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DEVELOPMENT OF COMPLEX TECHNICAL SYSTEMS. (Development of Complex Technical Systems Using Computer-Aided Engineering Programs with Artificial Intelligence and Artificial Neural Network Elements)

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Abstract

This paper examines the methodological foundations for the formation of complex systems of specialized technological equipment in accordance with contemporary requirements of digital design. Particular attention is given to preserving the applicability of TRIZ and ARIZ tools in the context of integrating machine-based design systems with elements of artificial intelligence.

The structure of dual parallel local subsystems is analyzed. These subsystems consist of multiple local technical systems interconnected through programmable processors and integrated into a central processor of a higher-level complex technical system. It is demonstrated that the architecture and interaction of local technical solutions are fundamentally governed by the laws of technical system evolution as formulated within TRIZ.

For a more in-depth analytical perspective, the paper proposes referring to examples of modern developments, taking into account interpretative comments on the laws of technical system evolution, as well as modifications of TRIZ and ARIZ definitions and classifications presented in the publications of the successful innovation specialist Mykyta Liakh.

Keywords: *Technical system; Complex technical system; Computer-aided engineering (CAE) program; Artificial intelligence; Artificial neural networks; TRIZ and ARIZ definitions; TRIZ and ARIZ classifications*

Structure and Interaction of Local Technical Subsystems within a Complex Technical System

Accordingly, each such dual parallel local subsystem consists of multiple local technical systems (subsystems) interconnected through local programmable processors and integrated into the central processor of the higher-level complex technical system.

The structural configuration and interaction of local technical solutions within each subsystem are fundamentally determined by the laws of technical system evolution as formulated within TRIZ.

Figure 1.

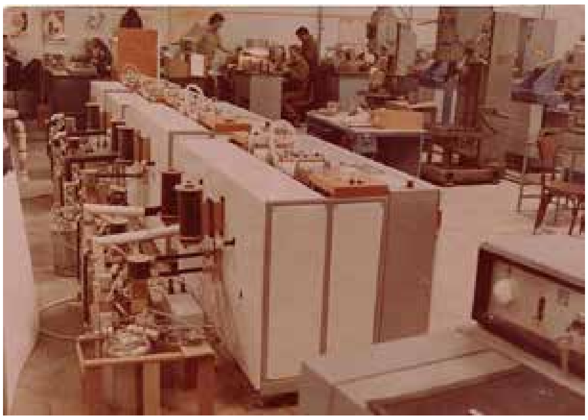


Figure 1 illustrates an automated production line for applying electroplated coatings to thin-film microassembly boards. This represents a higher-level complex technical system incorporating a series of interrelated technical systems connected through a unified technological cycle. These systems operate as dual parallel local subsystems, each comprising two coordinated processing lines chemical and mechanical integrated with electroplating operations.

For a more detailed analytical examination, it is appropriate to refer to examples of specific contemporary developments, taking into account the previously provided commentary on the laws of technical system evolution, as well as certain modifications of TRIZ and ARIZ definitions and classifications proposed in the well-known publications of the successful innovation specialist Mykyta Liakh.

Figure 2.

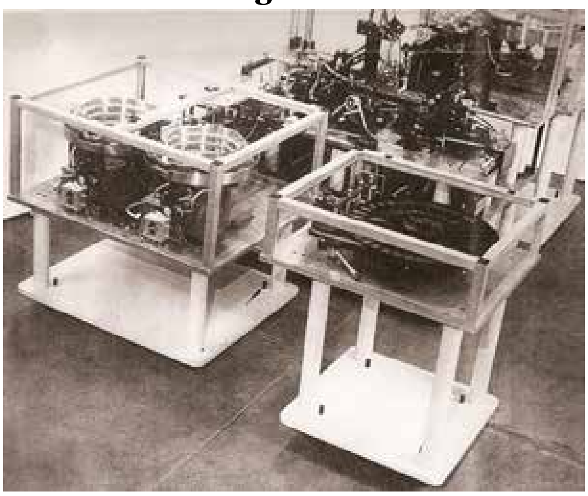


Figure 2 presents the technological modules of an automated robotic production assembly complex designed for the autonomous manufacture of contact blocks for telephone lines. As shown in the figure, the complex comprises four primary technological modules, three of which serve as part-preparation modules and are arranged around the central assembly module – the conveyor system.

