РОСАТОМ

НАУКА И ИННОВАЦИИ
управляющая компания

ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

Аддитивные технологии как основа производства будущего. Создание оборудования для аддитивных технологий в ГК «Росатом».

Additive technologies as a basis for future production. Creating equipment for additive technologies in Rosatom.

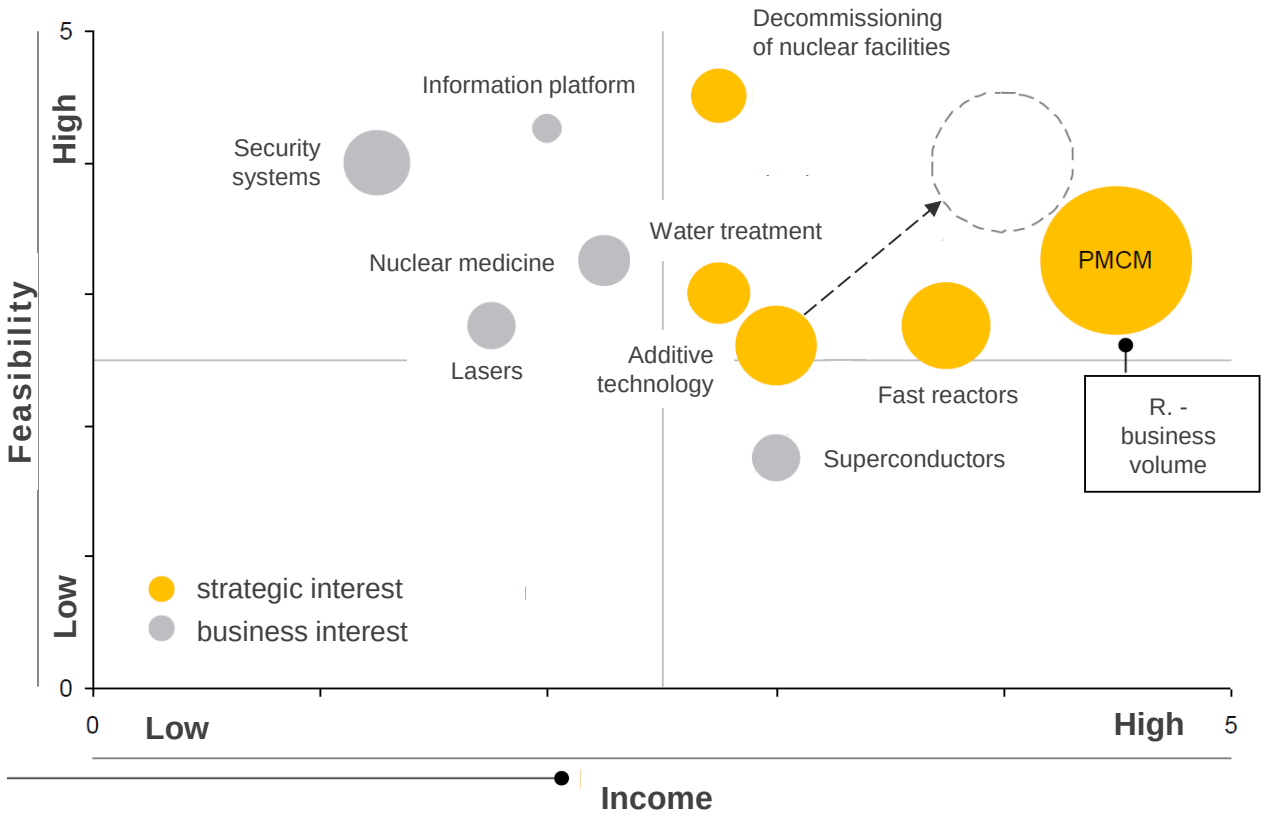
А.В. Дуб

Москва, Атомэкспо

31 мая 2016 г.

Additive technology – strategic direction of development

Direction of development of additive technologies and manufacturing is among the promising strategic areas of scientific and technological activities of Rosatom* and the program of new production technologies development in Russian Federation**



Goals:

- **Materials:**
  - metal
  - ceramic;
  - composites (multilayer, encapsulated);
  - organic materials for direct additive cultivation;
  - materials for PIM and MIM technologies
- **Technology:**
  - Automated additive machines (3D printers);
  - Equipment for drawing of multiplayer coatings
  - Production technology
- **Services:**
  - Regulatory documentation, properties database for received materials and critical product elements:
  - Digital design, process management and control systems and equipment
  - Product manufacturing by additive technologies

- *Strategic direction approved at the meeting of the strategic Committee of Rosatom, 25.12.2015.
- **Coordinated research and development program for the development of new industrial technologies (SPIiR PIT)

The advantages of using additive technology 1/2

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For product construction

No significant product form restrictions, specific to traditional manufacturing methods
complex geometry and shape that are impossible to reach by mechanical processing or casting

Unique material combinations
Using unconnected by other methods materials can produce parts from metals and ceramics either from their complex combinations

A significant product weight reduction
Exception of unloaded and unused volumes, mass decreasing by 50% and above

A significant time reduction of prototype production
prototyping combined with design.

