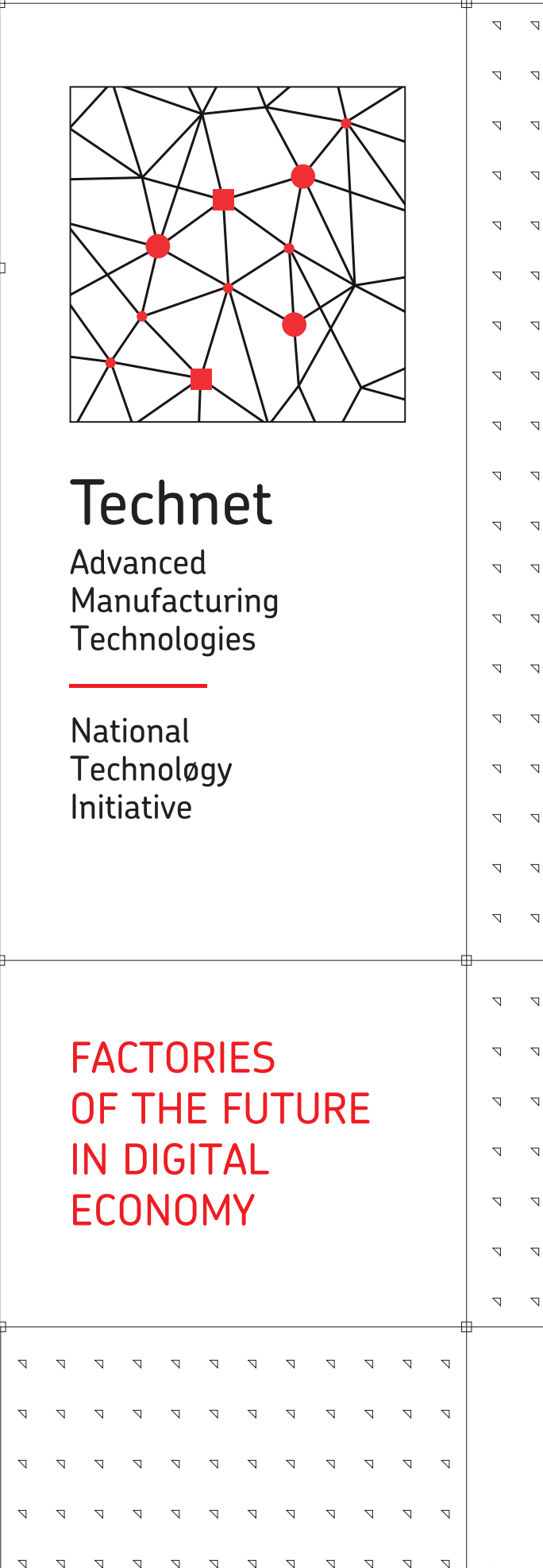


Technet

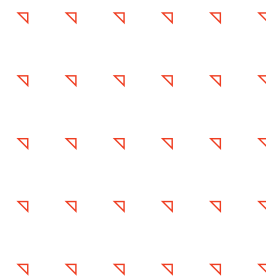
Advanced
Manufacturing
Technologies

National
Technology
Initiative

**FACTORIES
OF THE FUTURE
IN DIGITAL
ECONOMY**



1

DIGITAL
TRANSFORMATION

Today the world is on the cusp of an economy driven by a new generation of technologies, the Digital Economy, which is a data-based economy or, rather, **a smart data driven economy**. Central to this economy is the high-tech manufacturing industry which must meet the requirements of global competitiveness, efficiency and high labour productivity.

To meet these requirements, the industry is in the middle of a massive digitalization shift with widespread adoption of intelligent systems prompting the convergence of the physical and digital worlds. These enormous technological changes are accompanied by the development of fundamentally new business processes at all levels.

DIGITAL TRANSFORMATION IN THE INDUSTRY IS BASED ON THE USE OF ADVANCED MANUFACTURING TECHNOLOGIES (AMT) WHICH ARE BEING DEVELOPED AND DEPLOYED THROUGH LARGE-SCALE PROGRAMS IN LEADING ECONOMIES: “ADVANCED MANUFACTURING PARTNERSHIP” IN THE UNITED STATES, “INDUSTRIE 4.0” IN GERMANY, “FACTORIES OF THE FUTURE” IN THE EUROPEAN UNION, “MADE IN CHINA 2025” IN CHINA, ETC.