The operating cycle of each module is synchronized with the pitch (operating cycle) of the assembly conveyor module. This applies both to traditional modules used in such systems – for example, vibratory feeder (hopper) modules (shown on the left in the figure) – and to fundamentally new modules for contact stamping and subsequent transfer to the assembly and inspection conveyor (shown in the center).

Such an automated robotic production assembly configuration may be classified as a technical system with a rigid production cycle, wherein all technological modules of the complex are directly tied to the operational step of the assembly conveyor module.

Within this configuration, the technological modules perform the functions of subsystems, while the assembly conveyor module functions as the leading supersystem, to whose production cycle the subsystem modules are synchronized and subordinated.

As evident from the figure, despite the presence of numerous interaction points and synchronization requirements among production cycles, the system does not incorporate regulatory mechanisms aimed at increasing flexibility or enabling dynamic adjustment of module operating cycles.

This configuration is characteristic of complex technological solutions with a fixed operating cycle that is neither intended nor designed to be modified during the execution of the production process.

Logically, such complexes do not initially require computerization and can successfully operate within an automated production cycle designed for the mass manufacture of standardized products.

For a technical system performing tasks of this nature, all definitions of the classical technical system remain unchanged.

Likewise, the definitions and classification methods of its components – supersystems and subsystems – remain applicable without modification.

With regard to the specific structure and features of the automated robotic production complex, it is important to note elements of fundamental novelty within the overall technological configuration of the system and the characteristics of the product manufactured.

This primarily concerns the specific design of the contacts within the contact blocks.

As illustrated in the figure, a strip of special bronze with a high beryllium content is not fully stamped in the initial stamping module. Instead, it is only partially formed with contour incisions. The strip is then transferred to another module (located on the opposite side of the assembly conveyor module), where it is finally shaped into paired contacts and inserted into the appropriate conveyor cells, which already contain the plastic components of the contact block.

For complexes of this type, this represents a fundamentally new solution. It allows the system to maintain a constant production rhythm for contact blocks and eliminates the need for intermediate real-time inspection.

For the classification of a modern automated robotic production assembly complex designed for the autonomous manufacture of contact blocks for telephone lines, updated definitions of technical systems and their constituent elements may be applied, as developed and proposed by the well-known researcher and innovation specialist Mykyta Liakh in his works.

Figure 3.

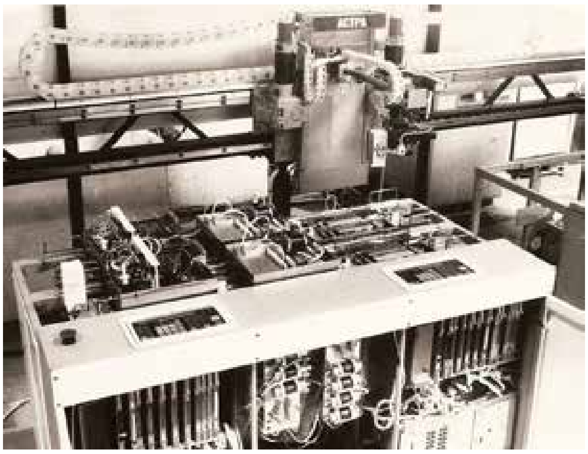


Figure 3 presents a configuration of a flexible photolithography processing module for thin-film microassembly boards.

The module incorporates two parallel technological processing streams. It is important to emphasize the complete operational autonomy of each stream, including the independence of their respective comprehensive computer control systems. In addition to these control systems, the module also includes a computer-based control and monitoring system for the operator robot, functionally integrated with the comprehensive control systems of both processing streams.

The specified module comprises several closely interconnected functional technical systems, each of which may be classified as a supersystem.

The aggregate of these systems includes loading and unloading modules, local loading – unloading units, transport tracks, centrifuges (spin-coating units), dosing and delivery units for chemical reagents and photoresist to the processing zone and centrifuge platform, as well as monitoring and control systems, among others.

Figure 4.

Figure 4 illustrates the working track of an electroplating installation designed for applying galvanic coatings to thin-film microassembly boards.

The working track includes an autonomous loading and unloading unit installed at both the process entry and exit points.