The development cycle of new products significantly reduced

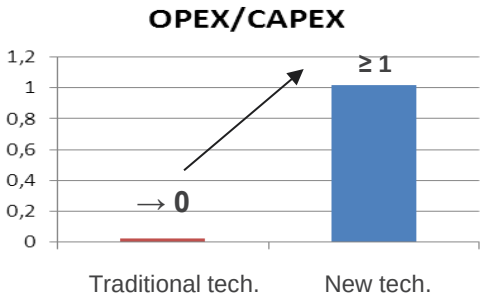
For production

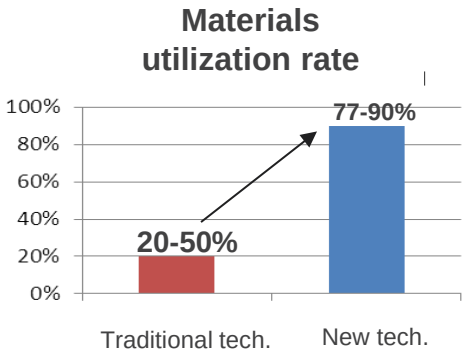
Production design economy
Construction changes without snap-in overhead, minimum duration of a technological preparation

Reduction of long production chains
Optimization

Material economy.
Unused powder for synthesis is applied again

Wage reduction
3-8 times reduction compared to traditional production





Product introduction cycle is significantly reduced

The advantages of using additive technology 2/2

Traditional production methods

Materials

Wide properties dispersion in the process of redistribution

Technology

multi-stage (errors accumulation)

Staff qualification dependence

New production methods

materials

Standardized
(dispersion properties are adjustable)

Technology

One stage (no staff)

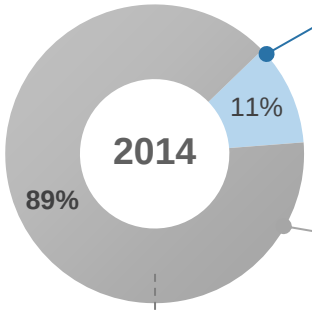
calls

- Control system for technological processes
- Small material database

Forecast world market development of additive technologies

(all types of 3D printers, 3D powder, services)

4,1 blns.$
The world market of additive technology.
All directions



Average growth of segment M-AM
(2016-2020) - 50% annual
(2021-2025)- 22% annual

*Average growth of quantity M-AM (2012-2014) ~**50-70%** annual*

Average growth of segment П-АМ
(2016-2020) - 26% annual
(2021-2025) - 17% annual

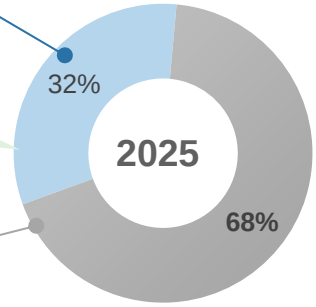
Average growth of quantity П-АМ (2012-2014) ~25-29% annual

Average growth
M-AM (2015-2025) ~ 38% annual

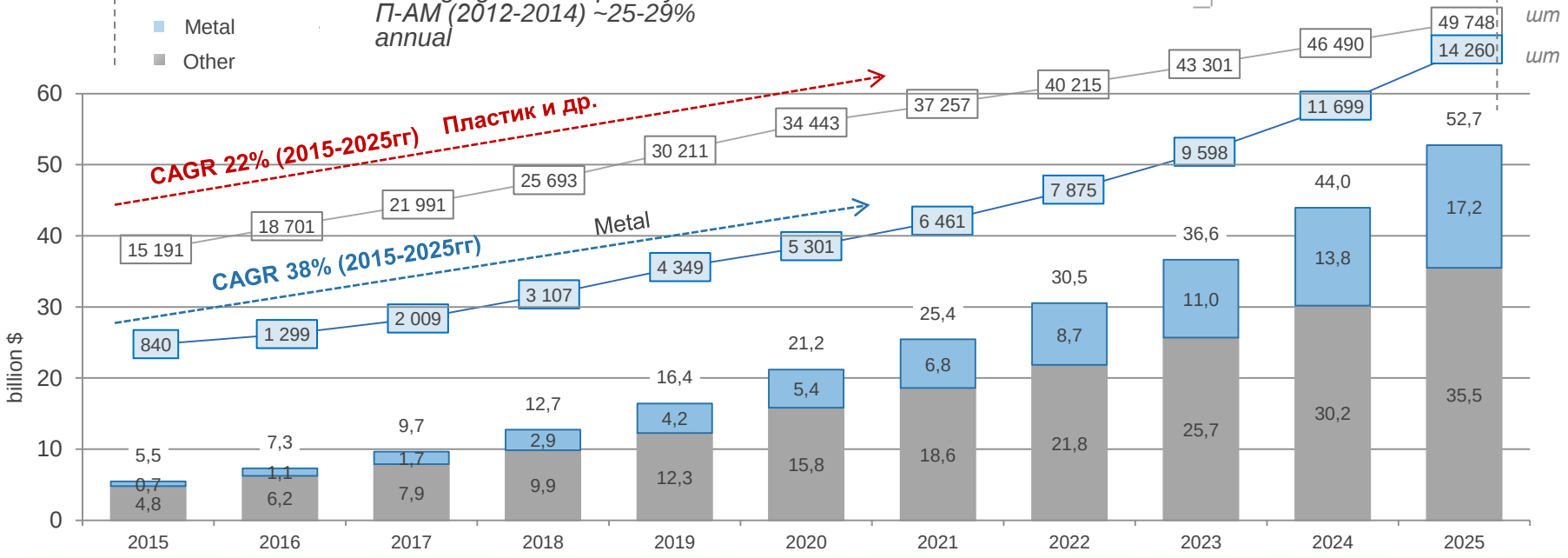
*Due to higher segment growth of metallic M-AM compared to plastic П-АМ **share M-AM segment growth is predicted by 32% in 2025***

