THE SCIENCE OF "MICRONANOMECATRONICS" INTEGRATED IN RESEARCH

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I. INTRODUCTION

- **The systemic and synergetic vision of "Micro-Nano-mechatronics (μnM) and Micro-Nano-Integronics (μnI)",** that authors have developed at The National Institute of Research - Development for Mechatronics and Measurement Technique - INCDMTM Bucharest, Romania, is identified and synthesized in philosophical essence in the **triad research - production – capitalization, by:**
  - capacity, competitiveness and credibility;
  - technical contributions and innovative and efficient technology;
  - systems / micro-nano-systems and equipment / micro-nano mechatronics equipment and high-tech integronics;
  - maintenance, traceability and dependability;
  - accuracy, fidelity and resolution, highly accurate;
  - hyper-integrated hardware, software and informatization;
  - assessment, diagnosis, monitoring and decision;
  - management coordination and management of high performance

- **The new concepts and advanced solutions of μnM & μnI** [1]applied intelligent mechatronic engineering measurement and integronics are **synergistically integrated in the "mixes of engineering techniques and adaptive generation" based on the accumulation of knowledge and discovery of new and used interactive and productive organic products and high-tech systems, based on modeling, expertise, self-diagnosis and self-regulation in intelligent manufacturing management, coordination and decision.**
- **As purpose and development at a micro and nano scale of** Mechatronics and Integronics - **Micro-Nano-Mechatronics (μnM) and Micro-Nano-Integronics (μnI) represents the conception of multidisciplinary engineering as a complex, advanced and hyper-integrated field of advanced intelligent hybrid systems of manufacturing and full control, and** as a scientific discipline, **a multi-disciplinary compendium of technical and technological mixes.**

- In research, **μnM** and **μnI cover** a great deal of areas of applications, such as:
  - advanced and competitive products / systems;
  - intelligent instrumentation;
  - intelligent manufacturing;
  - integration of computers and intelligent devices;
  - intelligent processes integrated intelligent;
  - materials and micro-nano-materials technology;
  - technical testing and diagnosis;
  - signal processing and information technology;
  - etc.
  - **In the manufacturing of products / intelligent** systems, **μnM and μnI,** are based on the one hand on multidisciplinary, auto-adaptability, flexibility and high working speed and on the other hand, on high complexity with high degree of integration and improved artificial intelligence.

  As a result of advanced technological development, Mechatronics **(M)** and μnMecatronics (μnM) have become a philosophy that marked a leap from sequential Mechatronics engineering to simultaneous or concurrent Mechatronics engineering.

- Moreover, **Mechatronics[2]** is defined simply as **intelligent machines science and** its extension to other areas is known as: **hydronic** in the field of intelligent hydraulics, **pneutronics** in the field of intelligent pneumatics, **thermotronics,** in the field of thermal technique, autotronics, in the field of intelligent automotives, a**grotronic** in the field of intelligent agriculture, etc..
- **The innovative vector Mechatronics (M)** & **Micro-Nano Mechatronics (μnM) - μIM & μnM [3],** is the **essence of our concept, synergy complex structures engineering in a combination and mix-integration of engineering / micro-nano-engineering, precision mechanics, micro-electronics engineering / nano-engineering engineering / micro-nano-computer science engineering (hardware and software), all in an architectural design with materials engineering / materials micro-nano-engineered, technology engineering / technology micro-nano-engineering, bio-systems engineering / micro-nano-bio-systems engineering, etc.**

- **Mechatronics as a whole has** great interest in applying micro-nano-integration mechanisms similar to those inspired by biology, micro-nano-robots, autonomous micro-nano-systems, etc. which architecture in **"Integrative Mechatronics - MI",** new concept patented by the authors.
- This new science, **" Integrative Mechatronics - MI Galaxy Science "** makes the transition to **Integronics (I)** and evolutionary / generative, to **Micro-Nano-integronics (μnI).** Besides **" Integrative Mechatronics - MI"** may be considered in the designed patent as a **"integronics in technology vision,"** the integration of hardware and software integration, opening up unexpected horizons in all areas due to the synergistic effect.
- A first application of **"Integrative Mechatronics"** and human adapted, **denominated " <<Human Adaptronic Integrative Mechatronics>> Galaxy Science (**fig. 1), is a complex of functions and human-machine interface for improving and fulfilling operational human skills.