The track comprises several centrifuge units corresponding to distinct process stages:

- a working position for surface preparation prior to coating;
- a working position for electroplating deposition;
- a working position for final post-coating treatment of the board.

The system is fully automated and controlled by programmable processors interfaced with the power supply unit for the electroplating process, allowing flexible regulation of current density depending on coating area and required thickness. The system incorporates two operational streams, one of which is shown in the figure. Control, adjustment, configuration, and monitoring of the system are performed through multiple programmable controllers, with programs, parameters, and commands entered via a touchscreen interface. It is important to note that each local technical system – even at the level of a lower-order subsystem – due to a high degree of unification and standardization, possesses significant potential for integrative adaptation within technical systems across the entire hierarchy that defines the composition and functional characteristics of the leading supersystem.

Given that, in practical industrial settings, prototypes of such equipment are typically developed at the level of invention, the correct definition, systematic qualification, and classification of all new technical solutions and their combinations across technical systems at all hierarchical levels are of critical importance.

Figure 5.

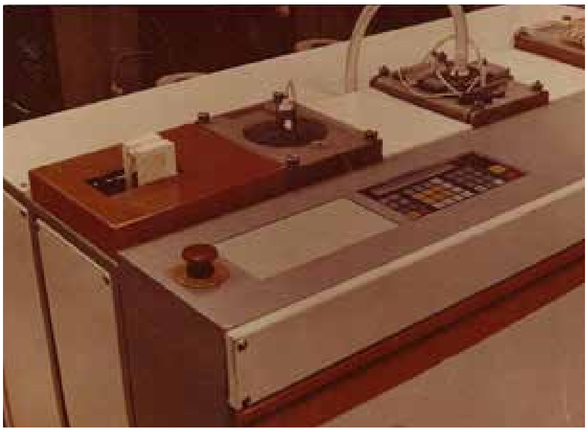


Figure 5 illustrates an automated electroplating installation designed for the application of galvanic coatings to thin-film microassembly boards under semiconductor manufacturing conditions.

The installation consists of two technological processing streams and provides a flexible and independently controlled configuration for monitoring and operational management. It is designed for integration into continuous flexible technological modules, which in turn may be incorporated into higher-level technical systems.

As shown in the figure, thin-film microassembly board blanks manufactured from specialized ceramic material (dimensions 48 × 60 mm) are placed in cassettes installed at both the beginning and end of the technological flow.

Operator participation in the process is not required, as all loading and unloading operations are performed by a robotic handling unit. Control of all operations and sequencing of control commands are carried out by a programmable processor, with user interaction provided via a touchscreen control interface.

Figure 6.

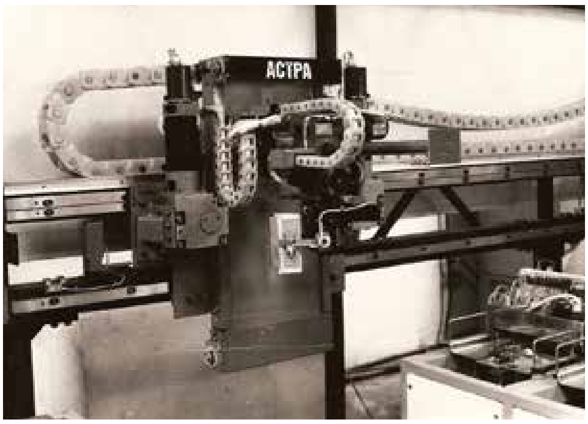


Figure 6 shows a flexible automated technological module from the perspective of the input devices, onto which the loading – unloading robot places a cassette containing blanks for thin-film microassembly boards.

The robotic manipulator retrieves the cassette from a storage cell, transfers it to a position aligned with the input device table, then lowers the cassette until it contacts the table surface and secures it in position.

The illustrated configuration of local technical systems may be classified as a combination of subsystems integrated into a localized yet functionally higher-level supersystem through a specific flexible algorithm governing the entire complex sequential process. This process includes: locating the cassette; identification and gripping of the cassette; transportation of the cassette; three-dimensional orientation; vertical alignment; identification of the cassette on the loading–unloading input table; and final fixation of the cassette on the table with subsequent transfer of operational functions to the conveyor track.

All of the aforementioned operations simultaneously constitute the technical specification for the development of the corresponding control software.

