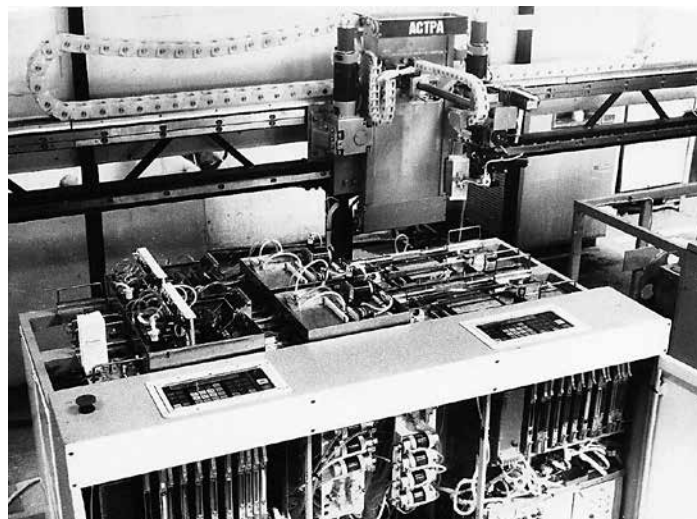


The operating cycle of each module is synchronized with the indexing step, or operating cycle, of the assembly conveyor module. This applies both to the vibratory hopper modules traditionally used in such complexes, shown on the left side of the figure, and to the fundamentally new modules used to stamp the contacts and feed them

to the assembly and inspection conveyor, shown in the center.

This configuration of an automated robotic production and assembly complex may be classified as a technical system with a fixed production cycle, in which all technological modules are synchronized with the indexing step of the assembly conveyor module.

Figure 2. *The figure shows a configuration of a flexible photolithography processing module for thin-film microassembly boards. The module comprises two parallel process flows, each of which is fully autonomous, including independent integrated computer control systems. In addition to these systems, the module also includes a computer-based control and monitoring system for the operator robot, which is functionally connected to the integrated computer control systems*



In this configuration, the technological modules function as subsystems, while the assembly conveyor module functions as the governing supersystem. The subsystem modules operate in accordance with the production cycle of this supersystem.

As can be seen in the figure, although the assembly complex contains numerous points of interaction and requires the coordination of its production cycles, it is not subject to any specific requirements governing increased flexibility or adjustment of the modules' production cycles.

This configuration is characteristic.

The module comprises several closely interconnected functional technical systems, each of which may be classified as a super-system.

Together, these systems include loading and unloading modules, local loading and unloading units, tracks, centrifuges, chemical reagent and photoresist metering and delivery units that supply these materials to the processing area on the centrifuge table, monitoring systems, and other associated components.

Figure 3. *The figure shows the processing track of a system used to apply electroplated coatings to thin-film microassembly boards. The processing track includes autonomous board loading and unloading devices installed at the process inlet and outlet*



The track comprises several centrifuges: a processing station for preparing surfaces for coating, a processing station for electroplating, and a processing station for the final treatment of the board after the coating has been applied.

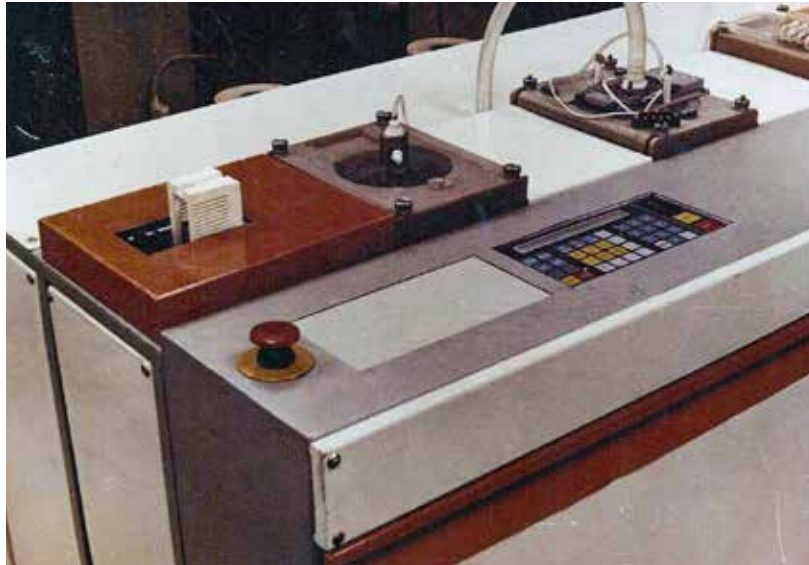
The system is fully automated and is controlled and monitored by programmable processors connected to the power supply for the electroplating process. The system provides flexible adjustment of the current density depending on the coating area and thickness.