In response to the challenges of the new economic realities Russia has launched the **National Technology Initiative (NTI)**.



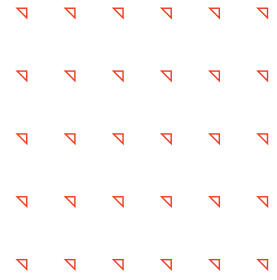
“We must be mindful of the ways we will address big issues of the future. In this regard, I propose to implement a national technology initiative. On the basis of a long-term forecast, it is critical to identify the challenges Russia will face in the next 10-15 years, to single out the state-of-the-art solutions we will need to ensure national security, to provide high standards of living and to develop next-generation high-technology industries.”

Vladimir Putin,
President of the Russian Federation,
excerpt from Address to the Federal Assembly,
December 4, 2014

The importance of advanced manufacturing technologies (AMT) within the National Technology Initiative lies in their cross-cutting impact on and applicability to the majority of NTI new markets and high-tech manufacturing industry. Only through the development, scale-up and transitioning of advanced manufacturing technologies to the Russian industrial base is it possible to make globally competitive high-tech products and provide services.

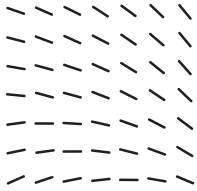
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WHAT IS THE NTI?

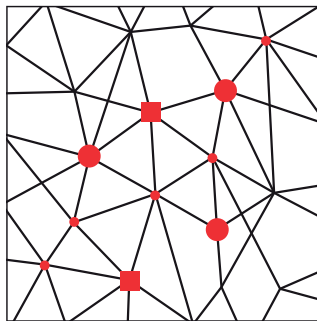


The National Technology Initiative (NTI) is a comprehensive cross-agency program to create fundamentally new markets and ensure Russia's global technological leadership by 2035 proposed by Russian President Vladimir Putin in his Address to the Federal Assembly on December 4, 2014.

A KEY FEATURE OF THE NTI IS A STRONG FOCUS ON NEW MARKETS WHICH ARE LIKELY TO CREATE NEXT-GENERATION HIGH-TECH INDUSTRIES ESSENTIAL TO ENSURE RUSSIA'S NATIONAL SECURITY AND PROVIDE HIGH STANDARDS OF LIVING.

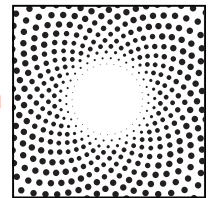


Energynet

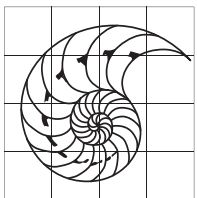


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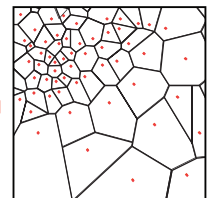
Cross-market and cross-industry focus area to provide technological support for the development of NTI new markets and high-tech manufacturing industry.



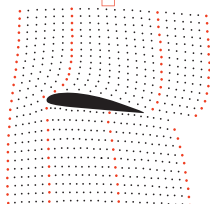
Foodnet



Safenet



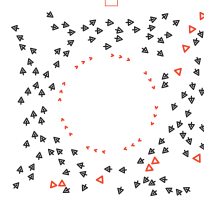
Healthnet



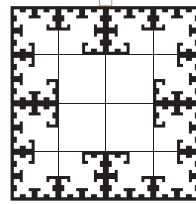
Aeronet



Marinet



Autonet



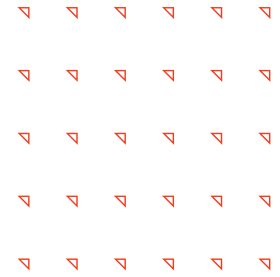
Finnet



Neuronet

3

WHAT IS TECHNET?



