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Erasmus+ Programme Key Action 2 Cooperation Partnerships
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Agreement number 2023-1-RO01-KA220-HED-000155412
European Network for Additive Manufacturing in Industrial Design for Ukrainian Context

AMAZE

ADVANCING INDUSTRIES: POLYMERIC MATERIALS IN ADDITIVE MANUFACTURING

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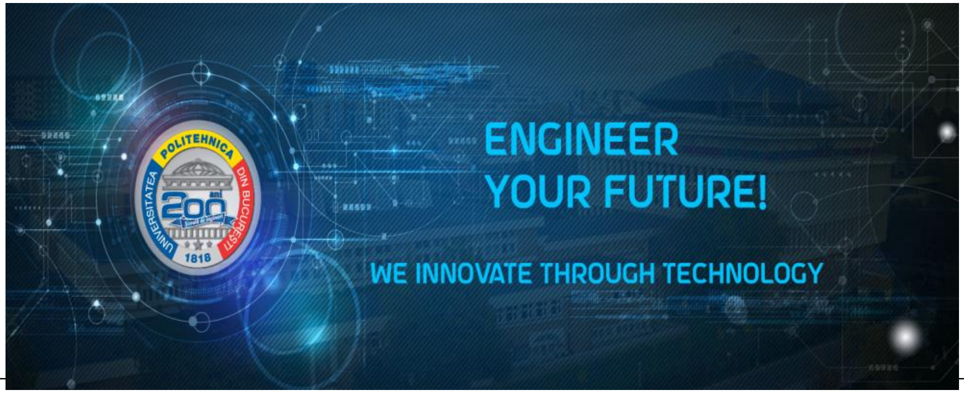
AMAZE Multiplier Event 2 (ME2), Advanced Research Methods for Additive Manufacturing in Industrial Design
Bucharest, 18.06.2024



National University of Science and Technology POLITEHNICA Bucharest

http://www.upb.ro/en/

POLITEHNICA Bucharest is the oldest and most prestigious engineering school in Romania, with a tradition of 200 years made possible by the efforts of some of the greatest Romanian professors, its specificity relies in creating knowledge through research and technological innovation, as well as through its implementation by means of education and professional training at a European level.

Politehnica Bucharest is formed by different faculties, classrooms and laboratories are distributed in 4 distinct residences:

Polizu – Strada Polizu, nr. 1-7, sector 1
Noul Local– Splaiul Independenței, nr 313, sector 6
Leu – Bulevardul Iuliu Maniu, nr. 1-3, sector 6
Pitesti Campus - Str. Targul din Vale, nr.1, 110040 Pitesti, Arges, Romania

National University of Science and Technology POLITEHNICA Bucharest

The main mission of POLITEHNICA Bucharest is to train an engineer capable of adapting to the requirements of market economy and new technologies, with an economic and managerial knowledge and promote the principles of sustainable development and environmental protection. To do this, he must be formed according to the modern principle of direct participation in choosing his formative trajectory and to be included in a learning process that will give him real chances to compete on the labour market.

POLITEHNICA Bucharest has the mission to bring together education, training and scientific research. The role of this intersection is to increase knowledge and innovation, two key concepts of knowledge-based economy and society.

APMG Advanced Polymer Materials Group

ADVANCED POLYMER MATERIALS GROUP POLITEHNICA BUCHAREST, ROMANIA http://www.apmg.pub.ro/

4 main research labs:

Laboratory for Polymer-based Nanocomposites Synthesis (and General Polymer Synthesis)

Laboratory for Advanced Chromatographic and Spectroscopic analysis (GPC, FTIR, FT Raman, Dispersive Raman, Confocal RAMAN, X-ray Photoelectron Spectroscopy)

Laboratory for Thermal Characterization (DSC, TGA, DETA, DMA, combined DSC-TGA-FT Raman)

Laboratory for Polymer Processing and Mechanical Characterization (FDM-DLP-SLA – 3D Bioplotter, tensile, compression, impact, hardness, rheometer, melt flow index, extruder, injection, AFM, nano-FTIR coupled with AFM) and collaborates with other labs in the University (SEM, TEM and XRD).

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ZAHARIA POLYMER GROUP

Assistant Prof.
Ionut-Cristian Radu

Erika

Derniza

POLYMERS AND POLYMERIC MATERIALS

Polymers are macromolecules formed by the chemical bonding of large numbers of smaller molecules, or repeating units, called monomers.

Monomers bonded together in two, three, and four are called dimers, trimers, and tetramers, respectively, and these short repeating units are further called oligomers.

The simplest form of polymer is one that is made up of only one type of monomer (a homopolymer).

Copolymers are composed of monomers that differ from one another. The degree to which they differ – either by structure or composition – and the quantities of each type of monomer relative to one another in the same polymer molecule ultimately determine that material's chemical and physical properties.

POLYMERS IN 3D PRINTING / ADDITIVE MANUFACTURING

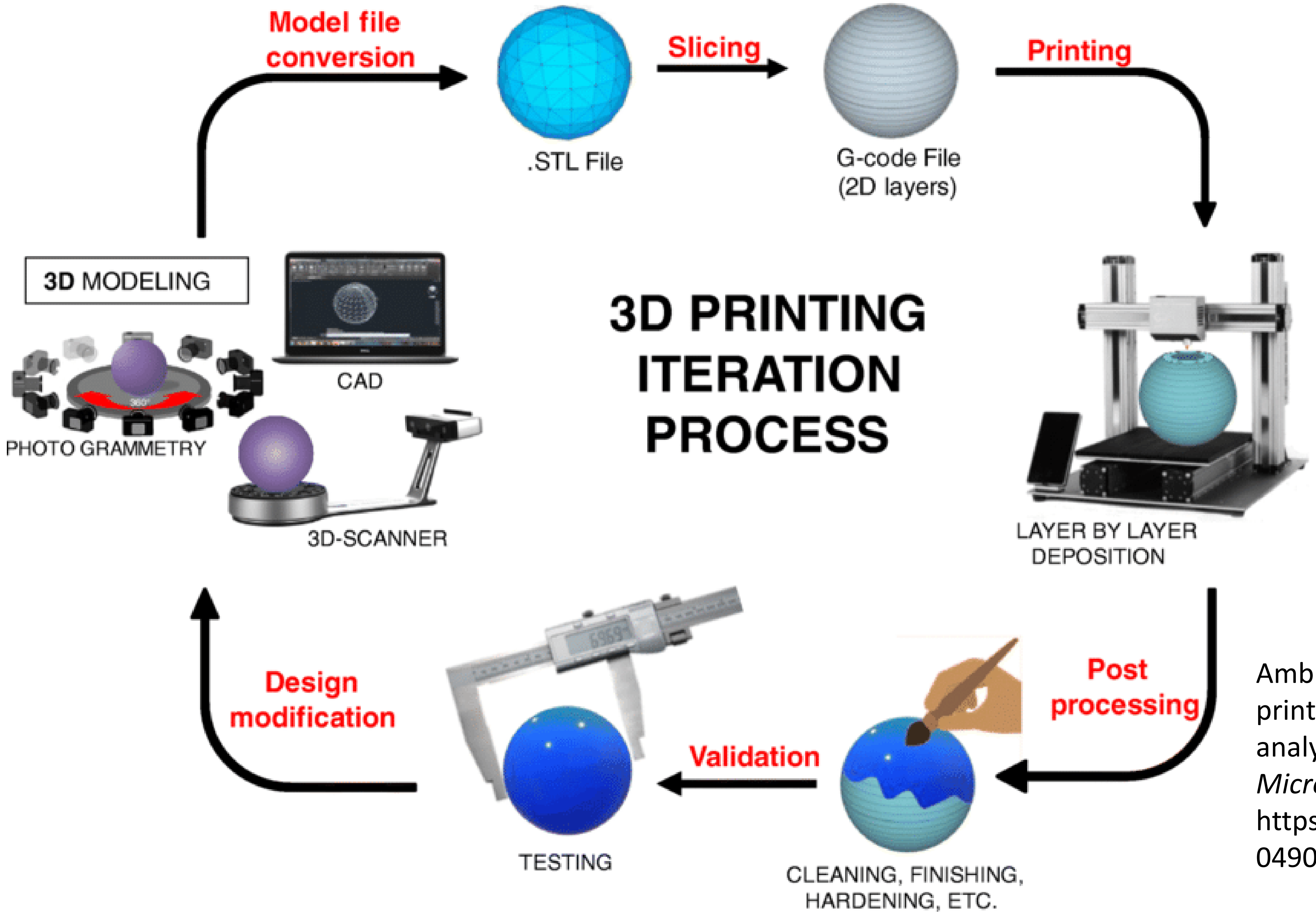
Polymer 3D printing has developed in recent years with many areas of research now translating to engineered products, especially in medical fields.

3D printing is a nice fabrication approach as it enables products with complex geometries and architectures that are not possible with conventional manufacturing processes.