The system has two process flows, one of which is shown in the figure. It is operated, regulated, configured, and monitored by several programmable controllers. Data, programs, and commands are entered into these controllers through a touchscreen.

It is important to note that each local technical system, even when functioning as a low-level subsystem, possesses considerable potential for integrative adaptation within technical systems at every level of the hierarchy due to its high degree of unification and standardization. This hierarchy determines the composition and functional characteristics of the supersystem at its highest level.

Because prototypes of such equipment are generally developed at the level of an invention in specific production environments, the accurate definition, systematic qualification, and classification of all new technical solutions and their combinations within technical systems at every level of the hierarchy are critically important.

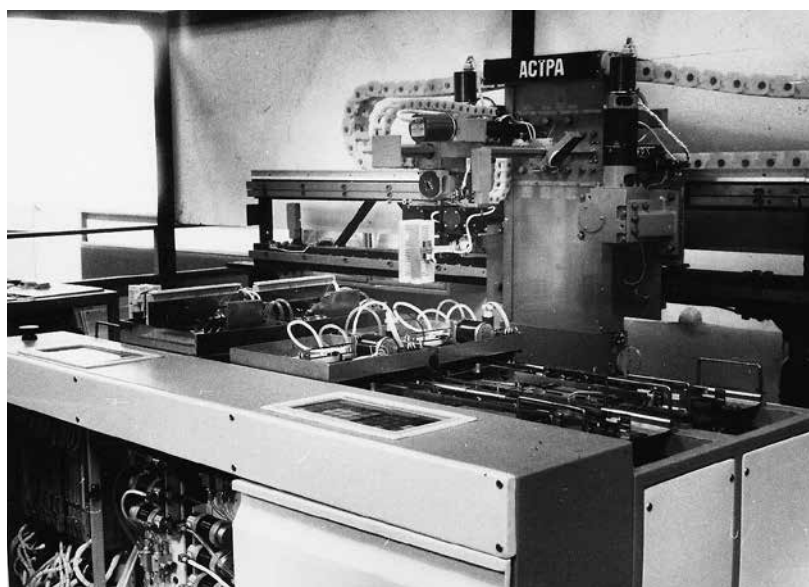
Figure 4. *The figure shows an automated system comprising two process flows, each equipped with flexible and independent control and monitoring. The system is designed to apply electroplated coatings to thin-film microassembly boards in a semiconductor manufacturing environment. It can be incorporated into flexible in-line processing modules, which, in turn, can be integrated into higher-level systems*



As shown in the figure, the thin-film microassembly board blanks, manufactured from a special ceramic material and measuring 48×60 mm, are held in cassettes positioned at the beginning and end of the process flow. Operator involvement in the process is therefore not required, since all

loading and unloading operations are performed by an operator robot. All operations and the sequence in which control commands are executed are monitored by a programmable processor, which is accessed through a touchscreen control panel.