TECHNET (ADVANCED MANUFACTURING TECHNOLOGIES) IS A CROSS-MARKET AND CROSS-INDUSTRY FOCUS AREA TO PROVIDE TECHNOLOGICAL SUPPORT FOR THE DEVELOPMENT OF NTI NEW MARKETS AND HIGH-TECH MANUFACTURING INDUSTRY.

Technet is designed to develop, scale-up and deploy advanced manufacturing technologies. It is on September 16, 2014 that these technologies were for the first time put on top of the agenda when the Presidium of the Russian President's Council for Economic Modernization and Innovation-Based Development held a separate AMT-specific meeting. According to the NTI concept, advanced manufacturing technologies are:

digital design and simulation as a combination of Computer-Aided Design (CAD); mathematical modeling, Computer-Aided Engineering (CAE) and High Performance Computing (HPC), Computer-Aided Optimization (CAO); Computer-Aided Manufacturing (CAM) with special focus on additive manufacturing (Computer-Aided Additive Manufacturing, CAAM); (Simulation & Optimization)-Driven Bionic Design; smart models; smart digital twins; Product Data Management (PDM) and Product Lifecycle Management (PLM);

new materials: primarily but not exclusively composite materials, metamaterials, metal powders for additive manufacturing;

additive technologies: additive manufacturing systems, materials, processes and services;

CNC technologies and hybrid manufacturing, including CNC machine tools and CNC drive components;

industrial sensing: smart sensing and control systems embedded into manufacturing equipment, shop floor or factory;

industrial robotics: primarily flexible manufacturing cells;

enterprise information systems: Industrial Control Systems (ICS), Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP), Enterprise Application Software (EAS);

Smart Big Data generation, collection, storage, management, processing and transmission;

industrial Internet;

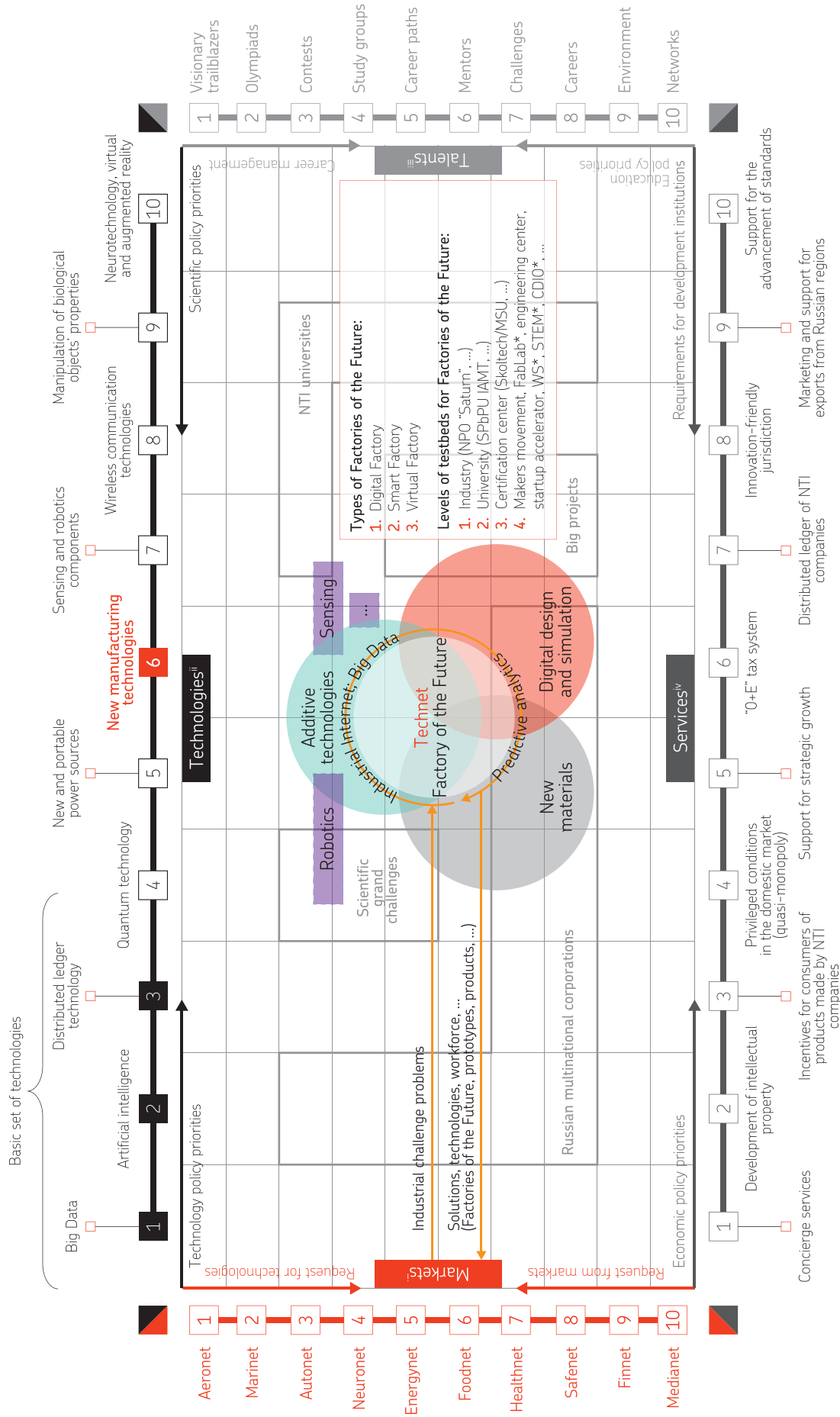
virtual and augmented reality;

