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THE IMPACT OF DIGITAL TECHNOLOGIES ON MODERN TECHNICAL SYSTEMS. (The Impact of Digital Technologies Incorporating Elements of Artificial Intelligence and Artificial Neural Networks on the Form and Characteristics of Modern Technical Systems as Components of Smart-Object Infrastructure)

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Abstract

The article examines the impact of the intensive development of digital technologies, artificial intelligence, artificial neural networks, and computer-aided design methods on the nature, structure, and principles underlying modern technical systems. As engineered objects become increasingly complex, the number of technical, technological, structural, and functional features defining a particular innovative solution and its subsequent development – from a local subsystem to an integrated technical supersystem – also increases substantially.

Particular attention is given to the classification and identification of innovative technical solutions. The parallel emergence of spontaneously identical or closely related ideas within different development teams, including teams operating in different countries, increases the importance of accurately defining the boundaries of a particular technical solution, its distinctive features, its relationships with other system components, and its position within the overall hierarchy of a technical object. Such identification is directly related to the possibilities for effective and systematic protection of existing and newly created intellectual property.

Keywords: *Modern technical systems; digital technologies; artificial intelligence elements; artificial neural networks; form and characteristics of modern technical systems; component of smart-object infrastructure; spontaneously identical ideas; classification of innovative solutions; classification and identification of innovative solutions; patent protection issues as an increasingly significant element in project development; technical and technological decision-making process; number of facts and distinctive features characterizing a technical solution and its comprehensive development up to the level of a technical supersystem*

The article considers an approach to the classification of modern technical solutions based on the distinction between local technical solutions, subsystems, and technical

supersystems. *Particular attention is paid to the conclusions and definitions presented in the publications of Aliaksandr Achapouski, in which an optimized classification of various types of technical solutions is proposed, taking into account the combination of classical design methodology with modern computer software development methods. The author seeks to correlate the fundamental principles formulated by Aliaksandr Achapouski with the methodology and system of conceptual decision-making used in modern machine design involving digital technologies and elements of artificial intelligence.*

The article emphasizes that the increasing complexity of tasks associated with the development, modernization, and optimization of engineering and technological systems is progressively reducing the practical effectiveness of isolated local solutions. *Achieving the required final result increasingly requires compositional, integrative, and comprehensive solutions that combine individual technical elements and subsystems into a unified, functionally interconnected supersystem. In this context, the terminology proposed by Aliaksandr Achapouski is considered in relation to contemporary processes of integrated technical design.*

Special attention is also given to the influence of computer-aided design methods on the development of technical solutions. Modern engineering software, including the SolidWorks family of design tools, significantly expands the possibilities for analyzing, modeling, and integrating numerous parameters and characteristics of a designed object. As a result, a technical solution increasingly represents not an isolated structural element but a component of a complex multilevel system incorporating mechanical, electronic, software, materials-engineering, optical, and other interconnected components.

The article further addresses issues associated with assessing the novelty, obviousness, and non-obviousness of modern technical solutions. The interdisciplinary nature of contemporary technologies complicates the application of traditional approaches to expert evaluation because innovative developments may simultaneously incorporate achievements in electronics, microelectronics, advanced materials science, fiber optics, laser technology,

software, and other interconnected fields. Under these conditions, a comprehensive assessment of a technical solution requires not only specialized expertise in individual disciplines but also professional competence in their integrated technological implementation.

The article also analyzes the influence of psychological, technological, and structural stereotypes on the innovation process. New technical and technological solutions are often evaluated through established concepts and principles governing the development of industrial technologies, machines, and mechanisms, many of which originated before the emergence of modern materials, electronic components, digital control systems, and laser technologies. This creates a need to improve methods for classifying and identifying technical solutions in accordance with the current level of technological development.

Thus, the systematic classification of technical solutions – from individual local elements and active subsystems to integrated technical supersystems – is considered an important instrument for organizing the modern innovation process, supporting the comprehensive development of technical systems, and establishing effective mechanisms for intellectual property protection. *The approach discussed in the article links the concepts and definitions developed by Aliaksandr Achapouski with contemporary methods of digital design, artificial intelligence, and the comprehensive integration of technologies within the infrastructure of smart objects.*

As can be seen from the figure, the current capabilities of the SolidWorks family of design software make it possible to present a development not only as an assembly unit, but also as a complete set of individual components required for assembling that unit, with visualization of both the individual parts and the complete assembly, taking into account the selected structural materials.