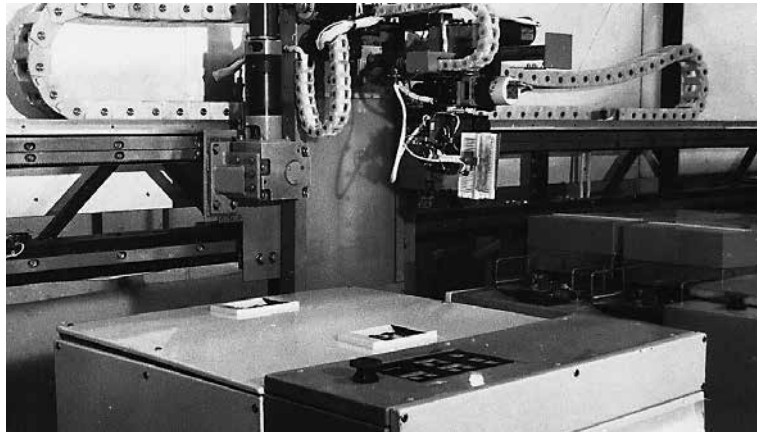
Figure 5. *The figure shows the technical solutions incorporated into and forming the transport systems at all levels of the flexible automated processing module. These range from transporting thin-film microassembly board blanks from the loading and unloading module to the processing stations to the integrated transport system of the robotic manipulator, which can be adapted for use with equipment designed for other technological processes and with computerized control and supervisory regulation systems*



Systems of this kind generally incorporate a wide variety of basic technical solutions. When these solutions are combined with technical solutions possessing world-

wide novelty, it is the resulting integrated technical solutions, in their various combinations and configurations, that may qualify as inventions.

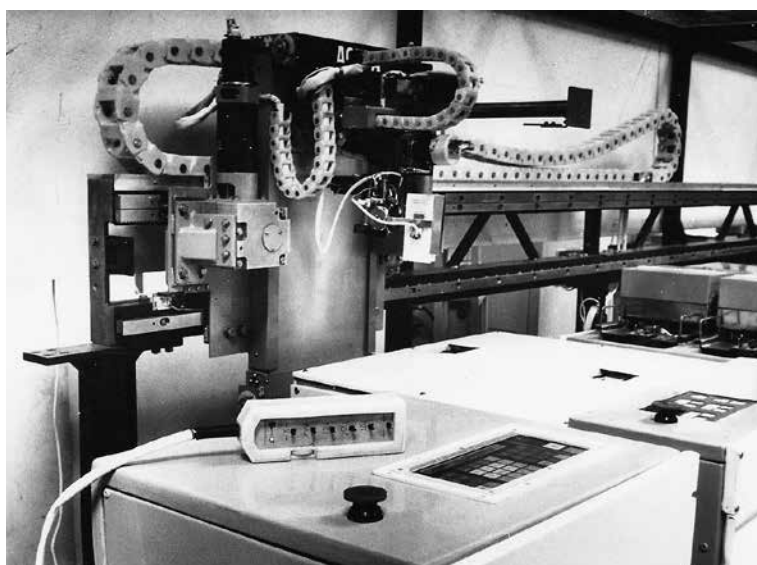
Figure 6. *The figure shows the integration of the transport systems of a flexible automated processing module with the transport and orientation systems of a buffer-storage module functioning as a universal supersystem*



In a configuration comprising technical solutions that extend upward and downward through the hierarchy of the highest-level supersystem, the strategy for patent protection from a technical perspective and licensing protection from a legal perspective depends heavily on the clear and technically accurate classification of the entire set of technical solutions and their functional interconnec-

tions. Of even greater importance are their relationships with the definitions and formulations applicable to the various categories and types of technical solutions incorporated into higher-level systems within the hierarchy, including subsystems and the technical solutions located at the interfaces of local and substantially autonomous technical systems that connect them into supersystems.