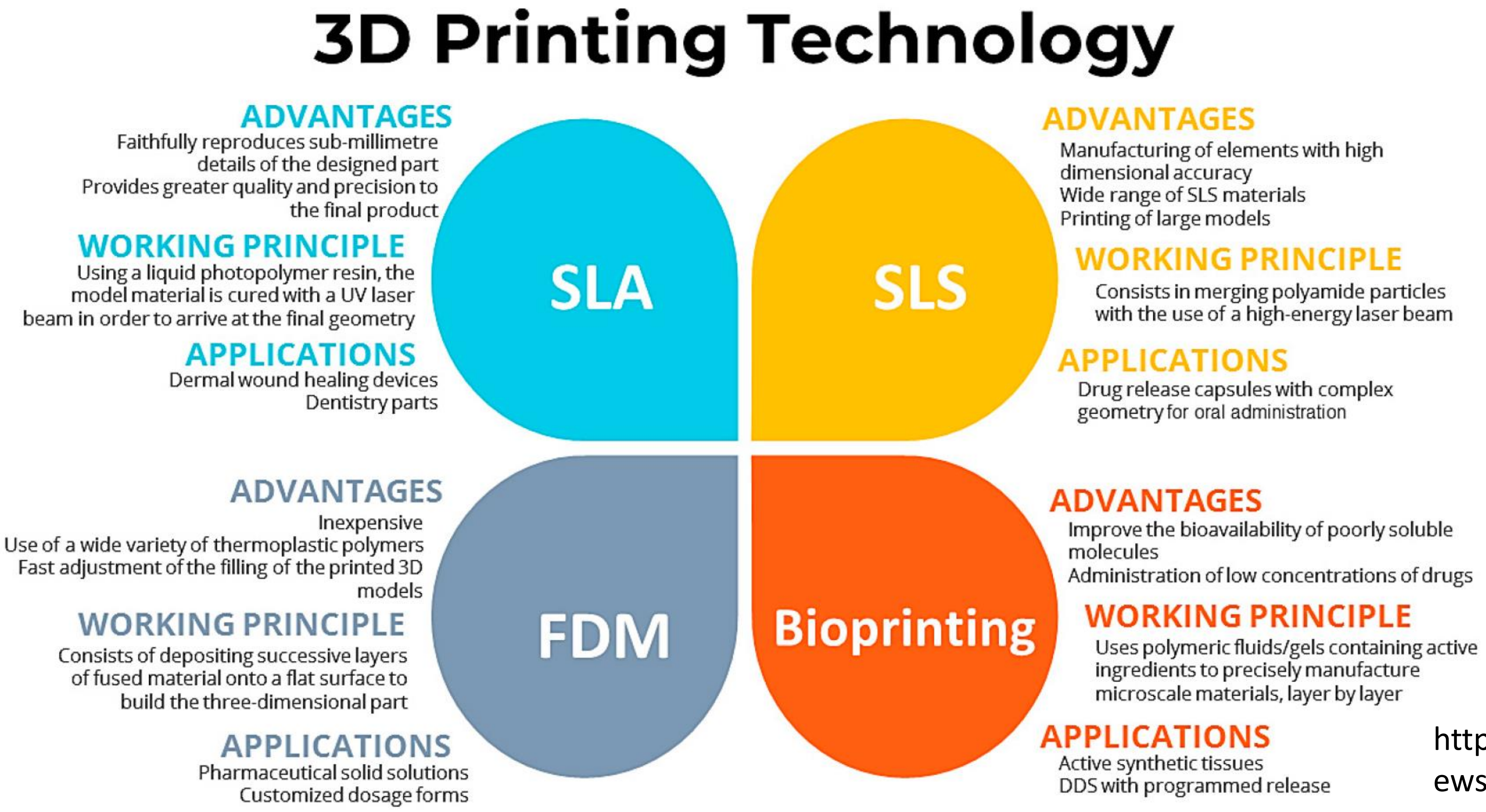
Polymer printing is possible using extrusion, resin, and powder 3D printing processes.

Types of polymers: **PLA, ABS, ASA, PP, PMMA, HIPS -** common plastics; **PC, PA, PET, TPU, TPE, TPC** (thermoplastic co-polyesters), **PETG** - engineering plastics; **PEI, PEEK, PEKK, PVDF, PPSU** - high-performance plastics.

PEI - Polyethylenimine; **PEEK** - Polyether ether ketone; **PEKK** - Polyetherketoneketone; **PVDF** - Polyvinylidene fluoride; **PPSU** - Polyphenylsulfone.



Ambrosi, A., Bonanni, A. How 3D printing can boost advances in analytical and bioanalytical chemistry. *Microchim Acta* 188, 265 (2021). https://doi.org/10.1007/s00604-021-04901-2



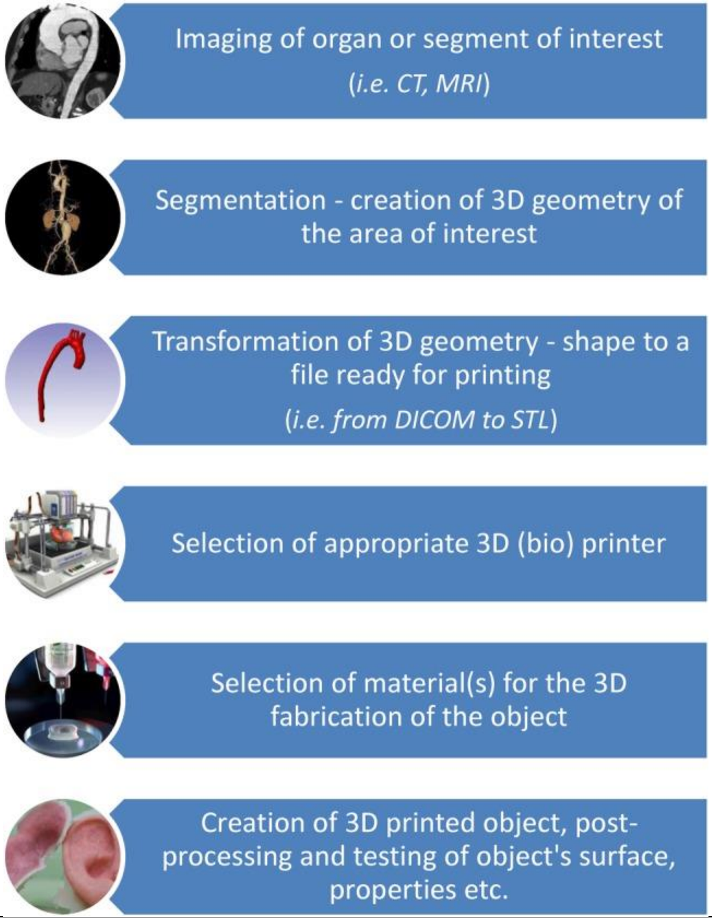
https://www.pharmaexcipients.com/news/3d-printing-techniques/

3D BIOPRINTING / BIOFABRICATION

Biofabrication is defined as "the automated generation of biologically functional products with structural organization from living cells, bioactive molecules, biomaterials, cell aggregates such as microtissues, hybrid cell-material constructs through bioprinting or bioassembly".

Groll J, Boland T, Blunk T, Burdick JA, Cho DW, Dalton PD, Derby B, Forgacs G, Li Q, Mironov VA, Moroni L, Nakamura M, Shu W, Takeuchi S, Vozzi G, Woodfield TB, Xu T, Yoo JJ, Malda J. Biofabrication: reappraising the definition of an evolving field. Biofabrication. 2016 Jan 8;8(1):013001. doi: 10.1088/1758-5090/8/1/013001. PMID: 26744832.

Lee JM, Sing SL, Zhou M, Yeong WY. 3D bioprinting processes: A perspective on classification and terminology. Int J Bioprint. 2018 Jul 3;4(2):151. doi: 10.18063/IJB.v4i2.151. PMID: 33102923; PMCID: PMC7582007.



The progress in 3D bioprinting has been largely driven by the global shortage of available organs necessary for the repair or replacement of damaged or failed organs and tissues. The most complex and demanding applications for engineered tissues encompass skin, cartilage, hard tissues like bones, cardiac tissue, and vascular grafts.

Papaioannou TG, Manolesou D, Dimakakos E, Tsoucalas G, Vavuranakis M, Tousoulis D. 3D Bioprinting Methods and Techniques: Applications on Artificial Blood Vessel Fabrication. Acta Cardiol Sin. 2019 May;35(3):284-289. doi: 10.6515/ACS.201905_35(3).20181115A. PMID: 31249458; PMCID: PMC6533576.

3D bioprinting involves the precise, layer-by-layer placement of biological components, biochemicals, and living cells, achieved through spatial control over the positioning of functional elements within the constructed 3D structure.

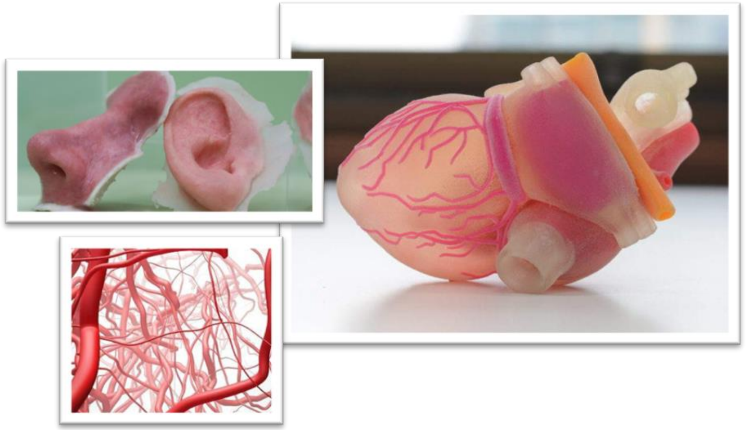
There are three core methodologies in 3D bioprinting: ***(i) biomimicry or biomimetics, (ii) autonomous self-assembly, and (iii) mini-tissue building blocks***.

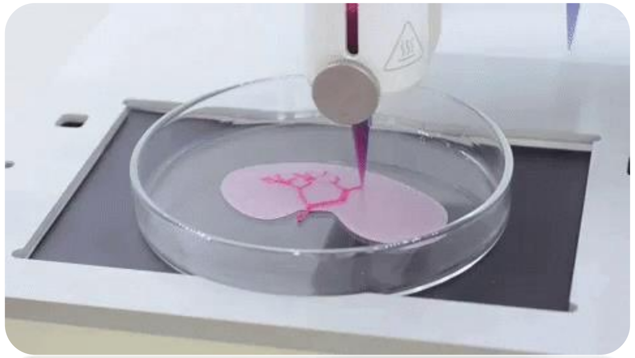
Biomimicry or biomimetics is defined as the process of studying nature, its systems, processes, and elements, to have inspiration and solutions for addressing human challenges.

Autonomous self-assembly is a process that replicates a specific organ or tissue in vitro. Early cellular components of developing tissue produce extracellular matrix components and appropriate cell signals that lead to the autonomous organization and patterning of the desired tissue. Using autonomous self-assembly, it is feasible to use cells for histogenesis and to modulate the composition, localization, and functional and structural properties of the tissue.