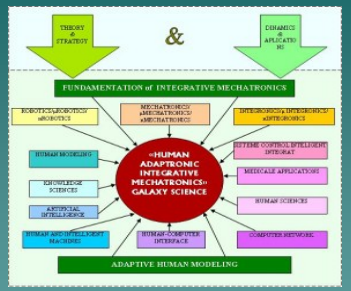


Figure 1

- **In the research and its application, <<Human Adaptronic Integrative Mechatronics>> Galaxy Science** has areas of applications, such as:
- human modeling and dynamics of an intelligent machine in environments with constraints;
- simulation and identification of psychological and physical characteristics of the human user;
- methodologies and integrated intelligent control to simulate human behavior and human operation;
- other medical applications adapted to humans.
- **The integrated mechatronics education** shall ensure flexibility in action and thought by addressing its principles: the development of systematic thinking and teamwork training.
- **The adaptronic concepts** of <<Integrative Mechatronics>> and **<<Human Adaptronic Integrative Mechatronics>> Galaxy Science** include mainly:

- **multidisciplinary combination of** intelligence & control integrated with computer science and human interaction – intelligent machines;
- **holistic hybrid applications in** medical, engineering, diagnostic services, etc;
- **hyper-integrated and advanced knowledge,** in intelligent knowledge sciences, medical robotics, human-computer and computer-human interaction, network monitoring, intelligent control systems, etc.
- **skills** of the uncertainties within the system, the handling of uncertainties in the real world and variable over time, on topics inspired by biological systems;
- **etc.**
- **Through a unique conceptual vision,** of generation development and evolution of <<Integrative Mechatronics>> and **<<Human Adaptronic Integrative Mechatronics>> Galaxy Science**, a new **polyvalent science <<integronics - I> >** was designed and patented.

- Bearing in mind the indissoluble unity of the world and the need of a unique insight into this world, INTEGRONICS - I, is the science of integration processes and hyper-integrated systems as the human body and human knowledge are.
- Compared with systems theory and cybernetics that study ready-made systems, INTEGRONICS - I, regardless of how the systems are established and developed.
- Thus, INTEGRONICS brings into focus new solution of integration and hyper-integration, such as genetic integration, integration by addiction, integration by choice, etc.
- The innovative vector INTEGRONICS - I & Micro-Nano-Integronics – μnI, VII & μnI, is the essence of our concept, "the perspective of evolutionary generation and integration of hyper-integrated mechatronics and adaptronics into a holistic structure of mix-engineering completely integronized and into a conception of integrated systems, totaling constructive - functional – decision solutions, similar to the human body, behavior and expression of intellectual, physical, moral and socio-human stated and evolving into a global vector innovative vision "Integronics (I)" - Micro-integronics (μI) and Nano-integronics (s) ".

- **The innovative concept Integronics, Micro - integronics (μI) and Nano-integronics (s),** patented by the authors, **already applies** at The National Institute of Mechatronics and Measurement Technique - Bucharest, Romania, integronic products and systems implemented in industry, especially in the **automotive industry, sintering laser technology, the metrology industry, etc..**
- In this application field, **"Integronics technique"** and the evolving forecast and generation of **"micro-nano-integronics technology",** they are found in various constructive solutions with integrated design / realized and capitalized, with hybrid integration of sensorics / micro-nano-sensorics, robotics / micro-nano-robotics, micro-electro-mechanical systems (MEMS) and nano-electro-mechanical systems (NEMS), human-computer interfaces, data integration and algorithms, modeling / analysis and integrated control, etc..