Figure 7. *The figure shows a section of a flexible photolithography processing module for thin-film microassembly boards, illustrating the fundamental method used to load and unload the processing stations by means of an operator robot. The robot retrieves a cassette containing substrates from the buffer-storage module and places it on the loading device table of the process flow. The same procedure is performed in reverse: the robot retrieves a cassette containing processed substrates and places it in the buffer-storage module*

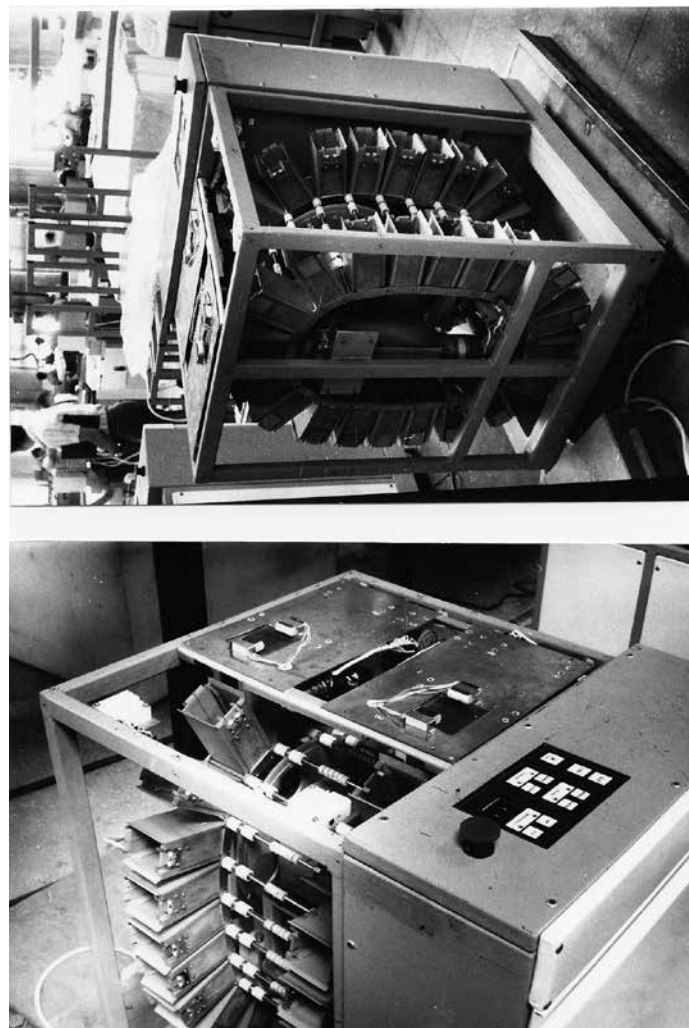


The presence of programmable control and monitoring controllers and processors naturally elevates the status of these technical systems from local technical systems to smart technical systems. The foregoing demonstrates the importance of the analytical work performed by Mykhailo Korobko in his pioneering research. His development of fundamental principles for classifying and systematizing the types and characteristics of technical systems, together with the definitions applicable to each level of such systems, is essential to the systematic continuation and further optimization of computer-aided design processes. This work enables the use of advanced computer-aided

design software in combination with the latest principles and methods of digital technology, while aligning them with the terminology and laws of technical system evolution established within the Theory of Inventive Problem Solving (TRIZ) and the Algorithm for Inventive Problem Solving (ARIZ).

As shown in the figure, the buffer-storage modules contain sealed cassette cells and are equipped with programmable control processors. These processors monitor the processing sequence and transmit signals to the conveyor of the buffer-storage module, identifying the cell that must either receive a cassette or be cleared of one.

Figure 8. *The figure shows the internal structure of the buffer-storage module. As can be seen in the figures, the module is equipped with a vertical conveyor to which cells are attached for inserting and removing cassettes containing workpiece blanks*



This technical system has undergone extensive testing. A detailed analysis demonstrates that virtually all layout, schematic, and structural technical solutions incor-

porated into the components of the flexible automated production module correspond – in terms of their design, functions, layout methods, and operating methods – to the

classification, terminology, and structure of modified technical systems, as well as to the definitions formulated in the works and publications of Mykhailo Korobko.

The analysis would be incomplete without examining the standard process for developing a new technical solution incor-

porated into a technical system at a higher level of composition and layout. It is also necessary to determine whether the relevant formulations and definitions correspond to the modified formulations and definitions for technical systems at all levels proposed by Mykhailo Korobko.

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