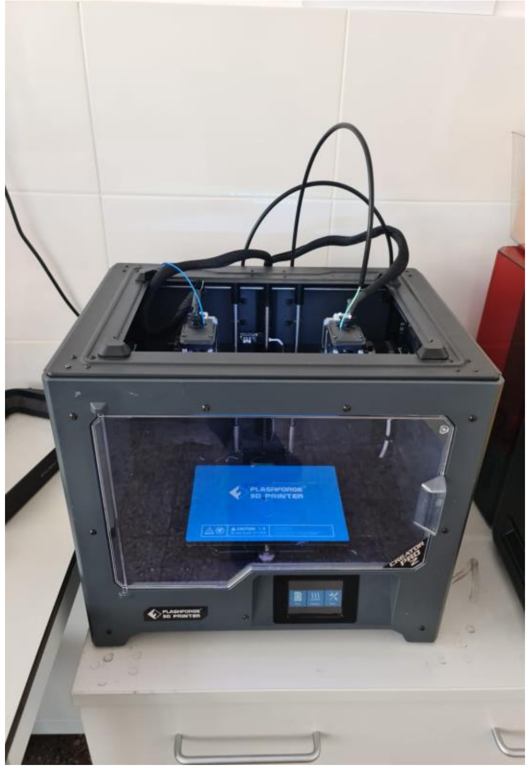
Ultra performance 3D bioprinter at POLITEHNICA Bucharest

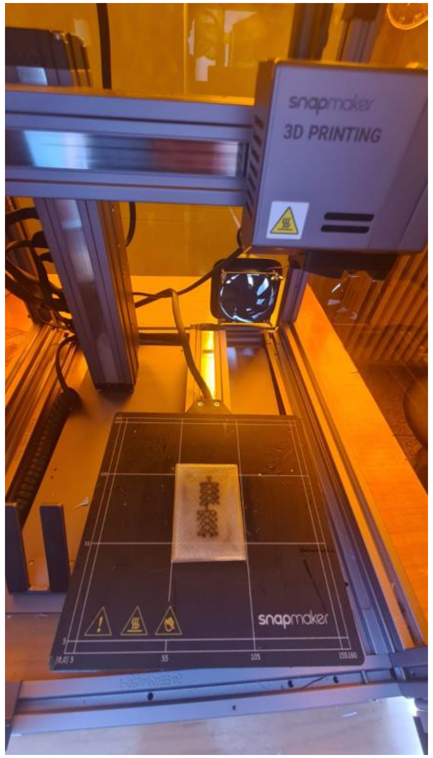
- ✓ Natural and synthetic 3D structures
- ✓ Cells incorporation
- ✓ Bioconstructs that stimulate the architecture and properties of biological tissues



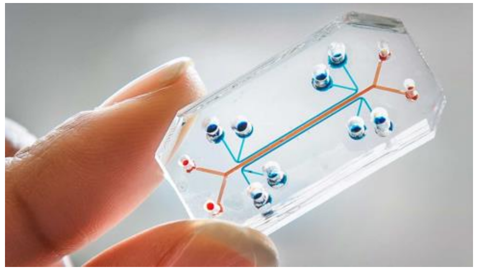


APMG FACILITIES IN ADDITIVE MANUFACTURING





ORGAN ON-A-CHIP (OoC) DEVICES

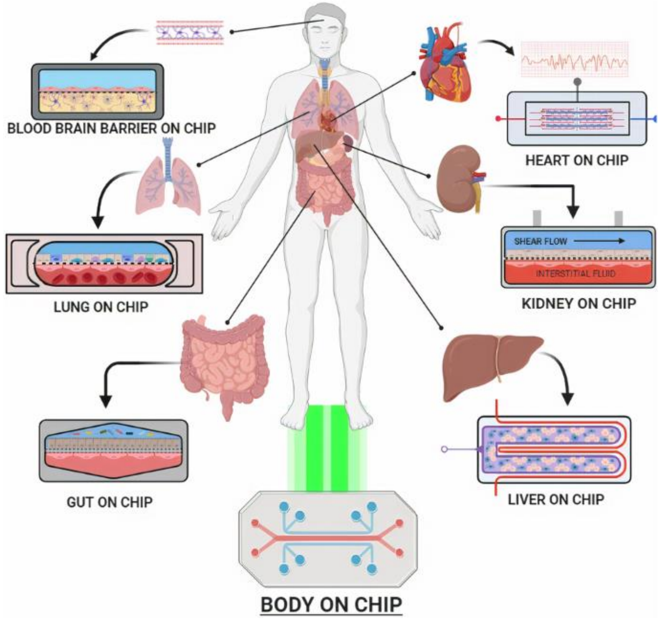


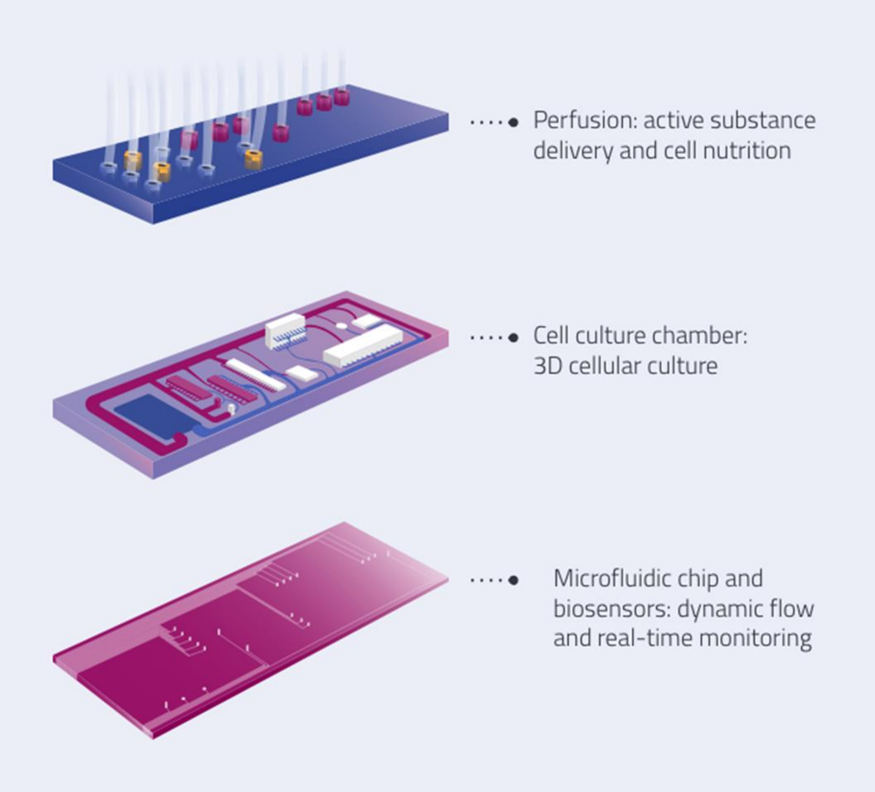
OoC is a biomimetic system that can mimic the environment of a physiological organ, with the ability to regulate key parameters including concentration gradients, shear force, tissue-boundaries, and tissue–organ interactions.

Organs-on-chips (OoCs) are systems containing engineered or natural miniature tissues grown inside microfluidic chips.

The chip is designed as a microfluidic device featuring networks of hair-thin microchannels, which guide and manipulate minute volumes of solution ranging from picolitres to millilitre.

Organ-on-a-chip (OoC) technology has advanced significantly due to the convergence of innovations in tissue engineering and microfabrication.





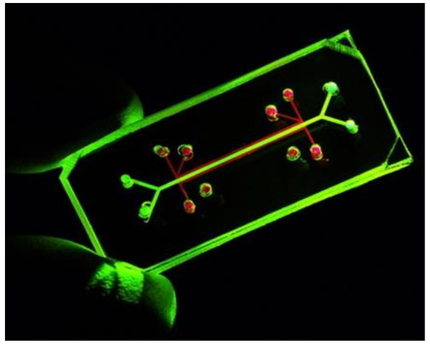
https://euroocs.eu/organ-on-chip/

Consensual working definition established by the European ORCHID vision group on 23 May 2018 in Stuttgart

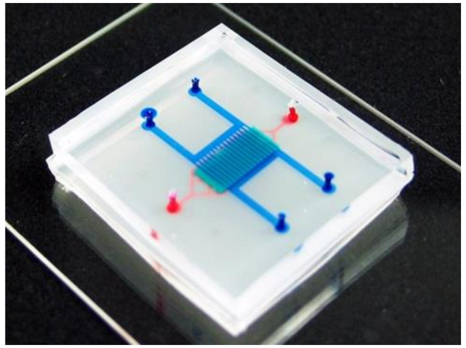
"An Organ-on-Chip (OoC) is a fit-for-purpose microfluidic device, containing living engineered organ substructures in a controlled microenvironment, that recapitulates one or more aspects of the organ's dynamics, functionality and (patho)physiological response in vivo under real-time monitoring".

SINGLE-ORGAN SYSTEMS frequently have a high level of biological authenticity, enabling the assessment of how a specific organ responds to a compound or mixture of compounds