Average growth of П-АМ (2015-2025) ~22% annual

52,7 blns.$
The world market of additive technology

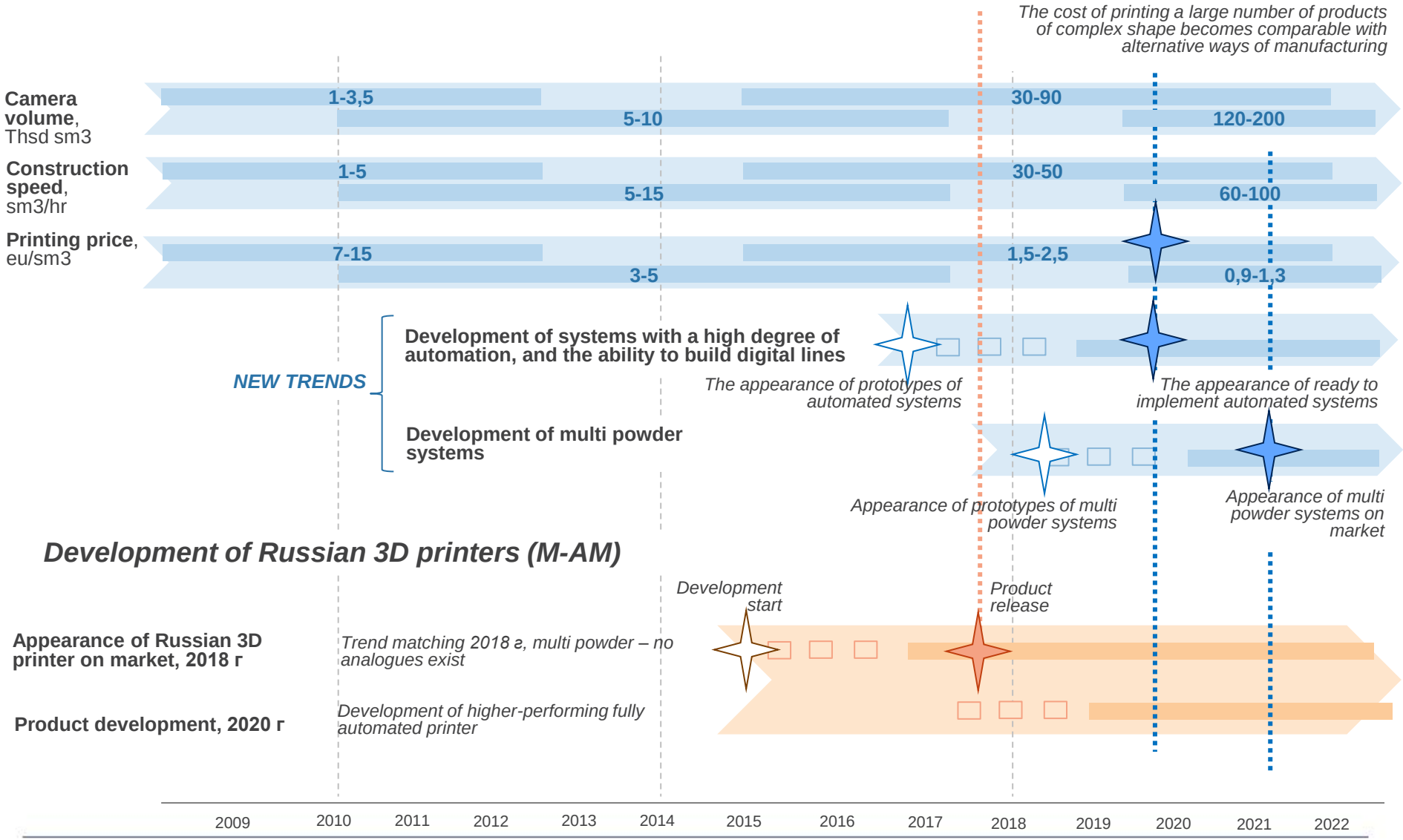


Metal
Other



source,: agency «Wohlers Report 2015»

Trends in technological development
in the segment of metal additive machines (SLM)



Source: agencies «Wohlers Report» 2015
Roland Berger Strategy consulting Report 2014