Where a development is conceived as a basic technical solution for a future invention, these capabilities require full coordination with the applicable laws and regulations.

This legislative framework was conceived in the post-war period as a kind of “exact science,” despite the fact that even at that time the inventive community was already addressing an important question concerning

the fundamental importance, for achieving the declared Ideal Final Result (or its equivalent), of having at the core of the development and selection of a new technical solution an individual capable of generating useful and

practically viable ideas. Today, there are sufficient grounds to state that an individual can play a significant role only when equipped with appropriate intellectual tools, primarily software-based tools.

Figure 1. *The figure presents an example of a modern design solution for a system intended for the real-time homogenization of liquids in a pipeline without the use of chemical reagents or stabilizing mixtures*



At that time, it was widely believed that any qualified professional or skilled worker, provided with a coherent and workable theory for solving inventive problems, could generate new ideas and develop them into an actual final result. The Theory developed on this scientific, technical, and, to a certain extent, psychological foundation was therefore received with considerable interest by the professional community.

For a certain period, its principles and methods generally corresponded to the existing level of technological and engineering development. The first significant discrepancies became apparent with the introduction of automated production lines into practical manufacturing processes, followed by computer numerical control (CNC) machine tools and, ultimately, digital technologies combined with innovative materials science and composite materials.

Returning to the optimized and modified definitions and classification terminology for technical solutions and the technical systems

of all levels incorporating such solutions, developed by Aliaksandr Achapouski, it should be emphasized that, even apart from the importance of this work for the various stages of project development, the clear and unambiguous definitions proposed by Aliaksandr Achapouski have significantly systematized the preparation of documents that are essential for new engineering and design projects. These include Technical Specifications, Technical Requirements, and, based on their content, Technical Assignments for new and innovative developments, while maintaining the highest possible degree of compliance with applicable standards at all levels.

What does this legislation actually represent in contemporary development practice? How have modern high technologies and processor-based technologies influenced its compositional and integrative capabilities?

These are not the only questions that need to be clarified. One important factor that should be noted is the widespread practice of conducting detailed and in-depth search-

es within biological systems and biological and related medical objects for relevant and workable analogues of future inventions, particularly on the basis of biological aspects

of mechanical research. How does this approach correspond with the laws, methods, and techniques applied today?

Figure 2. *The figure presents the same project as shown in Figure 1, but with sectional views providing a complete representation of the internal structure of the technical solution and the geometric requirements for its components. These are, of course, not all the capabilities of modern computer-aided design software; however, the application of appropriate principles, definitions, and methods in combination with such software can further enhance the efficiency of new innovative developments, while simultaneously significantly reducing design costs and the time required for the development process*



At present, many interesting and effective inventions arise from discoveries and the systematic analysis of particular elements of living nature, which inspire and encourage inventors to develop increasingly sophisticated, comprehensive, and integrative technical solutions. Such solutions address unusual problems through unconventional methods and techniques, often derived from the principles governing the development of living systems and, owing to the capabilities of today's digital technologies, modeled and subjected to systematic simulation before the initial technical requirements and technical specifications are formulated and the inventive task is assigned.

Today, numerous examples of this kind can already be cited. Most importantly, the process of developing new methods and approaches to computer-aided design continues to evolve and expand in accordance with

the constantly increasing capabilities of computer hardware and corresponding software.

For inventors and developers, it has proved both extremely important and particularly difficult to clearly define numerous parameters and relationships, since work of this kind was being performed for the first time and no relevant preliminary developments existed.

The application of methods recommended and regulated by the applicable legislation, despite the fact that this type of integration had not been implemented in previous developments, made it possible to create a fundamentally new product that came close to achieving the Ideal Final Result.

This, in turn, immediately resolved a number of technical, innovative, and integration-related problems and made it possible to achieve complete autonomy of the object under development.

At the same time, the autonomous operating time of the object proved to be practically unlimited.

Thus, overcoming a multidisciplinary conglomerate of technical problems, combined with a certain psychological barrier, made it possible to proceed to the remaining design tasks through comprehensive, integrative, modified, and optimized methods and techniques.

The integration methodology described above, as applied to the synthesis of an innovative technical solution, is currently the focus of a range of organizational, technical, technological, scientific, and engineering activities.

To a certain extent, answers to these questions are provided by the latest methods for utilizing the capabilities and advantages of modern computer-aided design software.

Such depth and detail in engineering development, even at the preliminary design stage, make it possible to use initial exploratory versions of models to perform a complete cycle of computer modeling and simulation of the device's operating cycle, without the need to manufacture physical prototypes for testing.