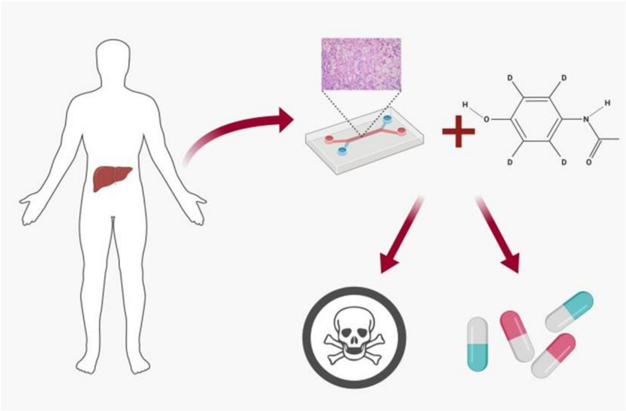
Brain



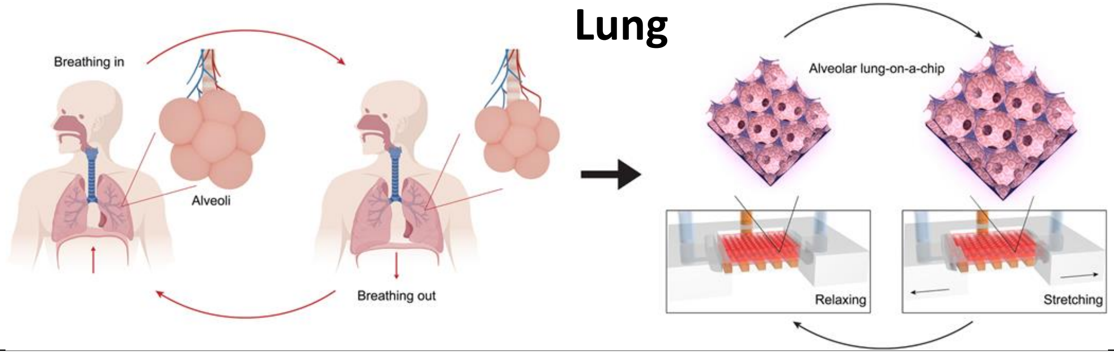
Heart



Liver



Lung



Blood vessels

Intestine

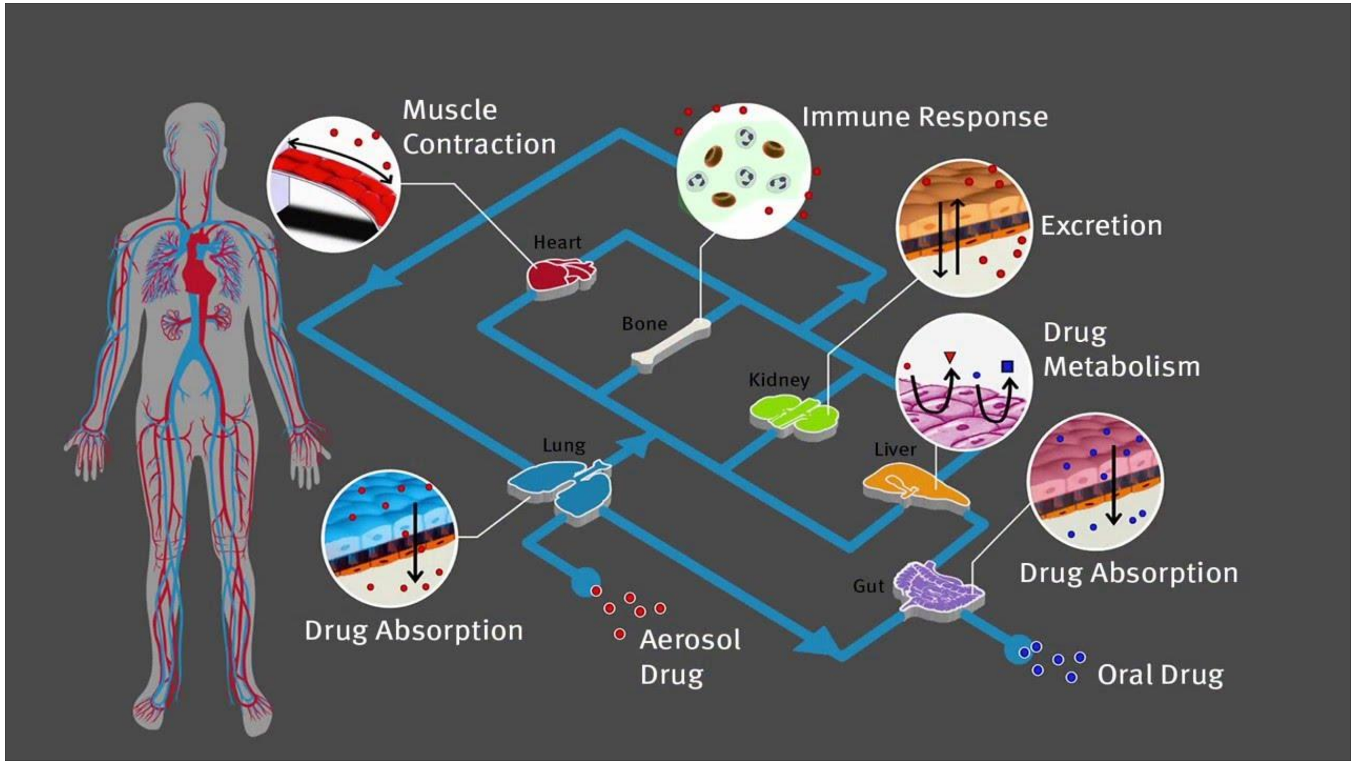
Skin

Cancer

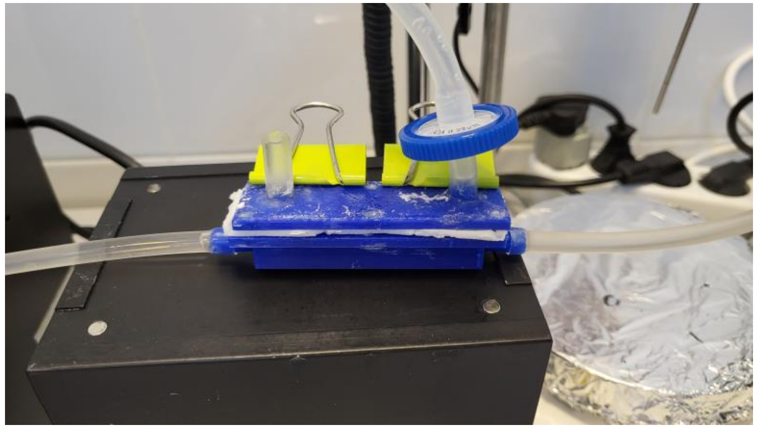
MULTI-ORGAN SYSTEMS offer a framework for studying the interactions between multiple organs, primarily through the exchange of metabolites or soluble signalling molecules.

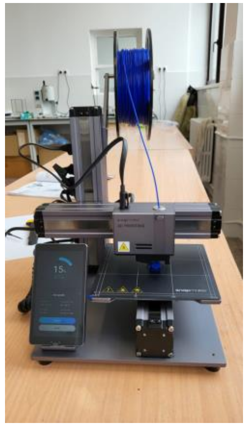
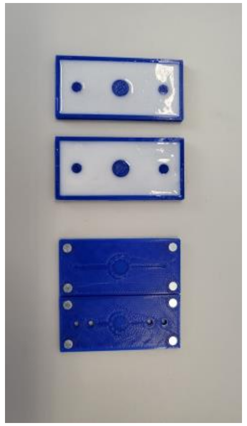
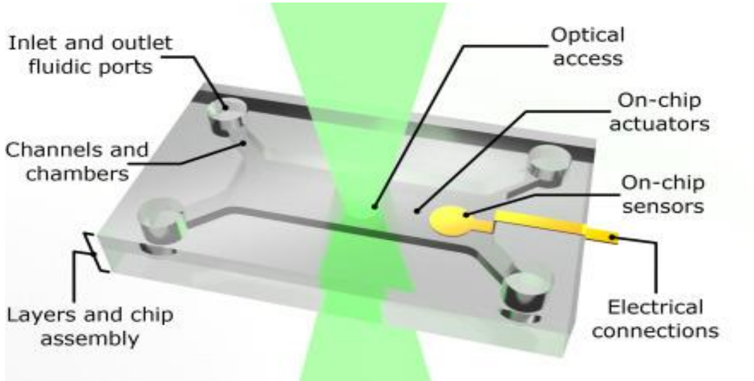
Human on-a-chip

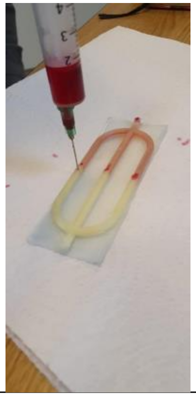
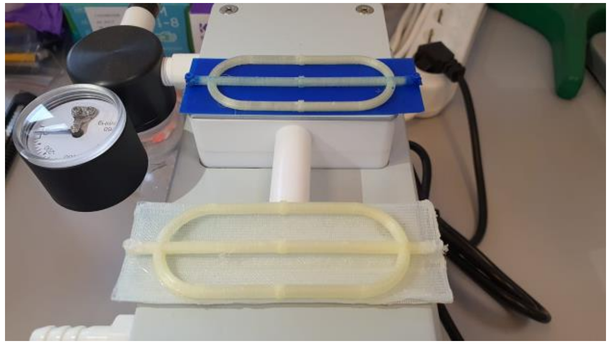
https://hesperosinc.com/