expert systems and artificial intelligence.

If taken separately, none of the advanced manufacturing technologies can provide a long-term competitive advantage in the market. Complex technological solutions are therefore needed to design and manufacture a new generation of **globally competitive** products in the shortest time possible. These solutions made up of the best world-class technologies are referred to in the Technet Roadmap as **Digital, Smart, Virtual Factories of the Future.**

NTI MATRIX

National Technology Initiative



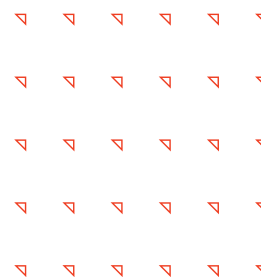
ⁱ Approved
ⁱⁱ Preliminary approval

ⁱⁱⁱ Under discussion
^{iv} Export support services

Source: St. Petersburg Polytechnic University's Institute of Advanced Manufacturing Technologies based on Agency for Strategic Initiatives data

4

MULTILEVEL STRUCTURE OF FACTORIES OF THE FUTURE



A FACTORY OF THE FUTURE IS A CERTAIN KIND OF BUSINESS PROCESS, A METHOD OF COMBINING BUSINESS PROCESSES, WITH FOLLOWING FEATURES:

- creating digital platforms which are a kind of ecosystems of advanced digital technologies. By leveraging predictive analytics and big data, the platform approach enables integration of spatially distributed designers and manufacturers, and allows to increase flexibility and customization while fulfilling customer requests;
- developing a system of digital models of both newly designed products and production processes. Digital models must have a high level of adequacy to physical products and actual processes enabling the convergence of the physical and digital worlds to generate synergy effects;
- digitalization of the entire product lifecycle, from concept and design to production, use, after-sales service and recycling. The later changes to a product in the lifecycle are made, the higher are the costs due to those changes. Investing more up front to get the design correct moves changes to an earlier point in the lifecycle where they are less expensive. The qualities of a product that make it globally competitive and appealing to consumers are also determined early in the product lifecycle, during the design phase before a physical representation is produced.

FACTORIES OF THE FUTURE NECESSITATE FUNDAMENTALLY NEW COMPETENCIES. AMONG THE CORE ONES ARE:

- quick and customizable response to market or customer request;
- application of systems engineering to address complexity, look at a problem in its entirety and consider all the interacting components integrated into a whole;
- constructing a multilevel matrix of targets and constraints that underpins the new paradigm of digital design and simulation. This paradigm allows to reduce risks, full-size experiments and rework inherent in the conventional process where engineers fine-tune and finalize various designs through expensive and time-consuming physical testing;
- development and validation (comparison with experimental data) of smart models, i.e. mathematical models with a high level of adequacy to physical products and actual processes;
- change control throughout the lifecycle;
- digital certification based on thousands of virtual tests of both individual components and the entire system as a whole.