Moreover, eliminating the need for a dedicated budget to verify a conceptual model can significantly reduce development time and make substantially greater resources and time available for the synthesis of innovative technical solutions aimed at developing and optimizing all project characteristics.

Within the framework of these capabilities, the system of psychological relationships between technology and equipment developers and investors also changes significantly. The fear of making a mistake is largely removed from these relationships because modeling and simulation of all processes occurring within a device make it possible not only to identify and analyze errors, but also to suggest alternative and potentially more effective directions for further project development.

For analytical consideration, let us adopt the following formulations of the laws of technical system evolution according to the modern classification:

1. Law of Completeness of the Parts of a System.

2. Law of Increasing the Degree of System Ideality.
3. Law of Displacement of the Human Being from the Technical System.
4. Law of Coordination of the Rhythms of System Parts.
5. Law of Energy Conductivity of a System.
6. Law of Uneven Development of System Parts.
7. Law of Transition from the Macro Level to the Micro Level.
8. Law of Increasing the Degree of Substance-Field Interactions.

Let us also adopt the modified classification of technical systems proposed by Aliaksandr Achapouski in his publications:

1. Technical System.
2. Local Technical System.
3. Developed Technical System.
4. Global Technical System.
5. Smart Technical System.

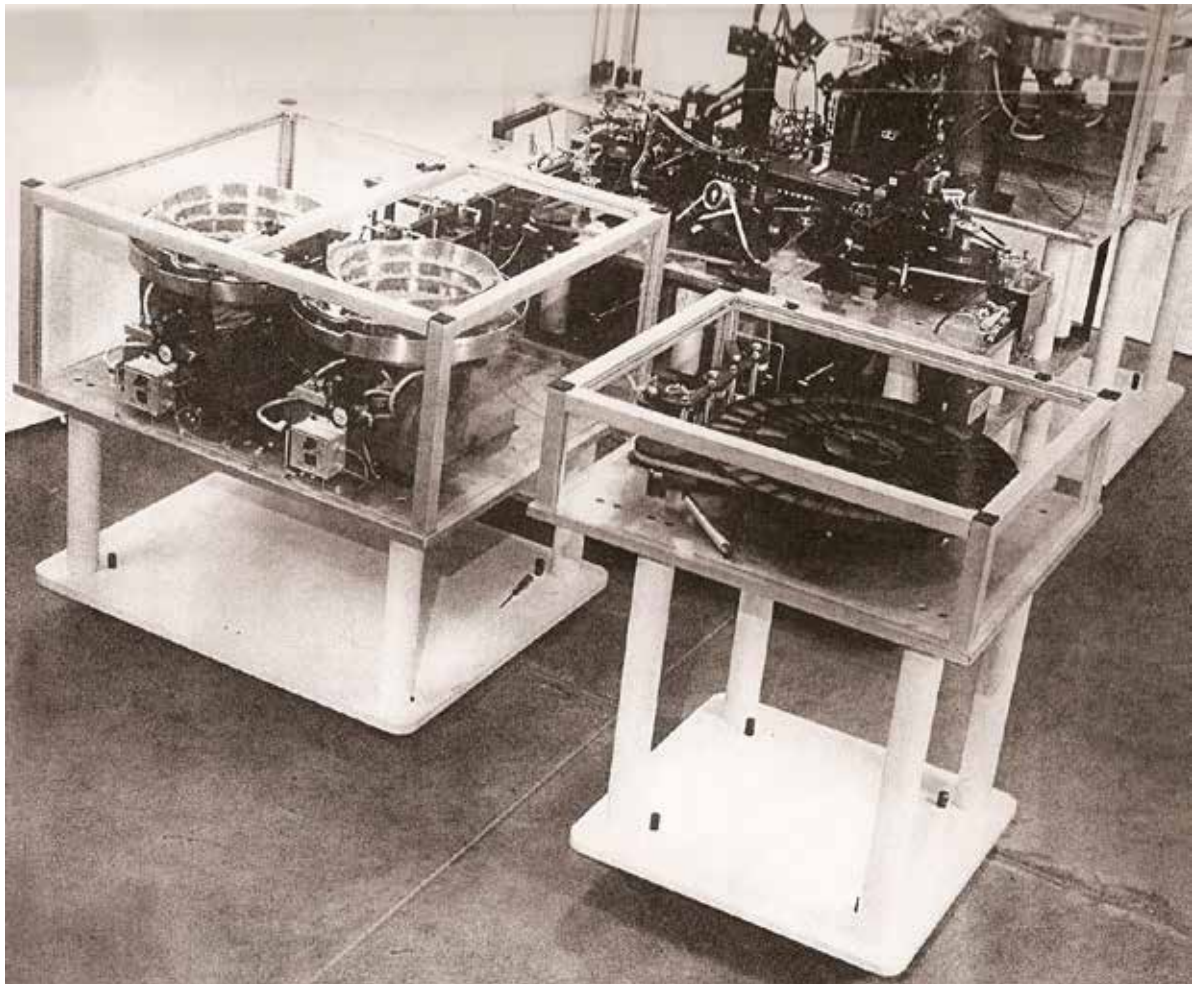
It is now appropriate to return to examples of specific contemporary developments, taking into account the above comments concerning the laws of technical system evolution, as well as the modifications to the definitions and classifications proposed in the publications of Aliaksandr Achapouski.