Figure 7.

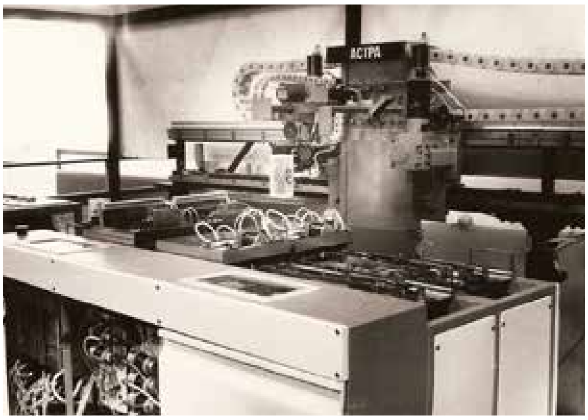


Figure 7 illustrates the technical solutions that constitute and define the transport systems at all hierarchical levels of the flexible automated technological module. These systems range from the transportation of thin-film microassembly board blanks from the loading–unloading module to the various working positions, to the comprehensive transport system of the robotic manipulator, which is capable of adaptation for integration with equipment of other technological domains and with computerized control and dispatch regulation systems.

As a rule, systems of this type incorporate a wide range of foundational technical solutions. The combination of these base solutions with technical solutions possessing worldwide novelty makes it possible to classify comprehensive configurations of such integrated technical solutions – in various combinations and structural arrangements – as inventions.

Figure 8.

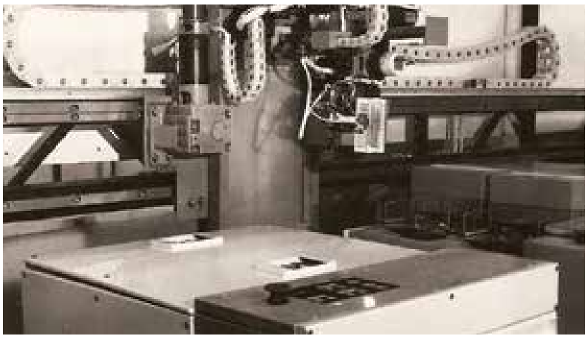


Figure 8 illustrates the integration of the transport systems of a flexible automated technological module with the transport–orientation systems of the accumulator module, functioning as a universal supersystem.

In such a configuration – characterized by ascending and descending technical solutions within the hierarchical structure of the highest-level supersystem – the strategy of patent (technical) and licensing (legal) protection is highly dependent on the precise and technically correct qualification of the entire complex of technical solutions, their functional interconnections, and, more importantly, their correlation with the definitions and classifications of various types of technical solutions.

This includes their relationship to subsystems at higher hierarchical levels and to the technical solutions that connect local and relatively autonomous technical systems into supersystems. Accurate systemic classification at these interface levels is essential for both technical integrity and legal defensibility.

Naturally, the presence of programmable control and monitoring processors elevates the status of such systems from a local technical system to a smart technical system.

All of the above demonstrates the importance of the analytical work conducted in the pioneering research of Mykyta Liakh. His developments addressing fundamental issues of classification and systematization of technical system types and characteristics, as well as the formulation of definitions for each hierarchical level of technical *systems, are essential for the systematic advancement and further optimization of machine-based design processes. This is particularly relevant in the context of applying modern computer-aided engineering tools in combination with advanced digital technologies and their integration with the terminology and laws of technical system evolution established in TRIZ and ARIZ.*

Figure 9.

Figure 9 illustrates a continuous automated production line for the complete cycle of photolithography and techno-chemical processing of thin-film microassembly boards, featuring a flexible organization of local technological processes within each installation included in the line.

According to TRIZ classification, the production line constitutes a highest-level technical system within the hierarchy – a supersystem. Each installation within the line represents a mid-level technical system – also a supersystem relative to its internal structure. Each working station within an installation constitutes a lowest-level technical system – a subsystem.

In hierarchical terms, as the system level increases, each successive system becomes a supersystem relative to the preceding one, while each preceding system is considered a subsystem within the ascending structure.

Such a structured classification substantially unifies the logical and technological interrelationships among technical systems at all hierarchical levels. It also enables a high degree of standardization of software and system-level interconnections between processors and programmable controllers across all constituent components of the automated installations and the modular technical systems of auxiliary elements incorporated into the line.