MULTILEVEL STRUCTURE OF FACTORIES OF THE FUTURE

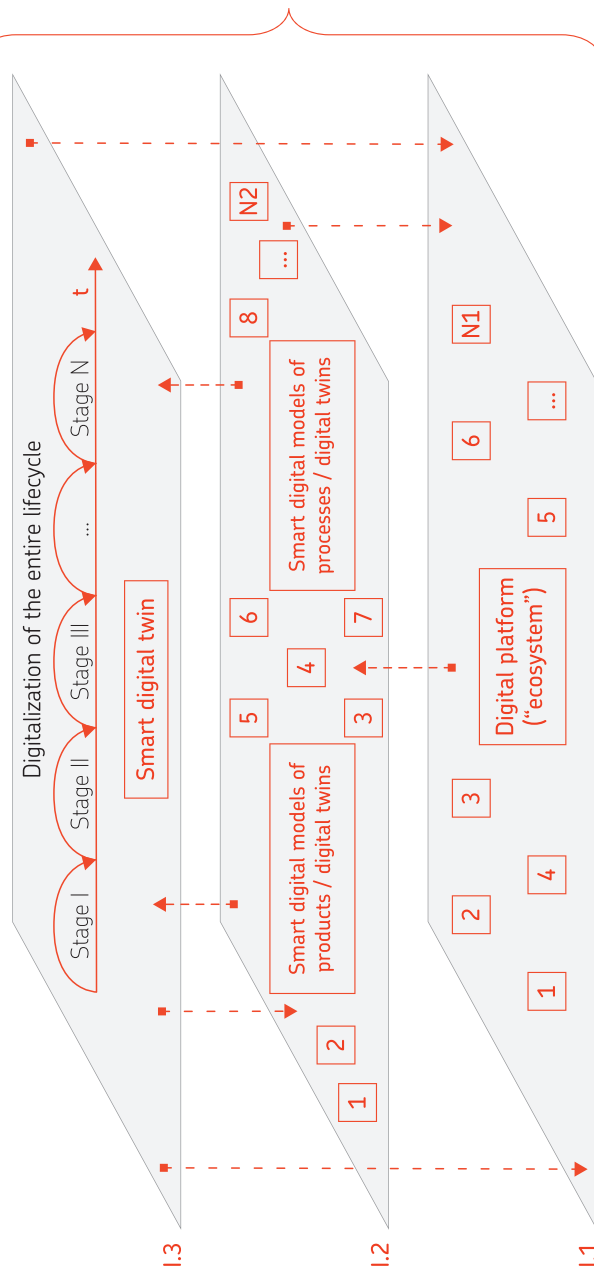
National Technology Initiative

- I. A Factory of the Future is a certain kind of business process, a method of combining business processes, with following features:
 - I.1 Massive digitalization of the entire product lifecycle (CAx, PLM, MES, ERP, ...)
 - I.2 Development of systems of digital models of products and processes;
 - I.1.1 Creation of a digital platform ("ecosystem");

- II. Workforce for Factories of the Future:
 - 1. "Elite special forces in engineering";
 - 2. Federal state educational standards (applied master's programs, ...);
 - 3. Professional standards;
 - 4. ...

- III. Legislative and regulatory framework:
 - 1. Quick wins >> Best practices >> Regulations >> ...
 - 2. Certification ("digital certification" based on validated mathematical models);
 - 3. ...

TECHNET (ADVANCED MANUFACTURING TECHNOLOGIES)

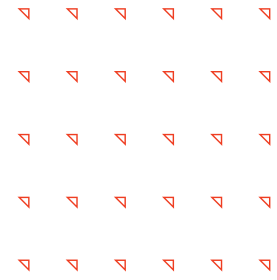


- Core competencies:
1. Industrial challenge problem: quick and customizable response to customer request;
 2. Systems engineering;
 3. Multilevel matrix of targets and resources/ constraints (~10⁴-10⁵);
 4. Development and validation of highly adequate mathematical models;
 5. Lifecycle (CAx, PLM, MES, ERP, ...);
 6. Input and output quality control (widespread use of virtual tests – digital certification);
 7. Incentive program;
 8. ...