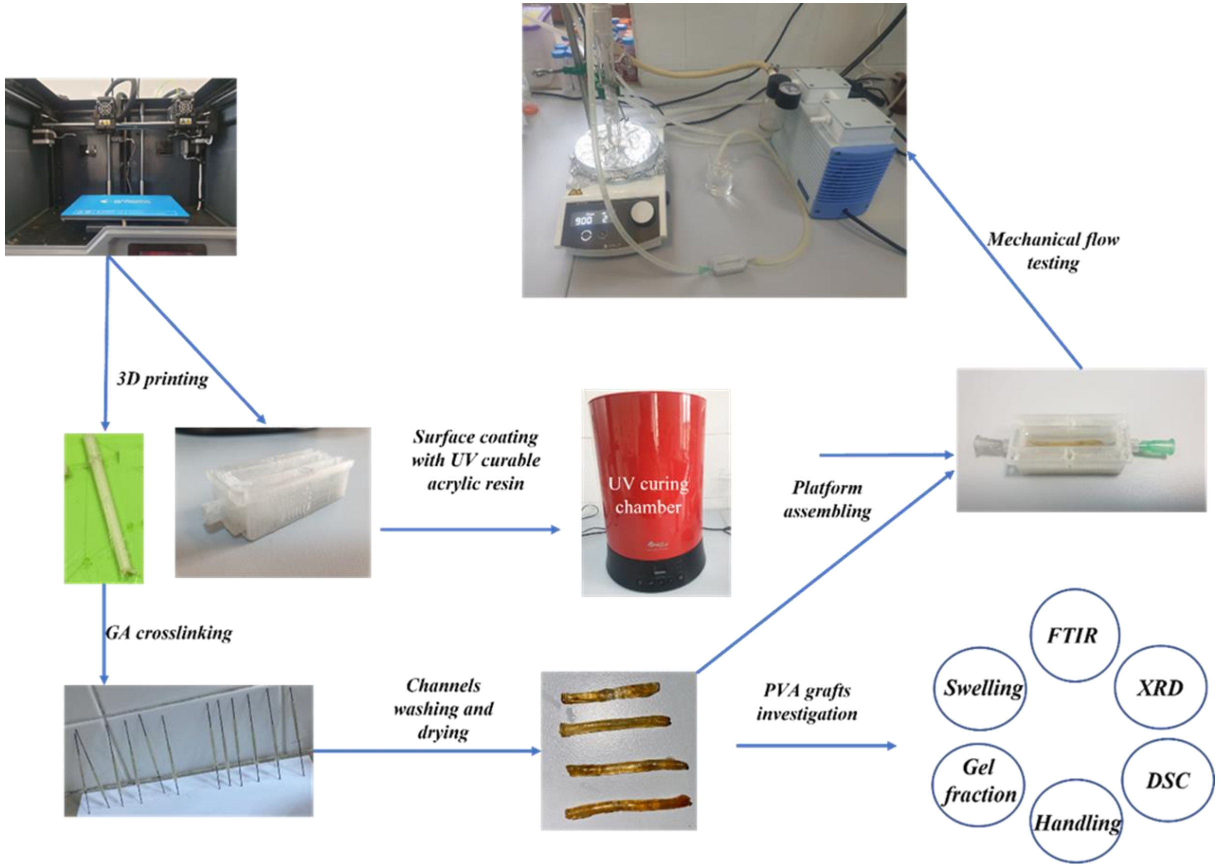
ORGAN ON-A-CHIP MODELS IN OUR GROUP

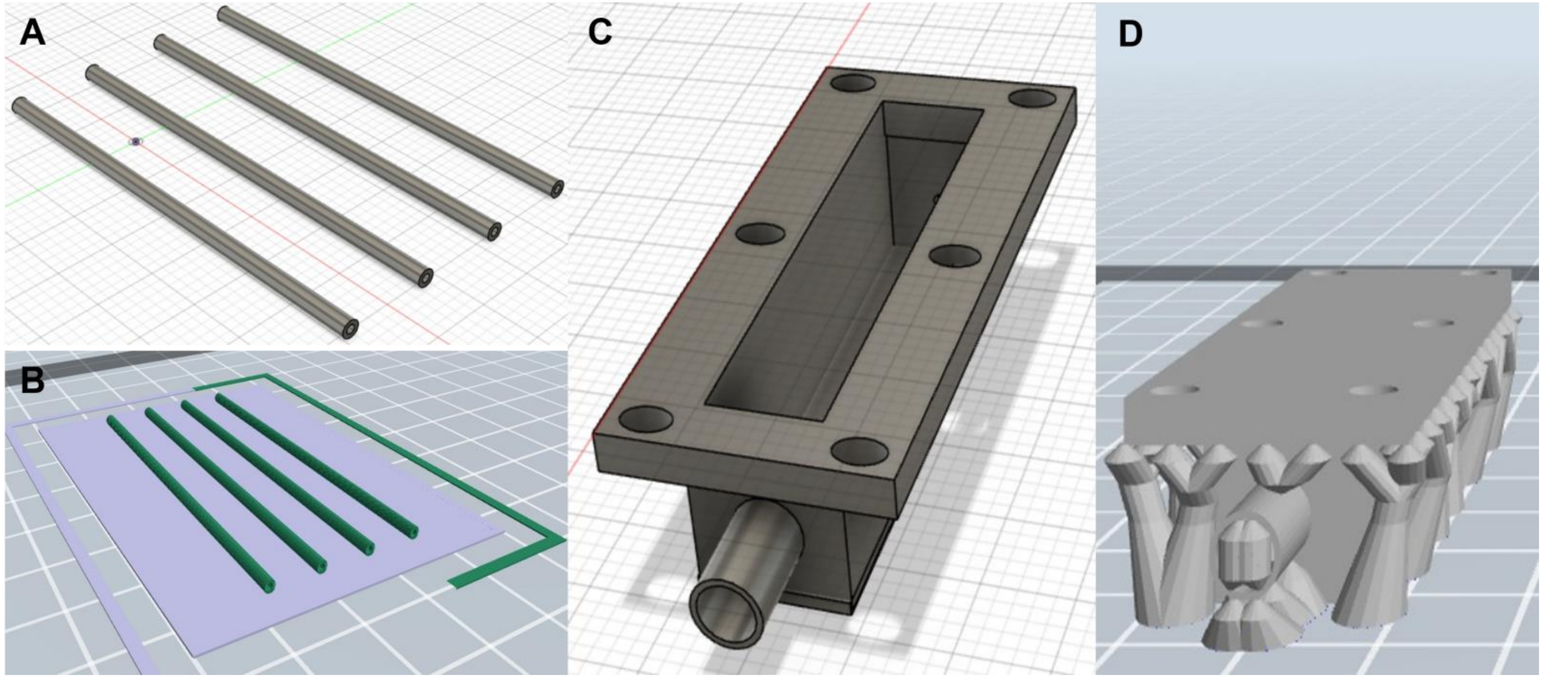



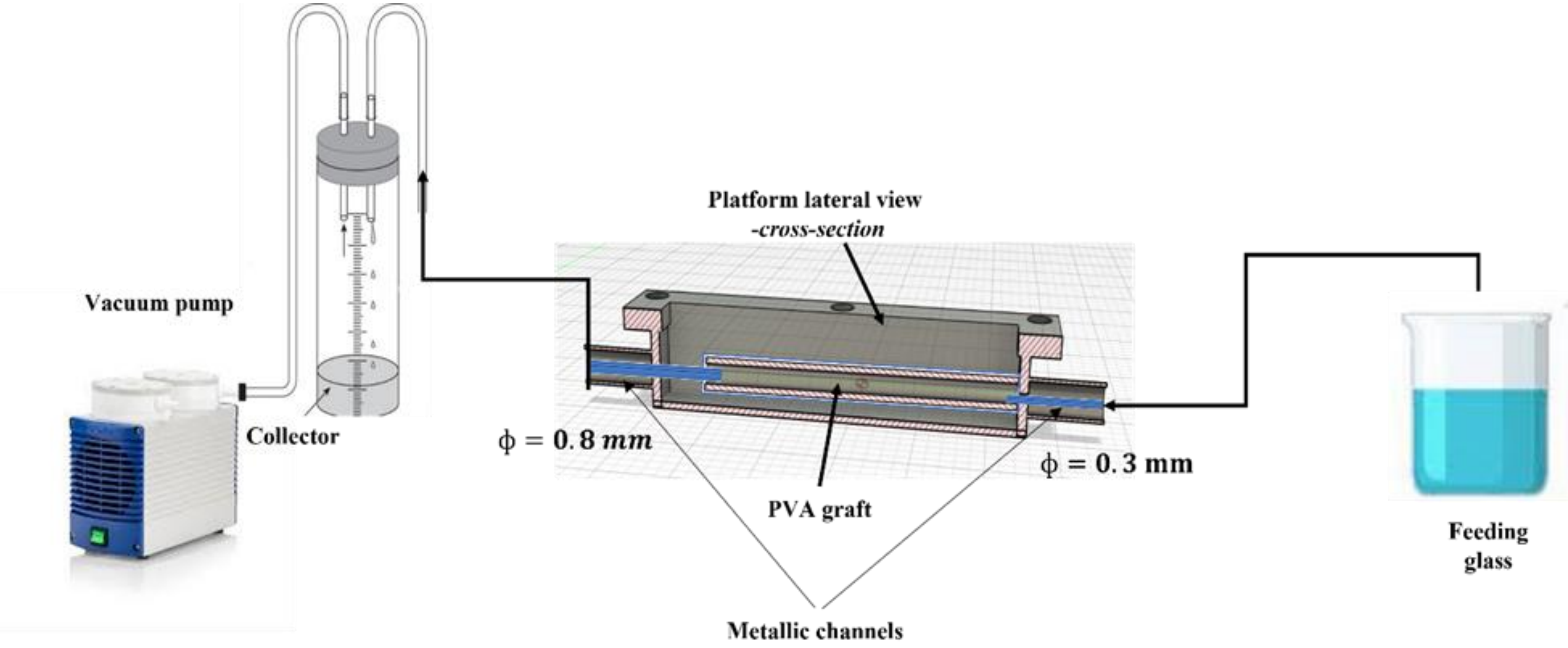



SMALL ARTIFICIAL BLOOD VESSES BY 3D PRINTING (FDM) – APMG LABS

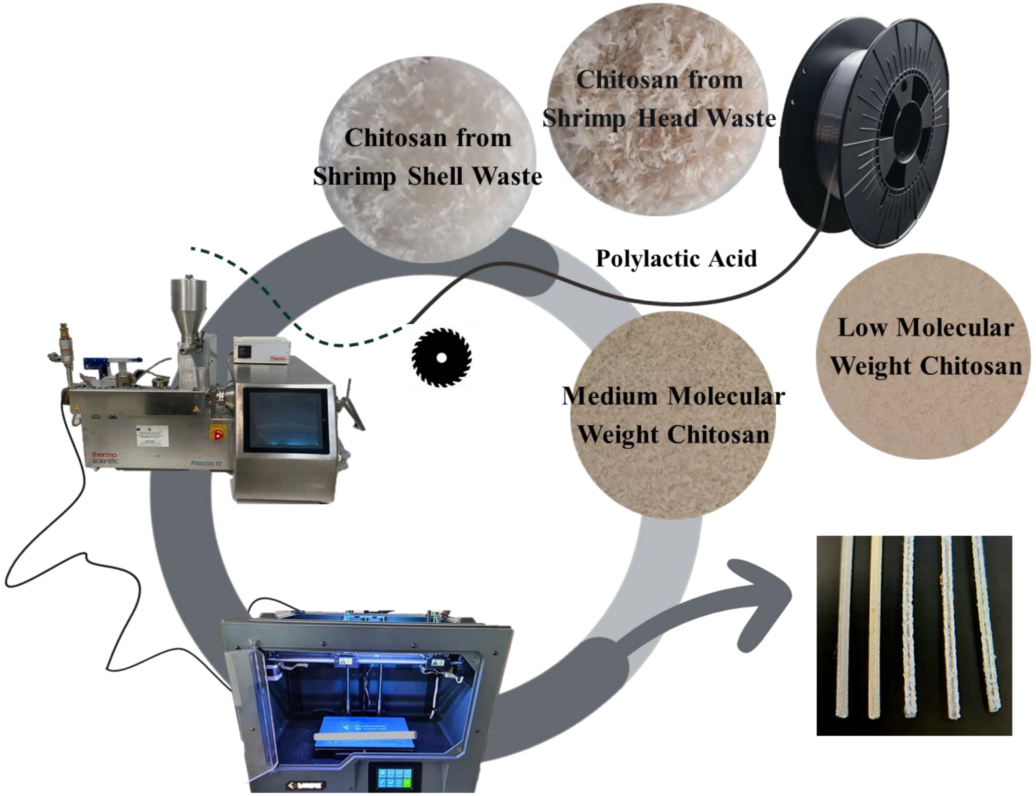




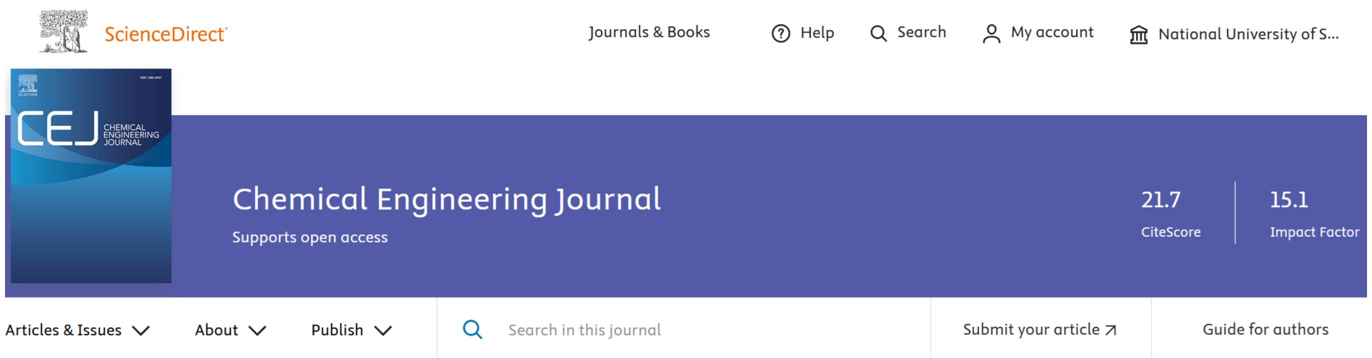
Computer-aided design of the channel and platform:
a – 3D representation of the channels in Fusion 360 software; b - 3D representation of the channels in the 3D printer software; c – 3D representation of the PETG platform in Fusion 360; d - 3D representation of the PETG platform the 3D printer software

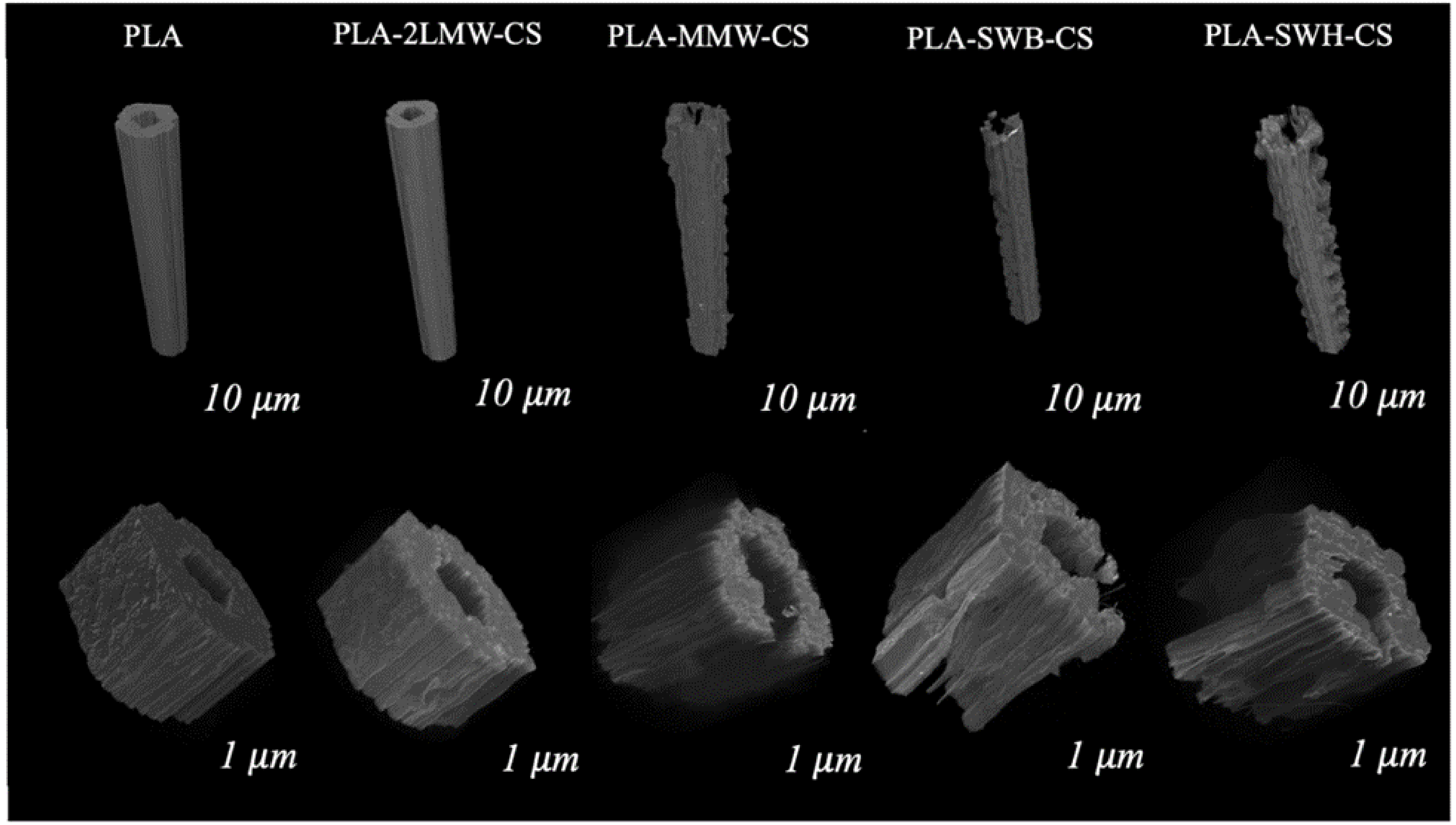


Schematic representation of biofunctionalized poly(vinyl alcohol) (PVA) graft flow testing

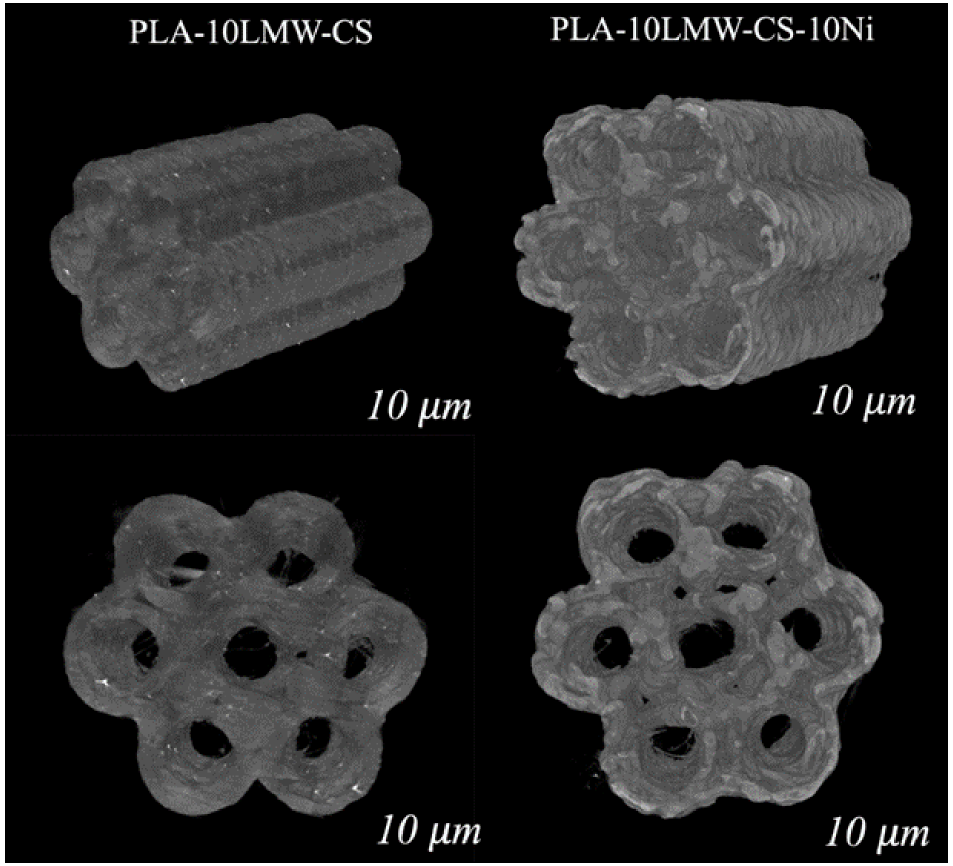


C. Zaharia et. al., Chitosan-Polylactic acid Composites: From Seafood Waste to Advanced Functional Materials for 3D Printing, Chemical Engineering Journal, IF 15.1, 2024, under revision.