When transitioning from a systemic continuous automated production line to a systemic flexible automated technological module, all classification definitions and formulations retain their validity and conceptual consistency.

Figure 10.

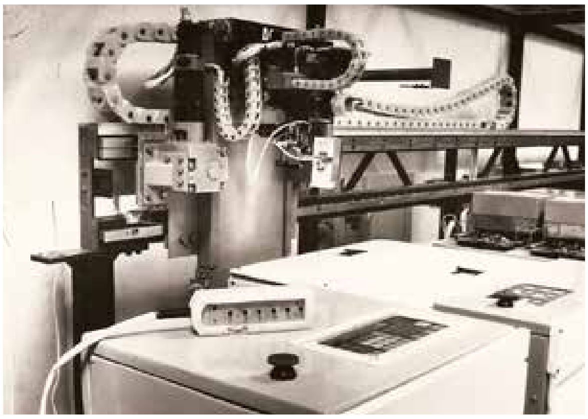


Figure 10 presents a fragment of a flexible photolithography technological module for thin-film microassembly boards, illustrating the fundamental solution for loading and unloading working stations using a robotic operator.

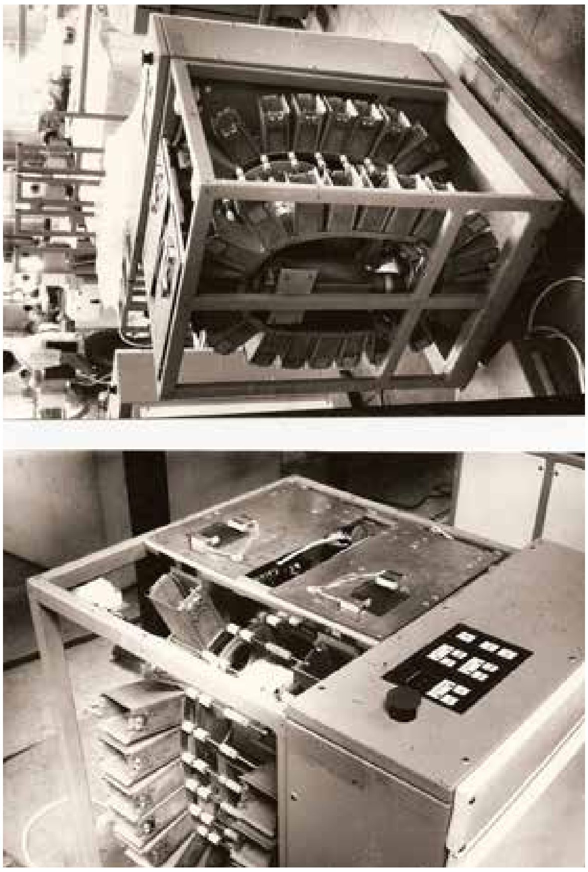
The robot retrieves a cassette containing substrates from the accumulator module and installs it onto the loading device table of the technological flow. The reverse process is performed in a similar manner – the robot grips a cassette containing processed substrates and places it into the accumulator module.

As shown in the figure, the accumulator modules are equipped with sealed cassette cells and incorporate programmable control processors that monitor the processing sequence and generate control signals for the accumulator module conveyor, indicating which cell is to be filled or cleared of a cassette.

Figure 11 illustrates the internal structure of the accumulator module. As shown in the figure, the accumulator module is equipped with a vertical conveyor system in which cells are mounted for the insertion and remov-

al of cassettes containing substrate blanks.

Figure 11.



This technical system has undergone extensive testing. A detailed analysis demonstrates that the layout, schematic design, and structural technical solutions of the constituent elements of the flexible automated production technological module – in terms of their configuration, functions, methods of arrangement, and operational principles – substantially correspond to the classification framework, terminology, and structural definitions of modified technical systems as formulated in the works and publications of Mykyta Liakh.

However, the analysis would remain incomplete without examining the standard process of developing a new technical solution as part of a higher-level technical system with a more complex compositional and structural organization. It is also necessary to assess the consistency of conventional formulations and definitions with the modified definitions and classifications of technical systems at all hierarchical levels proposed by Mykyta Liakh.

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