Source: St. Petersburg Polytechnic University's Institute of Advanced Manufacturing Technologies based on draft documents prepared during a series of deliberations between Andrey Belousov, Aide to the President of the Russian Federation, and the leadership of the NTI Technet Working Group.

5

FACTORIES OF THE FUTURE. KEY CONCEPTS



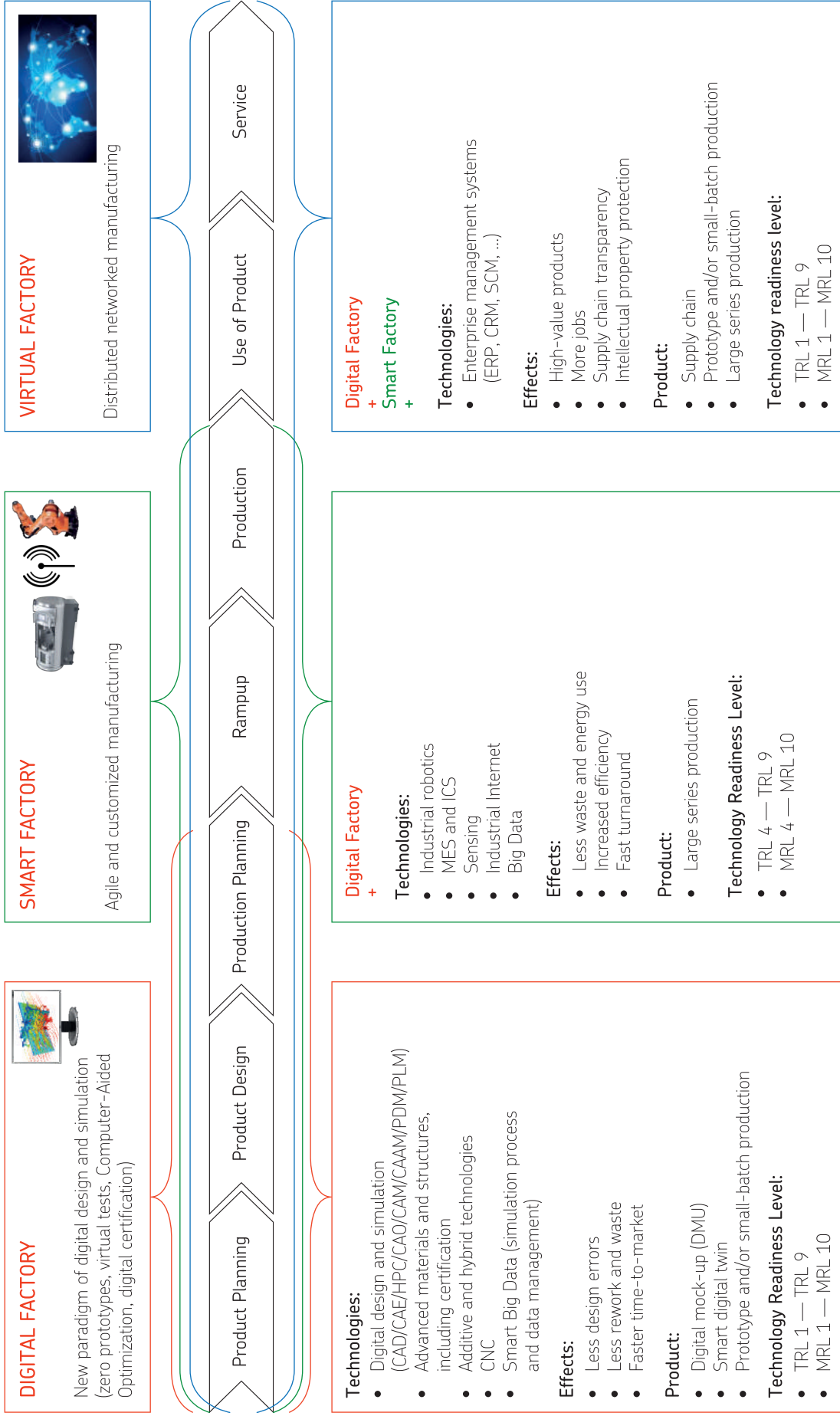
DIGITAL FACTORIES are complex technological solutions that ensure design and manufacture of globally competitive next-generation products in the shortest time possible. They span the product lifecycle from the R&D and product planning stage, where product basic characteristics are laid down, through the development of a digital mock-up (DMU) and digital twin up to making prototypes and small-batch production (paperless production, digital thread). A Digital Factory entails smart models of products (e.g. machines, structures, units, instruments, installations, etc.) developed through the application of the new paradigm of digital design and simulation called "Smart Digital Twin - [(Simulation & Optimization) Smart Big Data]-Driven Advanced (Design & Manufacturing)."