- **The integrated concept "I, μI & nI"**, includes **hardware and software of the advanced logical structure of the following fields: mechatronics, computer science, robotics, intelligent materials, control and management systems, logistics, decision-making, environmentally friendly behavior, social, psychological, economic and financial behaviour control exercised in a higher fuzzy neural network of microprocessors and micro-nano-processors and software integrated banks.**
- **The further forecast of "I, μI and nI",** supposes, in conception of the authors, in a predictive environment, the following issues:
  - **Research and development** of the super advanced integrated and holistic field;

- **Intelligent Integronic production;**
- **Hyper-advanced products / systems**;
- **Integronized Information Society;**

- **The Advanced Sciences,** on **Mechatronics** and evolving generation of **Micro-and Nano-Mechatronics Mechatronics** and **Integronics"** in evolution generation, **Nano-Micro-Integronics" and Integronics" started in concept and application are compatible with Europe 2020 and European Strategy 2030**, the fundamental processes **of nano-sciences and nanotechnologies,** the European Programmes: FP7 (2013), FP 8 (2020), FP9 and FP10 (2030), on **European research and innovation and European education.**

II. INTEGRONIC MECHATRONIC SYSTEMS AND EQUIPMENT AND HIGH-TECH INTELLIGENT MEASUREMENT AND INTEGRATED CONTROL OF PARTS IN THE AUTOMOTIVE INDUSTRY

- **The concept of integrated intelligent technologies for** systems / high-tech mechatronic and integronic equipment, is based on the modular structure, a mix of new engineering solutions and techniques (fig. 2).

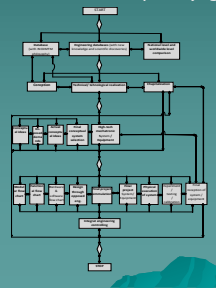


Figure 2

- The development of integrated intelligent mechatronic technologies in the automotive industry by the design of the "INCDMTM philosophy " based on the mix of new adaptive and generative engineering concepts and techniques, is based on the specialization of the " engineer in mechatronics", presently and / or in the future of the "engineer in integronics", a specialization that has emerged in Romania in late 1996, and respectively in 2001, although on the global market, it has emerged in 1978 (in Japan), and respectively in 2000 in Japan.
- Currently, the specialization as an engineer in mechatronics, however, is for university and postgraduate training in the main technical universities in Romania (Bucharest, Cluj, Timisoara, Brasov, Iasi, Targoviste, Sibiu, Suceava, Bacau, Galati, Craiova, etc..), the synthetic preparation through a synergistic and integrative knowledge of several disciplines such as precision mechanics, electro-technique, electronics and informatics, after which the specialization as an engineer in integronics has emerged both as university training, postgraduate training and as preparation synthesized by a multi-integrative system of technical knowledge, science and humanities, this technical training in centers and universities in both in their R&D centres and at the National Institute of R&D for Mechatronics and Measurement Technique.

- **Examples of intelligent and integrated technologies and equipments** in the automotive industry in Romania:
  - **Intelligent Mechatronic technology and equipment for diameter and axial quotas control of the cranckshaft** (fig.3)

Figure 3

Technical and functional characteristics:
Duration of measuring cycle: max. 50 sec.;
Display resolution: 0,001 mm;
Measuring transducers: 24 pieces/ZDB103 /lap ±1 mm;
Industrial computer: CMZ 200 ETAMIC / 220 V.c.a/50 Hz;
Interface mechanical device-Central: ETAMIC SATELITE;
Working programmes: OS: Windows/Measuring programmed by INCDMTM Bucharest;

Structure:
CMZ 200 ETAMIC Central with a SMD Satellite Module;
Basing and control mechanical systems.

- **Intelligent mechatronic technology and equipment for tightness control at the „engine cylinder head assembled F8Q”** (fig. 4)

Figure 4

Technical and functional characteristics:
Supply tension: 220V/50 Hz;
Air pressure supply: 6 bar;
Work pressure (regulated by the machine regulator): 5 bar;
Tightness control pressure: 1 bar;
Admitted tightness loss: 25 cm3/min;
Cycle time: 30 sec.
Structure:
Framework;
Piece basing system;
System of displacement of the piece in the measurement position;
Closing-tightening system of the piece with pneumatic cylinders;
Marking system;
ATEQ cell;
Pneumatic panel;
Electronic panel;
Wenglor non-material barriers.