The cycle of creation of new production technologies

1. Materials
2. Technology – equipment,
   - modes,
   - management;
3. **Design**
   – database
   - testing
   - Standards and regulation
4. Resource product

Key consumer requirements to products

	Characteristic	Key consumer requirements to products
The most commonly used in the media, by experts	Sizes/ construction zones, (LxHxD), mm	Not less then 400x400x400
	Construction speed (average), sm3/hr	More then 30
The most commonly used requirements by 3D printers consumers	3D printer price*, mlns. rubs.	Not more then 70 mlns. rubs.
	Types of metal powders used in complex	Basic characteristics - see.12, alloy composition according to GOST*
	Build precision parts	Kvalitet 6-14 - GOST 25346
	Surface roughness, not worse	Ra 40
	Printer manufacturer, provided the customer supply of metal powders on value at 20% below their foreign counterparts	Yes
	Manufacturer of 3D printers, assisted in the introduction of 3D technology to the Customer	Yes
	Working with the two powders together (in one Detail)	Yes
Additional requirements for commercialization	The ability to automate 3D printer and embedding in automated lines	Yes
	Cost of ownership for 3D-printer, % annual from the value of the 3D printer	Less then 10%
	The cost of printing products, rub/cm3	Less then 200
	The repeatability characteristics of the printed products in a shipment, the percentage of deviation	Less then 1%

*steel grades 14Х17Н2 ГОСТ 5632-79, 30ХГСА ГОСТ 4543-71;
- Ti and its alloys ВТ1-0 ГОСТ 19807-91, ВТ6 ГОСТ 19807-91;
- Ni base alloys ХН62ВМЮТ (ЭП-708 ВД) ТУ14-1-1018-98, ЭП-718 ТУ 1-809-823-99;
- Al base alloys АК12 ГОСТ 1583-93, АК9ч ГОСТ 1583-93.

Stakeholders and their basic requirements / values / expectations to the product / service

	The initiator of the projectл АО «УЭХК»	Developer (partner) «Science&Innovations»	The State Ministry of education and science	Project participants (ООО «УЗГЦ», ООО «ЗЭП» и др.)	Consumers [customers]
Institutional solutions	• The presence of the greater part of production required to master output (circuit design, metalworking, etc.) • Interested in creating new productions on site	• Subsidiaries download in R&D projects • Using existing competencies for one beam 3D printer	• Subsidizes 215 million rubles for the development of 3D-printer • Interested in import substitution of foreign producers	• Loading of existing capacities(equipment, personnel) • The creation of new manufactures	• Wary of imposing a ban on the purchase of a 3D due to the sanctions • Interested in buying at lower cost • Needed in service
Commercial solutions	• Confirmed the need for 3D in ДЯОК and related industries. • The probability of occupation of a substantial market share in Russia-more than 50% (the market is just being formed).	• Commercialization of scientific competences of subsidiaries. • Possibility to attract for future R&D projects	• Interested in mastering the production of Industrial partner • Sales of 3D printers to Russian enterprises	• Obtaining of additional revenues and profits from the production materials and components	• The economic benefits of the application of 3D technologies by reducing production time, material usage, etc.)
Technical solutions	• Mastering the production of high-tech products corresponding to the best foreign analogues	• Opportunity to develop 3D printer, not inferior to import analogues	• Development of Russian 3D printer corresponds to future market requirements	• Availability of competencies and experience, production technologies of materials and components for 3D	• Creation of functional parts with improved/new features (small weight, high complexity, etc.)

-Existing competitive advantages

-To strengthen to create additional competitive advantages

Main product groups
(metallic additive machines (M-AM)

POCATOM

Product groups

Low-productivity

20-60 mln.rub*

Single-beam 3D printers with lower-powered laser (less than 400 W), small area build (no more than 1 thousand/cm3) and low speed (5-10 cm³/h or less)

High-productivity

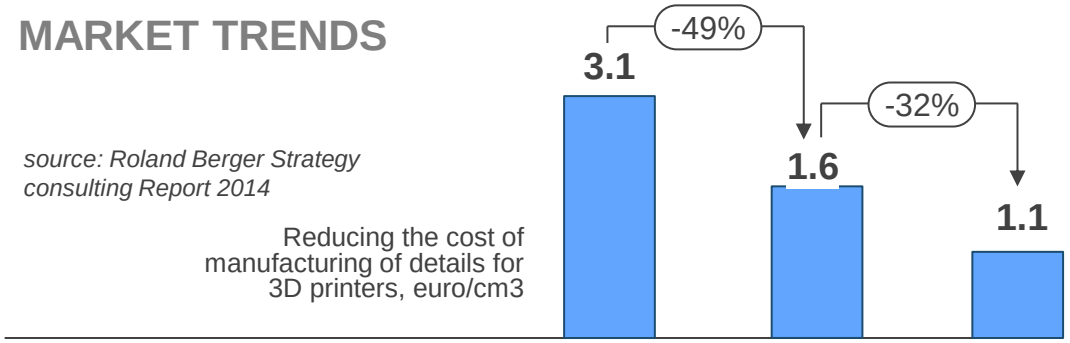
65-120 mln.rub *

Multi-beam 3D printers (2-4 laser) (-2 0.4 kW or more) big build area (over 25 thousand/cm3 and build speed over 20 SM3/h)