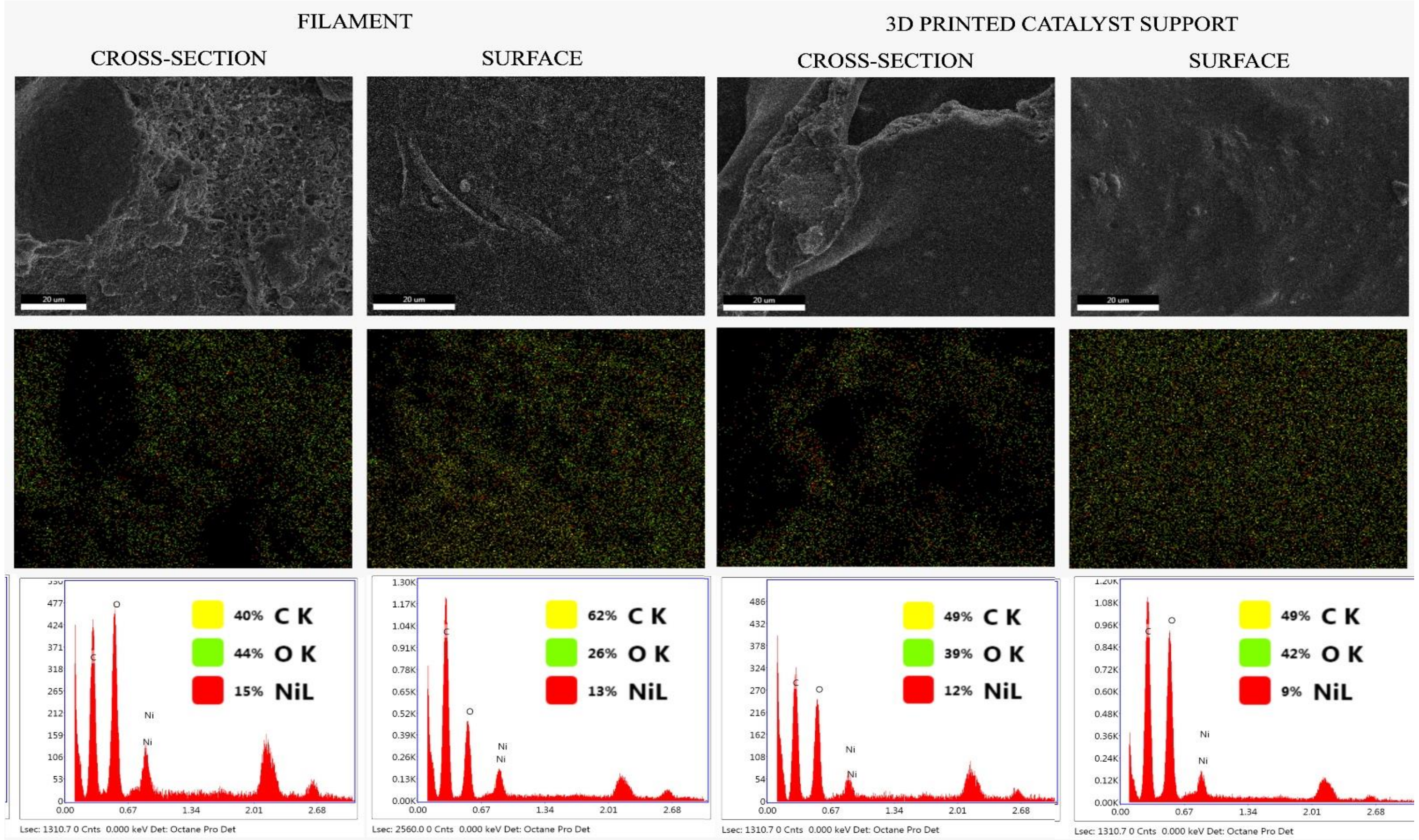




Micro-CT micrographs of the 3D printed objects made of PLA filament and PLA-chitosan composites (2% w/w) at 1 and 10 μm.



Micro-CT micrographs of the 3D printed objects made of PLA-10LMW-CS and PLA-10LMW-CS-10Ni at 10 μm.



EDAX mapping and spectrum of PLA-10LMW-CS-10Ni filament and 3D printed catalyst support.

APPLICATIONS OF 3D PRINTING IN AEROSPACE AND AVIATION

3D printing is well-suited for numerous prototyping and end-use applications in the aerospace and aviation industry. Additive manufacturing can produce parts that are both stronger and lighter compared to those made with traditional manufacturing methods.

Companies in the aerospace industry started using 3D printing in 1989, and by 2015, the aerospace sector accounted for 16% of the additive manufacturing industry's $4.9 billion global revenue.

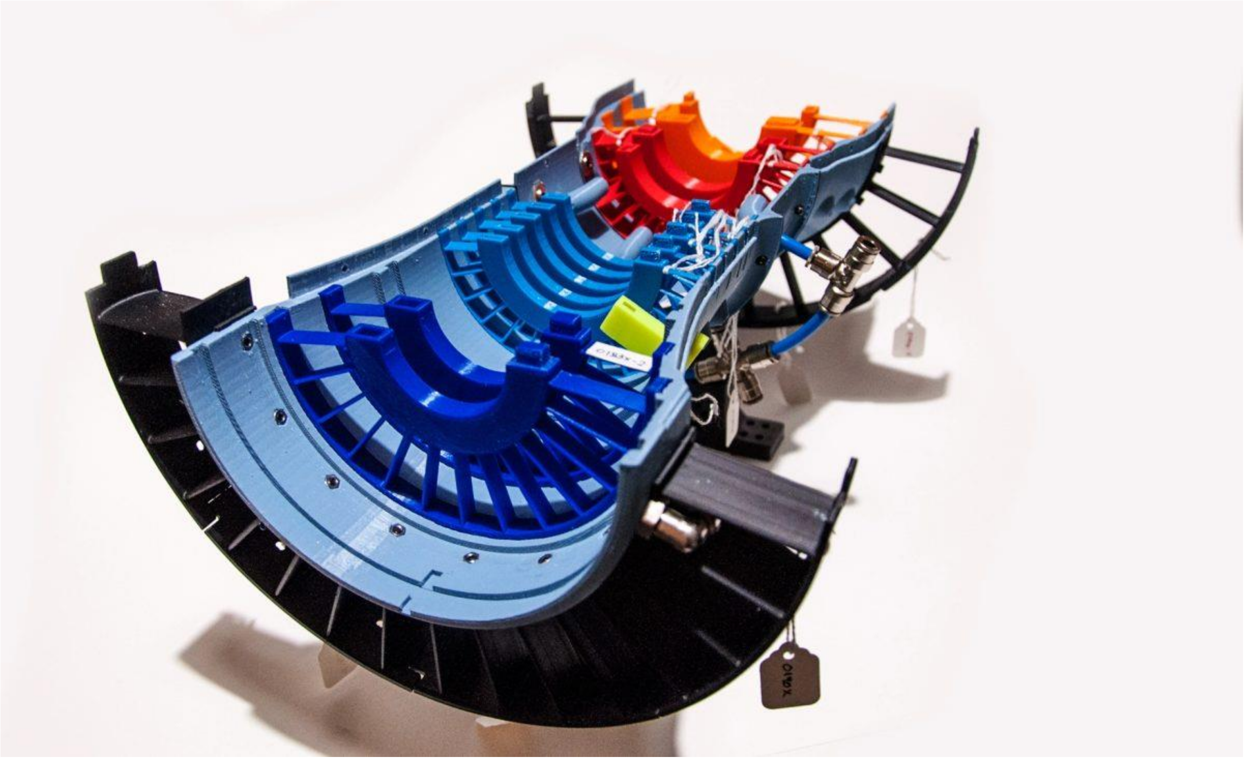
Corporate aircraft typically travel an average of 75,000 miles per month. A single component designed and manufactured with 3D printing can reduce air drag by 2.1%, resulting in a 5.41% reduction in fuel costs. This highlights the significant impact that even one 3D-printed part can have.

Examples: https://www.hubs.com/knowledge-base/aerospace-3d-printing-applications/

Jigs & Fixtures - For each individual aircraft, companies typically 3D print hundreds of fixtures, guides, templates, and gauges. This approach generally results in a 60 to 90 percent reduction in both cost and lead time compared to traditional manufacturing processes.

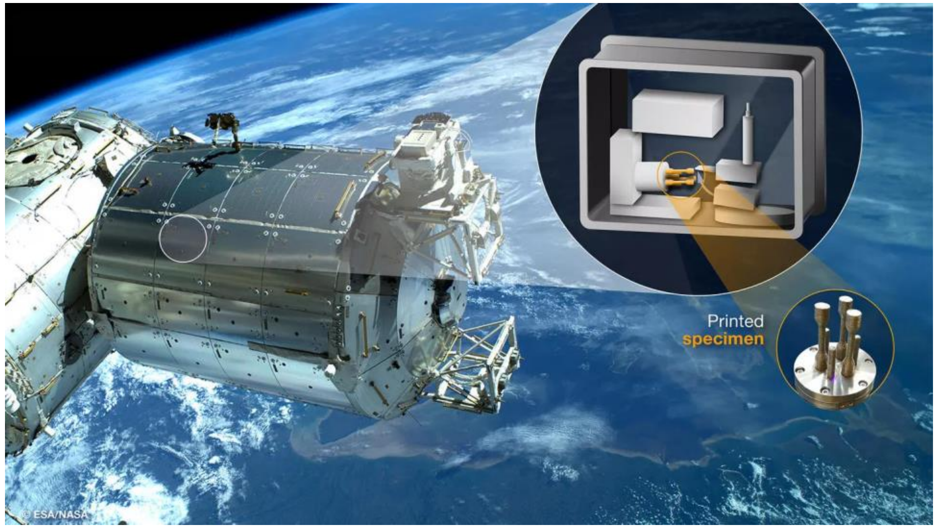
Surrogates - placeholder parts used throughout production to represent components that will be installed in the final assemblies. These parts are primarily used for training purposes. NASA and several Air Force bases frequently use surrogate parts on their production floors.

Application	Example part	Requirements	Recommended Process	Recommended Material
Engine compartment	Tarmac nozzle bezel	Heat resistant functional parts	SLS	Glass-filled Nylon
Cabin accessories	Console control part	Customized functional knobs	SLA	Standard Resin
Air ducts	Air flow ducting	Flexible ducts and bellow directors	SLS	Nylon 12
Full size panels	Seat backs & entry doors	Large parts with smooth surface finish	SLA	Standard Resin
Casted metal parts	Brackets and door handles	Metal parts casted using 3D printed patterns	SLA & Material Jetting	Castable Resin or Wax
Metal components	Suspension wishbone & GE Jet Engine	Consolidated, lightweight, functional metal parts	DMLS/SLM	Titanium or Aluminum
Bezels	Dashboard interface	End use custom screen bezels	Material Jetting	Digital ABS
Lights	Headlight prototypes	Fully transparent, high-detail models	Material Jetting & SLA	Transparent Resin



Jet model engine was 3D printed for educational purposes.

https://www.hubs.com/knowledge-base/aerospace-3d-printing-applications/



The first metal 3D printer for space, developed by Airbus for the European Space Agency (ESA), will soon be tested aboard the Columbus module of the International Space Station (ISS). It could be a real game changer for manufacturing in space and future missions to the Moon or Mars.