The operating cycle of each module is synchronized with the step (operating cycle) of the assembly module – the conveyor. This applies both to the vibratory hopper modules traditionally used in such systems (shown on the left in the figure) and to fundamentally new modules for stamping contacts and feeding them to the assembly and inspection conveyor (shown in the center).

This configuration of an automated robotic production and assembly complex can be classified as a Technical System with a fixed production cycle, in which all technological modules of the complex are synchronized with the operating step of the assembly module – the conveyor.

Within this configuration, the technological modules perform the functions of subsystems, while the assembly module – the conveyor – performs the function of the principal supersystem, with the production cycles of the subsystem modules being synchronized with its production cycle.

Figure 3. *The figure presents 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 photograph, the complex comprises four main technological modules, three of which are modules for preparing parts and components for assembly and are arranged around the assembly module – the conveyor*



As can be seen in the figure, although the assembly complex contains a considerable number of points of interaction and requirements for synchronizing production cycles, it does not incorporate any specific regulatory requirements aimed at increasing the flexibility or adjustability of the modules' production cycles.

Such a configuration is characteristic of integrated technological solutions operating with a constant working cycle that does not need to be adjusted or modified during the production process.

Accordingly, such complexes do not inherently require computerization and can operate successfully within an automated production cycle involving the mass production of standardized products.

For a Technical System performing tasks of this kind, all definitions applicable to a classical Technical System remain unchanged. The definitions and classification methods applicable to the components of such a system – the supersystem and subsystems – also remain unchanged.

With regard to the specific structure and characteristics of the automated robotic production complex, it is necessary to note certain elements of fundamental novelty in both the overall technological configuration of the complex and the characteristics of the product manufactured by it.

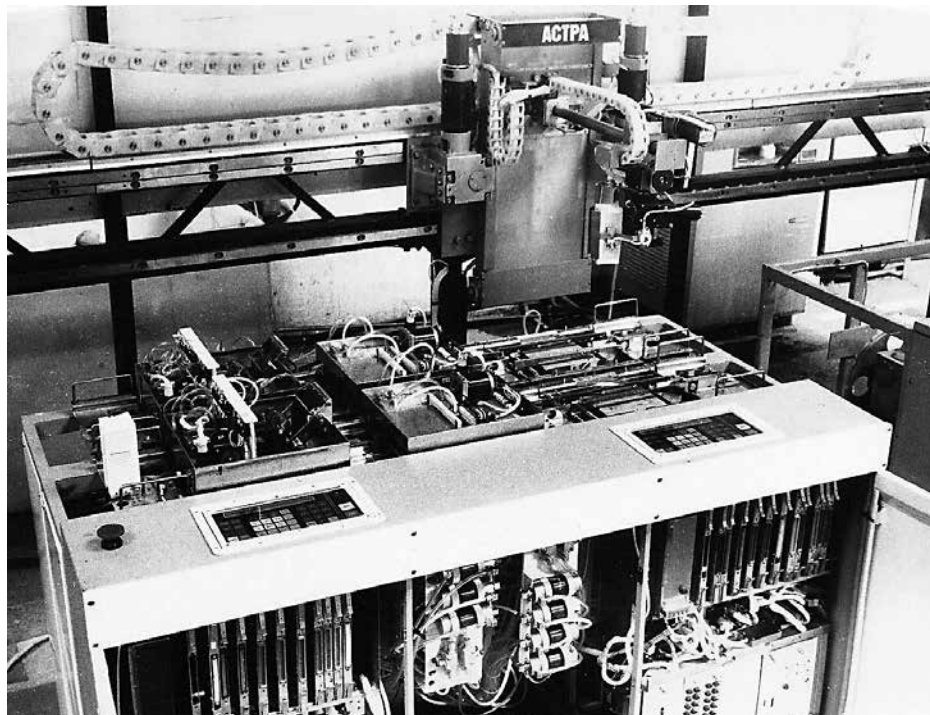
This primarily concerns the specific design and production of the contacts used in the contact blocks.