MARKET TRENDS

source: Roland Berger Strategy consulting Report 2014

Reducing the cost of manufacturing of details for 3D printers, euro/cm3



Correspond to trends of 2014 year	2014	2018	2023
Construction speed, sm3/hr	10	40	80
Energy costs in euro/kg	89	70	30
Post-processing, men/h/kg	1,52	1,05	0,96
The cost of manufacturing details, euro/cm3	3,1	1,6	1,1

Correspond to trends of 2018 year

63 mln.rub

Developed the printer will have the following characteristics:
- multibeam (2 beam, one part makes contour, second melts layer)
- powerful, high-performance lasers (400 Watts and 1000 Watts)
- build a large area (80 thousand cubic centimeters) high speed (more than 43 SM3/h)
- ability to use 2-x powders when printing (unique!)

Developed 3D printer:
- ❑ **Refers to high-productivity M-AM.**
- ❑ **fully corresponds with the trends of product development directions for the year 2018**

*-price of 3D printers in Russia, taking into account transportation costs, customs duties and other charges

Comparison of properties Master3D-550

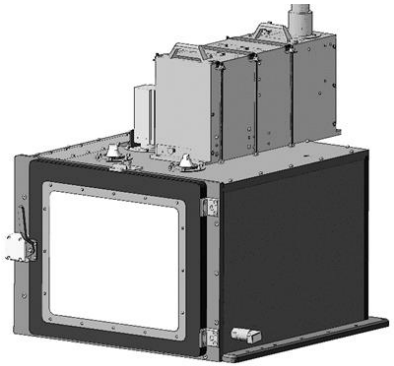
	SLM 500HL	EOS M400	X line 1000R	MeltMaster -550
Max size of construction , mm	500×280×325	400×400×400	630×400×500	550×450×450
Laser Amount /output kWt / type	2×0,4 (2×1,0) Itterby, fiber	1 / 1 / Itterby, fiber	1 / 1 / Itterby, fiber	1 / 1 / Itterby, fiber
Construction speed, r	до 70	-	10-100	15-100
Layer thickness , mkm	20-200	-	30-200	20-250
Focus diameter, mkm	80-150/700	90	-	50-700
Scanning speed, m/s	до 15	7,0		до 15

Contract is under support of Ministry of Education and Science , Contract № - RFMEFI58214X0004.

Printer MeltMaster3D-550

MeltMaster^{3D}-550

MeltMaster^{3D}-550 without of external shell

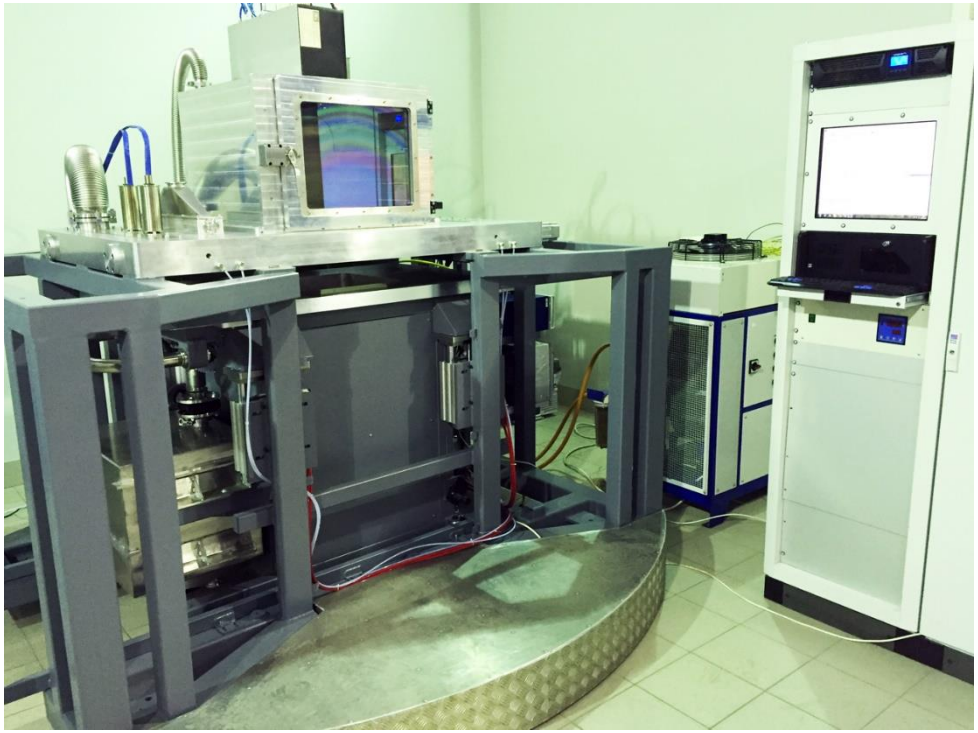


Рабочая камера

Main parts of equipment:
1.Working cell;
2.Supplement of powder materials system
3. Powder Recirculation system
4.Gas protection system;
5.Automatic control system.