- **Mechatronic intelligent machine for tightness checking (air-air) gear casing JHQ, JRQ – ROUGH** (fig. 5)

Figure 5

Operation
The machine has an automatic work cycle;
The intelligent measuring program is setting for the testing piece;
The piece is set inside the machine, on the tightening plate;
Press the START-Button;
The piece is fixed on plate with the toggle-clamps;
The carriage move the piece in the testing position;
The pressure subassemblies push the piece on the tightening plate;
The tapered and clamping subassemblies pressurize the bores of the piece;
The ATEQ-cell introduces air in the obtained cavity of the piece (0,2 bar);
The machine verifies the air loss (admissible air loss less then 0,15cm3 /s);
If the piece is good it’s automatically marked;
The machine is protected with immaterial barriers against the intruders over the function, in the work space.
Technical Features:
electrical supply: 220 V.a.c./50 Hz;
pressure supply: 6 bar;
work pressure: 5 bar;
tightness test pressure: 0,2 bar;
admissible air loss: 0,25 cm3 /s;
accuracy: ± 0,02 cm3 /s;
work time/tour: ~ 40 sec/piece

- **Intelligent mechatronic unit for tightness checking (air-air) case timing H5 (machined) – export Portugal** (fig. 6)

Figure 6

Operating mode:
One of the pieces is placed in the unit on the carriage tightening plate.
On set the measurement program.
On push the START button; the signalization lamp must be light.
The carriage transports the piece in the testing position.
The pressing subassemblies press the piece on the tightening piece.
The tapered and the clamping subassemblies pressurized the bores of the piece.
The ATEQ-cell is putted in action and it realizes the filling of a circuit with pressure air, the stabilization and the measurement of the air losses. If the value is good on initiate the filling of the other circuit.
If the values of the both circuits are good, the piece is automatically marked.
After the marking, the action elements will be driven in the opposite direction.
On the end of the cycle the signalization lamp is on, the piece is removed from unit and the another piece will be verified.
The machine is protected with immaterial barriers against the intruders over the function, in the work space.
Technical Features:
electrical supply: 220 V.c.a./50 Hz;
pressure supply: min. 6 bar;
work pressure: 4,5 bar;
tightness test pressure: 1 bar;
admissible air loss|:
3,6 cm3 /min on Low-Pressure circuit;
12 cm3/min on High-Pressure circuit ;
work time / tour: ~ 40 sec/piece.

III. SELECTIVE LASER SINTERING ADVANCED SYSTEMS AND INTEGRONIC TECHNOLOGY FOR INTELLIGENT MICRO-NANO-SYSTEMS

- **Selective laser sintering** (Fig. 7) is an additive manufacturing technology for ultra-precise fusion by melting metal powder (Direct Metal Laser Sintering), in parts / assemblies with the desired 3D shapes by scanning a cross-sectional image generated by a 3D three-dimensional descriptive model (a Computer Aided Design CAD file or scan data from 3D) [5] surface of powder bed, each cross section, it is scanned, the powder bed is lowered by the thickness, a new coating material is applied and the process repeats until the piece / subassembly is completed.

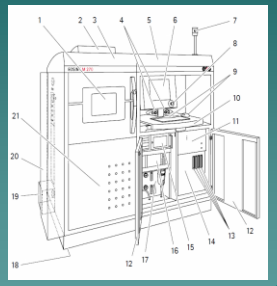


Figure 7

Legend:

1. Processing chamber
2. Scanner lid
3. Left hood of the optic system (only for EOS staff)
4. Only in the installation Xtended module: Unblock key
5. Right hood of the optic system (only for EOS staff)
6. Display
7. Only in the installation Xtended module: Signaling lamp
8. AVARY STOP key
9. Keyboard and mouse
10. Operation table (pivot)
11. Laser
12. Front door
13. Only in the installation Xtended module: Protective gas passing indicator
14. Only in the installation Xtended module: Protective gas command unit
15. Process computer
16. Final motor steps
17. Pneumatic maintenance unit
18. Antistatic carpet connection
19. Cable shielding
20. Control cabinet
21. Mountain front cover (only for EOS staff)

Figure 1

Figure 2

Figure 3

- **The laser sintering process for micro-nano-systems and mechatronic systems** in the design, realization and capitalization phases is depicted in figure 8.