As can be seen in the figure, a strip made of a special bronze alloy with a high beryllium content is not immediately stamped into finished contacts within the stamping module. Instead, it is initially formed and partially cut along the contour of the contact. The strip is then transferred to another module, located on the opposite side of the assembly module – the conveyor – where it is finally formed into paired contacts and inserted into the corresponding conveyor cells in which the plastic components of the contact block have already been positioned.

For complexes of this type, this represents a fundamentally new technical solution that makes it possible to maintain a constant production rate for the contact blocks without requiring intermediate real-time inspection.

For the classification of a modern automated robotic production and assembly complex designed for the autonomous manufacture of contact blocks for telephone lines, the updated definitions of Technical Systems and their constituent elements, developed and proposed by the well-known researcher and innovation specialist Aliaksandr Achapouski, may be applied.

Figure 4. *The figure presents a version of a flexible photolithography processing module for thin-film microassembly substrates. The module includes two parallel technological process lines, and it should be noted that each process line is fully autonomous, including the independence of their integrated computer control systems. In addition to these systems, the module also includes a computer control and monitoring system for the robot operator, which is functionally connected to the integrated computer control systems*



The specified module comprises several closely interconnected functional technical systems, each of which can be classified as a supersystem. The combination of these systems includes loading and unloading modules, local loading and unloading units, tracks, centrifuges, dispensing and delivery units for supplying chemical reagents and photoresist to the processing zone on the centrifuge table, control systems, etc.

The track comprises several centrifuges: a processing station for surface preparation prior to coating, a processing station for electroplating, and a processing station for final treatment of the substrate after coating deposition.

The system is fully automated and is controlled and monitored by programmable processors connected to the power supply for the electroplating process, with flexible reg-

ulation of the current density depending on the coating area and thickness.

The system has two processing lines, one of which is shown in the figure. The system

is operated, regulated, configured, and monitored by means of several programmable controllers, with data, programs, and commands entered via a touchscreen interface.

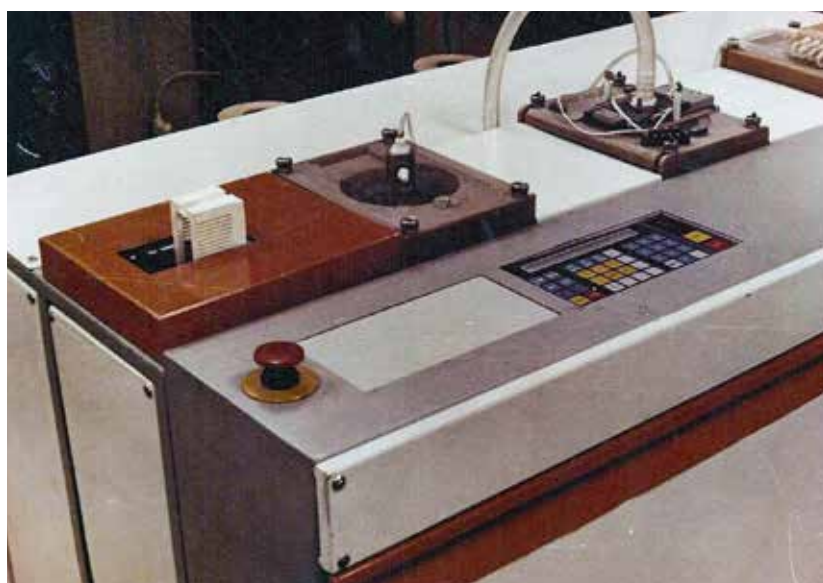
Figure 5. *The figure shows the processing track of an electroplating system for thin-film microassembly substrates. The processing track includes autonomous substrate loading and unloading units installed at the process inlet and outlet*



It should be noted that similar engineering solutions are implemented throughout the specialized process equipment used in the photolithography production line for thin-film microassembly substrates. These

solutions are based on technical systems of the same general type, with fundamental differences primarily in their software infrastructure.