Horizontal modulo structure was used for creation the equipment.

MeltMaster3D-550

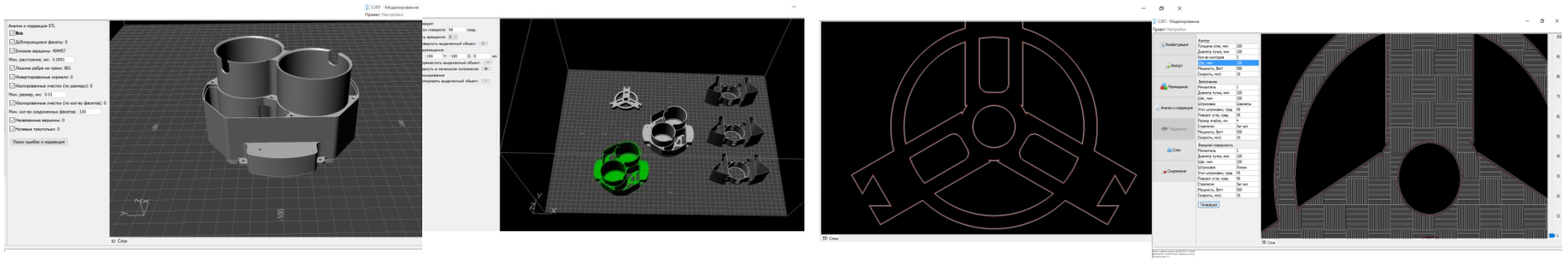


Equipment can used different metal powder:

1. Particle size– 20-40 mkm
2. Particle shape– spheroid

Control software

2 special software product were created for MeltMaster^{3D}-550 technological processes «SLM-Modelling» & «SLM-Production».



a) b) c) d)

Examples of interface а) – checking of 3D-model; б) – positioning of the potential product at the working cell; в) – slicing the layers; г) – visualization of each layer

Simulation modelling of alloying technologies

POCATOM

- ✓ transfer of radiation in order to calculate distribution of thermal energy allocation between the layers of powder and substrate
- ✓ heat transfer with phase transitions
- ✓ mass transfer in melt powder

- ✓ heat and mass transfer for modeling the distribution of alloying elements, shape of molten pool

- ✓ heat and mass transfer during the cooling, crystallization process analysis in order to predict mechanical properties of the product
- ✓ optimization (prediction of optimum SLM-condition)

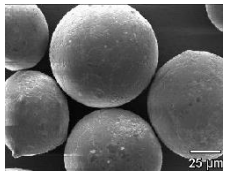
“Virtual 3D printer”-

multiscale mathematical system with feedback and adaptive control for SLM technology, linking together such concepts as process, structure, properties for created products and integrated with the CAD tools

Metal powders for 3D printer

Project
«3D printer»

Project will develop a laser system for layered synthesis of complex-metal parts made of multipowder compositions



As a part of Project «3D printer»

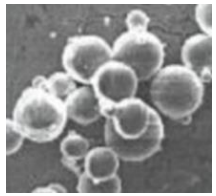
«Powders»

Development of technology, design documentation for production of powders by hydrogenation, followed by pulverization and ovalization of the particles, producing sample printer. Capacity - 10 tons / year

Ti

And alloys

Status: approved by the investment committee of TVEL, development activities 2016-2017
Launch of production: 2018

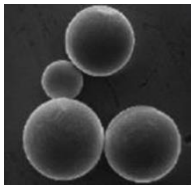


Project
«Powders»

Production of powder by gas atomization (capacity- 20 tons)

Ni | Fe | Al | Cu | Ni *And alloys*

Статус: на одобрении ИК ТВЭЛ, создание установки 2016 год
Начало выпуска продукции: **2017 г**



Project
«Powders»

Production of powder by centrifugal plasma spraying

Ti | Ni | Co *And alloys*

Status: preparation of documents 2016, creating a facility 2017
Launch of production: 2018

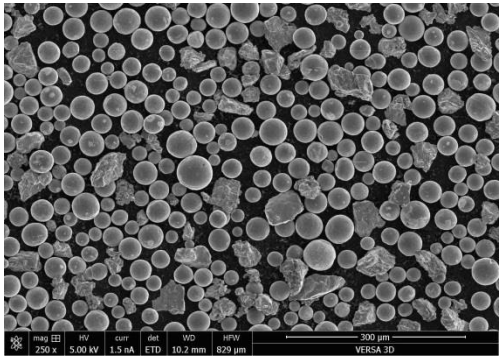
The developed machine will be adapted for EOS powders