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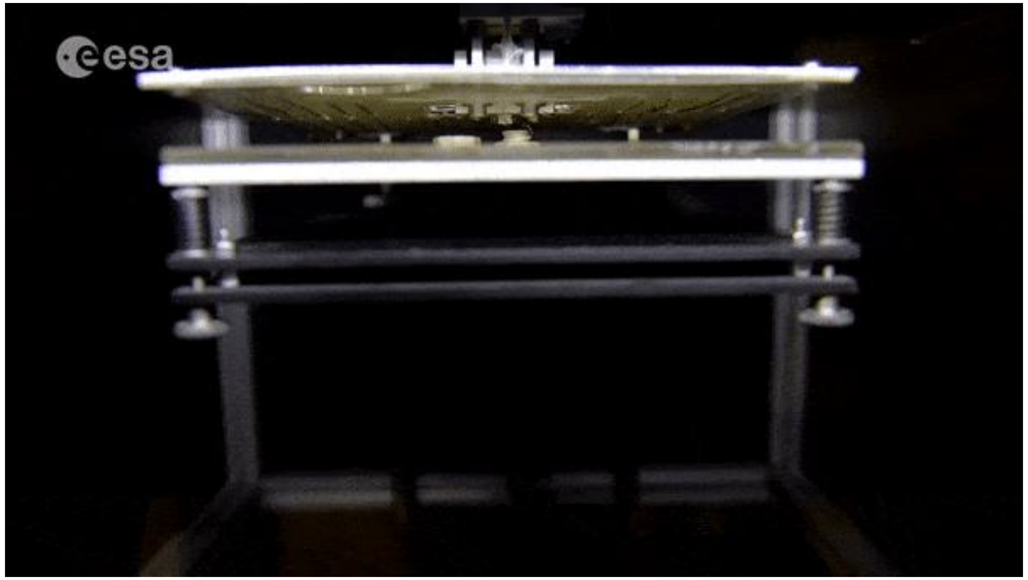
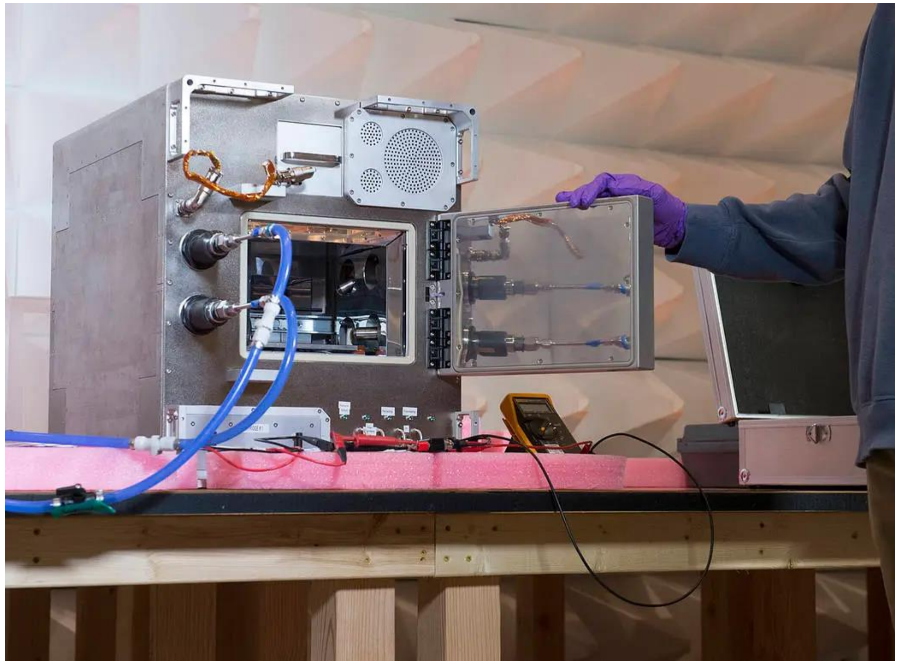
There are already several plastic 3D printers on board the International Space Station (ISS), the first of which arrived in 2014. Astronauts have used them to replace or repair plastic parts, addressing one of the major challenges of life in space: the supply of equipment, which can take months to arrive. But the metal 3D printer is a new approach…



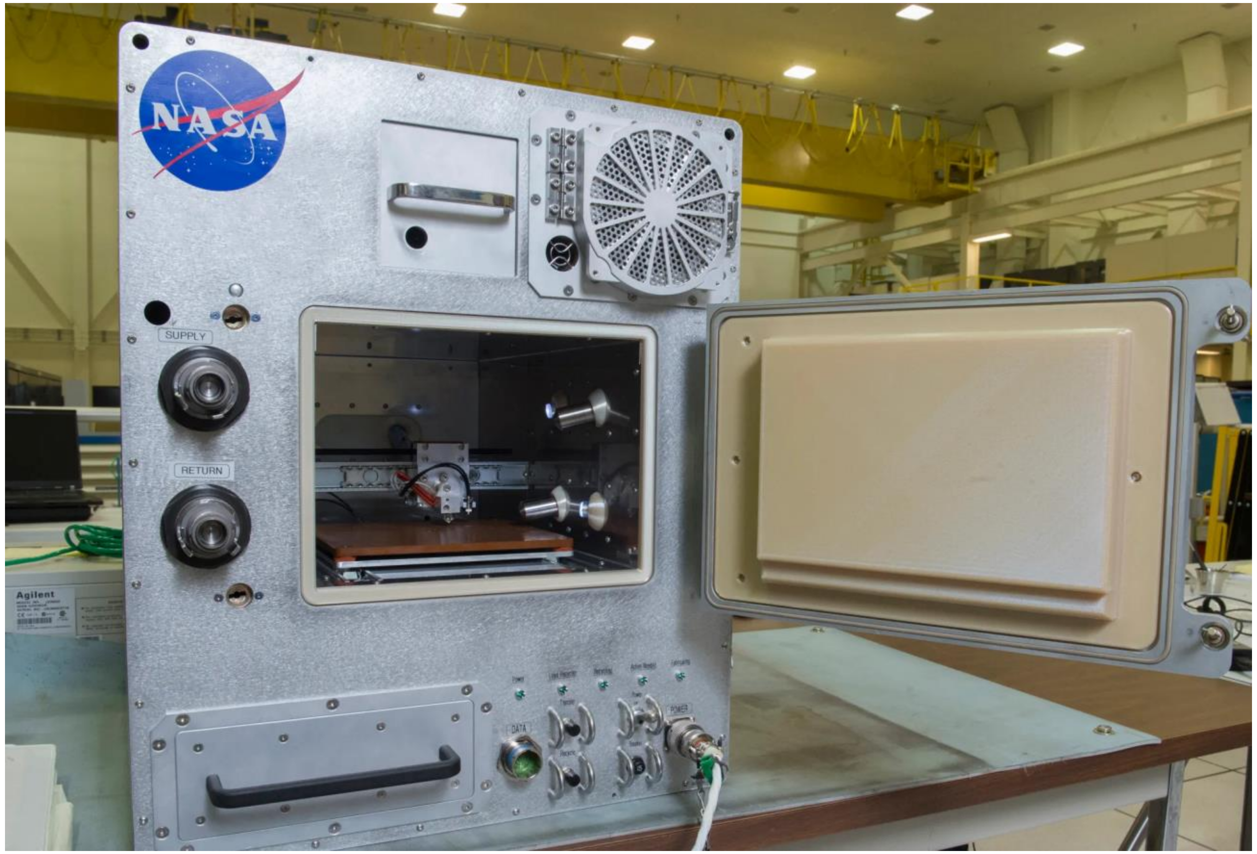
PEEK, Polyether ether ketone, is a thermoplastic known for its exceptional mechanical properties, including strength, stability, wear resistance, and temperature resistance. These characteristics make PEEK parts comparable in performance to some metal parts.

The use of PEEK opens the door to producing customized 3D-printed parts capable of withstanding the extreme conditions of space. Previously, plastic 3D printers primarily used weaker plastics such as ABS and PLA, typically employed for making toys or non-structural parts. The PEEK 3D printer at ESA's Materials and Electrical Components Laboratory is only the second of its kind, manufactured by a small German company called Indmatec.

2018 - Combination 3D Printer will Recycle Plastic in Space - The first integrated 3D printer and recycler is part of the cargo that was launched to the International Space Station on Northrop Grumman's Cygnus spacecraft's 10th commercial resupply services mission.



The machine, known as **Refabricator**, will demonstrate the ability to convert waste plastic and previously 3D-printed parts into high-quality 3D printer filament, effectively creating new tools and materials. This process will involve recycling control plastic multiple times to produce parts, which will then be tested for quality upon return to Earth.

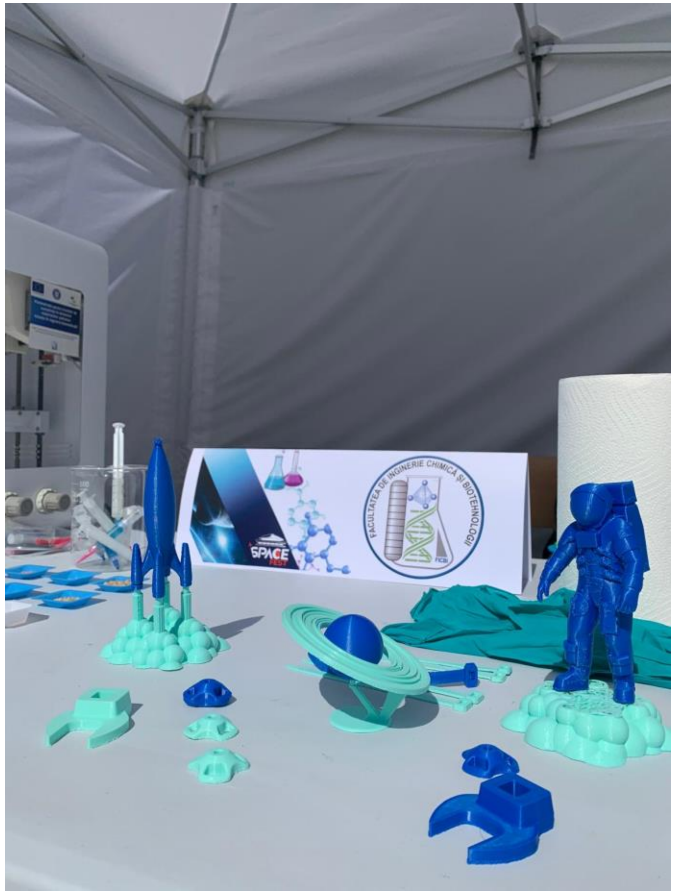


The “Refabricator” is a recycler and 3D printer in one unit about the size of a dorm room refrigerator. Pictured is the tech demonstration unit that will be tested at NASA’s Marshall Space Flight Center in Huntsville, Alabama before a flight unit is launched to the space station in April 2018.

NASA awarded a Small Business Innovation Research contract valued at approximately $750,000 to Tethers Unlimited Inc. of Seattle in April 2015, to build the recycling system.

https://www.nasa.gov/missions/station/full-circle-nasa-to-demonstrate-refabricator-to-recycle-reuse-repeat/


SPACE
Campus POLITEHNICA

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