Figure 6. *The figure shows an automatic electroplating system for thin-film microassembly substrates used in semiconductor manufacturing. The system consists of two process lines and provides flexible and independent control and monitoring of each line. The system is designed for integration into flexible in-line processing modules, which, in turn, can be integrated into higher-level systems*

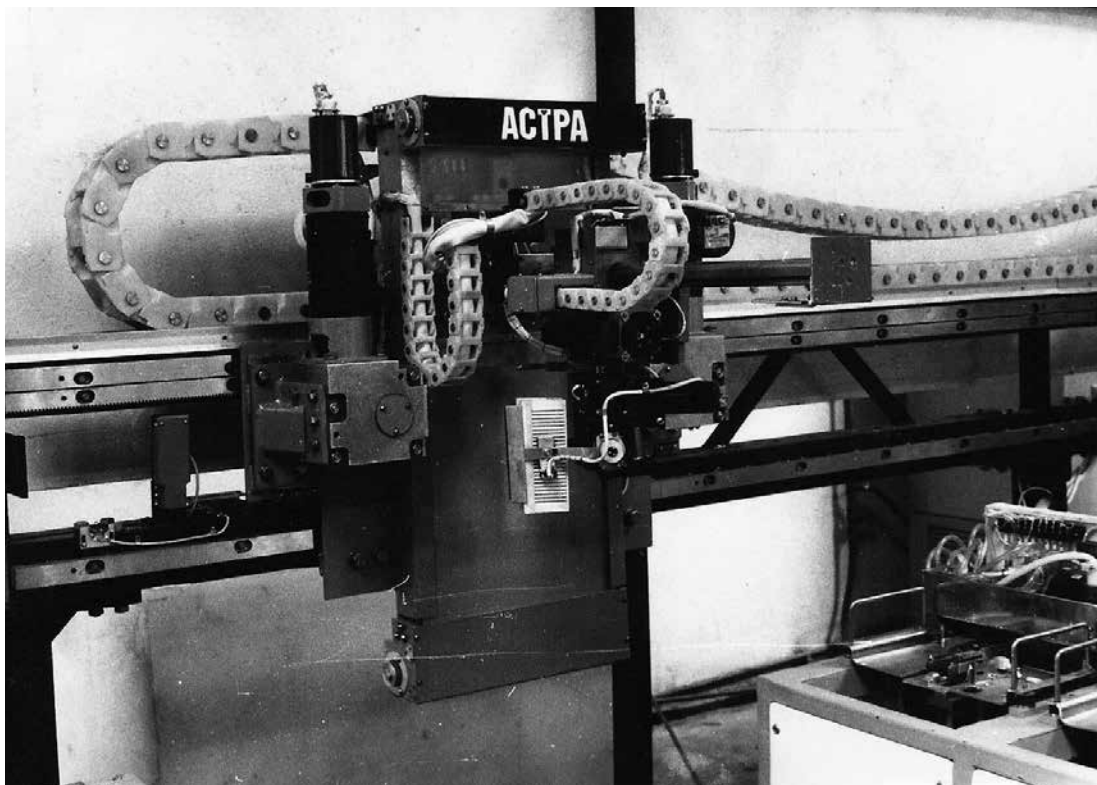


As can be seen in the figure, thin-film microassembly substrate blanks made of special-purpose ceramic material, measuring 48×60 mm, are contained in cassettes positioned at the beginning and at the end of the process line.

Thus, no operator involvement in the process is required, since all loading and un-

loading operations are performed by a robot operator, while all operations and the sequence of control commands are monitored and controlled by a programmable processor, which is accessed through a touchscreen control panel.

Figure 7. *The figure shows a flexible automated processing module viewed from the side of the input units, onto which the loading/unloading robot places a cassette containing thin-film microassembly substrate blanks*



The robot manipulator grips the cassette from a storage cell, transfers it to a position aligned with the table of the input unit, then lowers the cassette until it comes into contact with the table and secures it in position.

The combination of local technical systems shown in the figure can be classified as a combination of subsystems interconnected within a local, yet nevertheless integrated, supersystem by means of a specific flexible algorithm governing the entire integrated and sequential process: locating the cassette,

identifying and gripping the cassette, transferring the cassette, orienting its position in three dimensions, vertically aligning the cassette, identifying the cassette on the table of the loading/unloading input unit, and finally securing the cassette on the table, followed by the transfer of operational functions to the conveyor track.

All of the above operations simultaneously constitute the technical requirements for the development of the corresponding software.

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