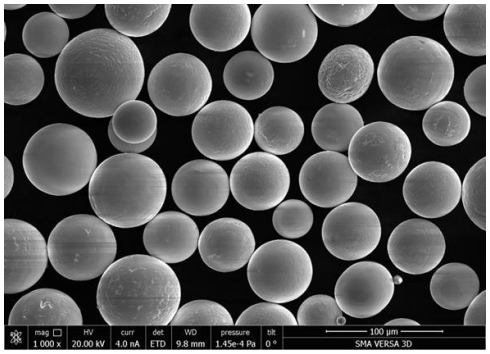
- A wide range of high quality powders.
- there is a large number of M-AM EOS machines in Russia

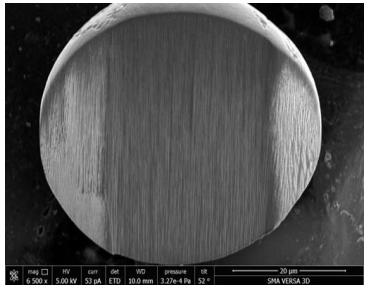
Powder production

Plasma spheroidisation equipment.

Powder





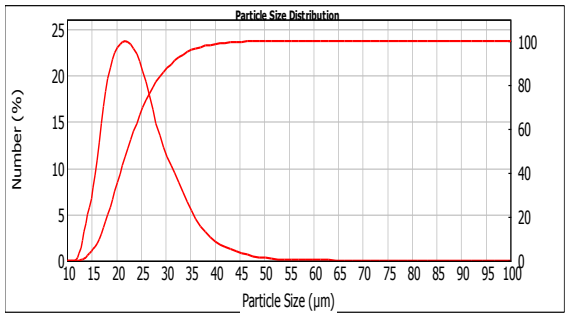


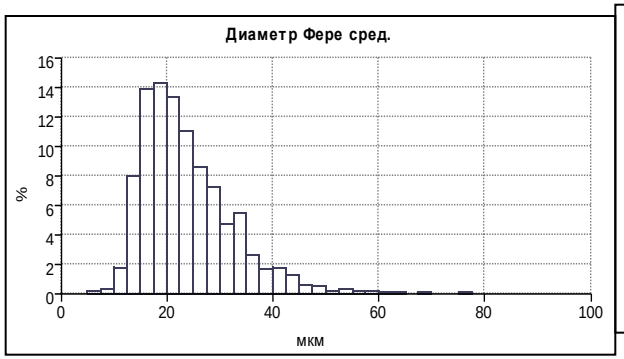
Experimental amount of spheroid Ti powder BT1-00 and BT-6 were produced. Size ~10-40 mkm.

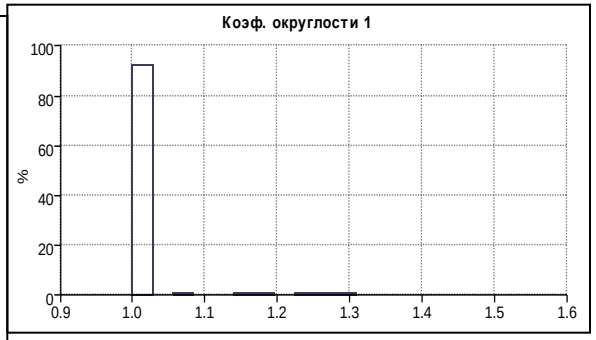
No porosity

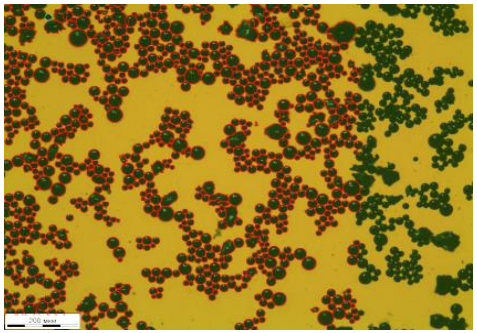
Powder

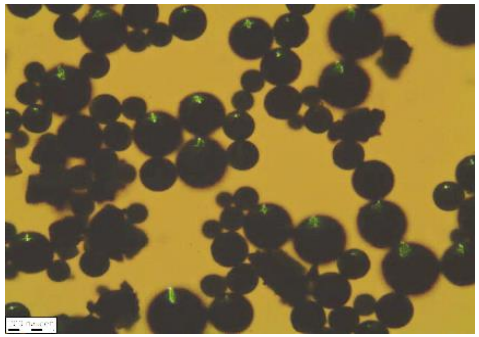
Size distribution analyses. Ti –spheroid powder external view.