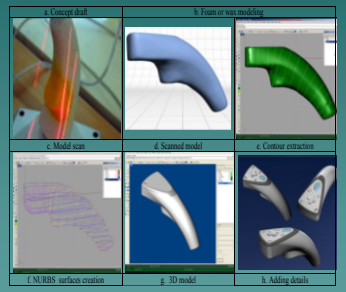
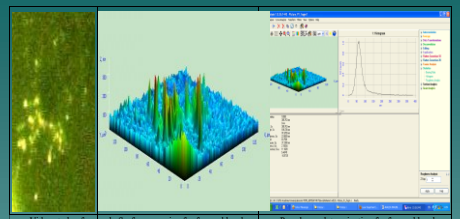


Figure 8: Laser sintering of micro-systems

IV. HIGH-TECH SYSTEMS AND INTEGRONIC MICRO-NANO-TECHNIQUES FOR SURFACE TOPOGRAPHY

- **The High-tech systems and integronic micro-nano-techniques for surface topography** are made and applied in industry and metrology **for the study, scanning and measuring of surface topography and micro-nano-geometry [4].**
- As high-tech integronic systems used in the testing and experimentation of surfaces, one integronic system highlights, that shows the measured profile and micro-nano-roughness and atomic force microscopy.
- As integronic micro-nano-techniques used by authors in testing and experimentation processes of micro-surface topography there are nano-techniques of visual study, the scanning surface and / or micro-nano-roughness determination techniques basing on image processing and analysis of surface topography at micro and nano scale.

- The testing and experimentation of surface topography at micro and nano scale were achieved in intelligent MEMS and NEMS laboratories by mechatronic and integronic systems on different areas of benchmarks in various field: precision mechanics, automotive industry and optical and medical devices.
- With the <<**atomic force microscope**>> the **micro-nano-roughness of surfaces of the femoral heads of hip prostheses was determined.**
- They were used by patients with 10 to 15 years and now is doing research in order to improve the hardness of materials which are produced in these prostheses.
- Prostheses used in these studies, for characterization using atomic force microscopy, are from stainless steel.
- After the characterization of thin films filing is intended to improve the hardness of prostheses and thus extend their use.
- Using atomic force microscopy, femoral head surfaces were scanned and were configured in 3D by video camera.
- By using software to obtain micro-nano-roughness surfaces, was made at a resolution of 1 nm by video.
- Testing and experimentation results are presented in Fig.12 and Table 1.



a. Video study of femural heads surfaces	b. Surface scanning for femural heads surfaces	c. Roughness determination for femural heads surfaces

Figure 12: Surface topography micro-nano-technique: femural heads images analysis

Length of the measured piece	Micro-nano-roughness
1	2
(140x140) µm x 150 nm	21,24 nm
(100x100) µm x 100 nm	15,62 nm
(140x140) µm x 300 nm	39,99 nm
(130x130) µm x 300 nm	27,069 nm
(70x70) µm x 140 nm	24,27 nm
(120x120) µm x 100 nm	15,5967 nm
(75x75) µm x 155 nm	20,280 nm
(75x75) µm x 150 nm	33,370 nm
(180x175) µm x 75 nm	27,224 nm
(65x65) µm x 50 nm	15,4472 nm
(90x90) µm x 25 nm	80,865 nm

V. CONCLUSIONS

- The paper "The Science of <<Micro-Nano-Mechatronics>> Integrated in Research", highlights new concepts and shows results obtained in this field, including:
- Development trends in the present and future of the new sciences <<Micro-Nano-Mechatronics>> in generative evolution to the science of <<Integronics-Micro-Nano-Integronics>>;
- New concepts / techniques and methodologies specific to the high-tech fields <<Micro-Nano-Mechatronics and Micro-Nano-Integronics>>;
- New achievements of mechatronic / integronic and micro-nano-mechatronic and micro-nano-integronic products, systems and technologies;
- New directions of application of research results in the advanced fields of micro-nano-mechatronics and micro-nano-integronics.