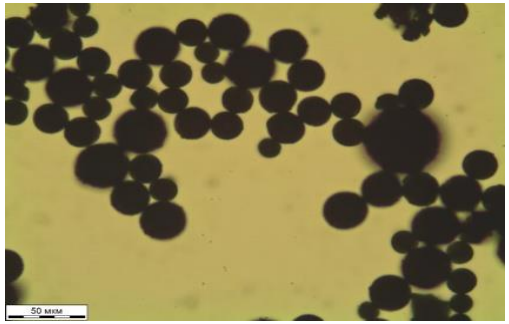








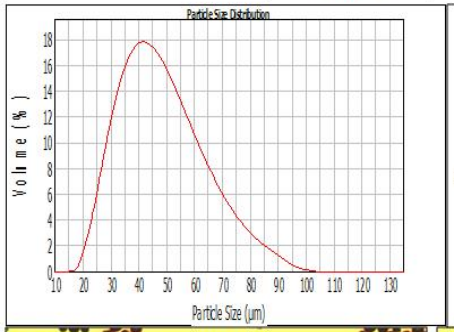


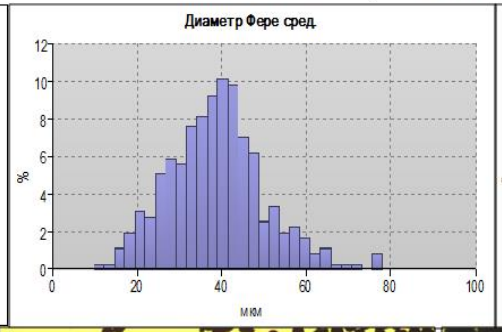


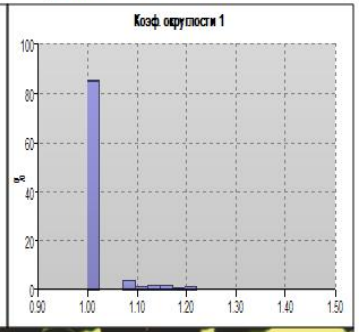
Powder

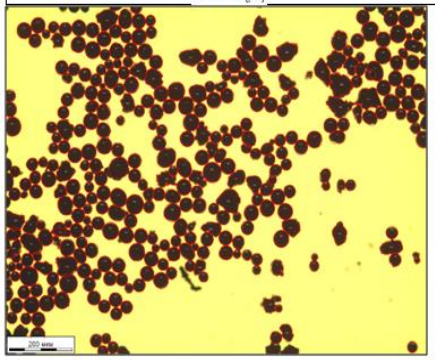
Size distribution analyses. 12X18H10T (316) –spheroid powder external view.

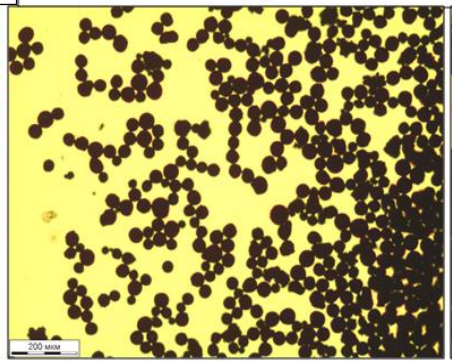
Измеряемый признак		Способ определения	Среднее значение	Диапазон значений	СКО
Средний диаметр (Фере)		Среднее из длин проекций на 64 оси	38,9 мкм	10-77 мкм	11,4 мкм
Средний диаметр		Лазерная дифракция	41,9 мкм	16-97 мкм	-
Коэф. округлости		Отношение периметра объекта к периметру круга с той же площадью	1,02	1-1,49	0,066
Содержание сферических ч-ц	Кол. %	Стат. обработка микрофото (около 400 частиц)	80,0%	*С пересчётом – 80,6%*	
	Площ. %		72,0%	*82,8%*	
	Масс. %		64,1%	*65,2%*	

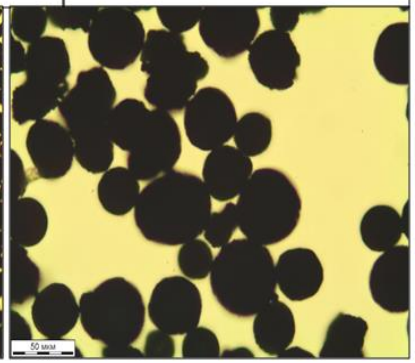






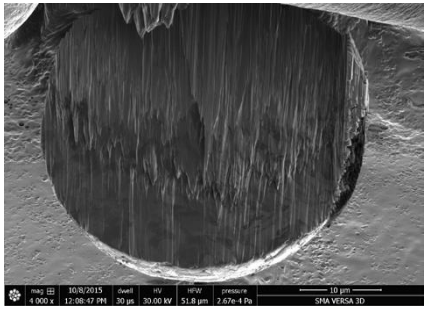






Plasma Entalphy 2,2-3,8 кWt/м^3 creates overage size about 41,9 mkm.

MEB picture - no porosity



Project organization structure

Project manager

Russia Ministry of Education

State budget

Consortium

Science&Innovations;
TVEL;
MISIS;
CNIITMASH;
UPGC;
GIREDMET;
SPbPU;
VNIIEF

Rosatom budget

IP

АО «УЭХК»
Industrial partner

- production of 3d printers in 2018

- individual components of 3D printer and documentation for them.
- prototypes of individual components of 3D printer.
- prototype of the whole 3D printer, documentation and software for it
- transfer of IP and prototype to industrial partners.

Standardization – ТК182:

Science&Innovations, VIAM

Выводы

- Создан консорциум участников (отраслевые/ не отраслевые);
- программа реализуется по графику;
- организованы работы по разработке нормативной документации.

- A consortium of participants was created (in&outside of Rosatom);
- the program is implemented in accordance with the schedule;
- development of national standard was organized.