SMART FACTORIES are complex technological solutions that ensure manufacture of globally competitive next-generation products from workpiece to finished part in the shortest time possible. Smart manufacturing is distinctive in that it provides a high level of automation and robotics which drastically reduce quality losses due to human errors (workerless production). Smart Factories usually use digital mock-ups, digital twins and prototypes developed by Digital Factories. A Smart Factory entails manufacturing equipment – machine tools with computer numerical control, industrial robots, etc. – as well as industrial control systems (ICS) and manufacturing execution systems (MES).

VIRTUAL FACTORIES are complex technological solutions that ensure design and manufacture of globally competitive next-generation products in the shortest time possible by linking Digital and/or Smart Factories into a distributed network. A Virtual Factory entails enterprise application software (EAS) which allows to develop and use virtual models of organizational, technological, logistical and other processes as a single object at the level of global supply chains (supply => production => distribution and logistics => sales => after-sales service) and/or at the level of distributed production assets.

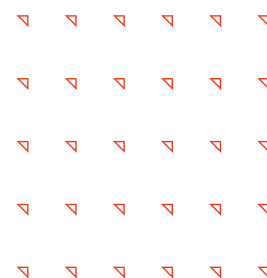
COMPONENTS/LAYERS OF THE FACTORIES OF THE FUTURE

National Technology Initiative



Source: St. Petersburg Polytechnic University's Institute of Advanced Manufacturing Technologies based on European Commission data

6

TECHNET
ROADMAP
GOALS

The National Technology Initiative's Technet (Advanced Manufacturing Technologies) Roadmap was approved on February 14, 2017 at a meeting of the Presidium of the Russian President's Council for Economic Modernization and Innovation-Based Development chaired by Prime Minister of the Russian Federation Dmitry Medvedev.



“The Technet Roadmap focuses on the development of advanced manufacturing technologies. These technologies are a whole set of solutions aimed at revolutionizing manufacturing, making it more efficient and intelligent through the digitalization of the entire product lifecycle, from concept to recycling.”





Dmitry Medvedev,
Prime Minister of the Russian Federation

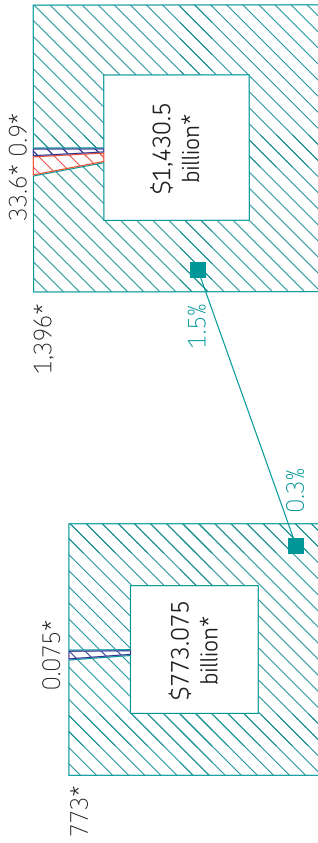
The NTI Technet Roadmap aims to attain the following goals:

- to develop a set of core competencies that ensure the integration of advanced manufacturing technologies and business models for their promotion as Factories of the Future of first and subsequent generations;
- to create a new generation of globally competitive customized/ personalized products for NTI markets and high-tech manufacturing industry.

National Technology Initiative

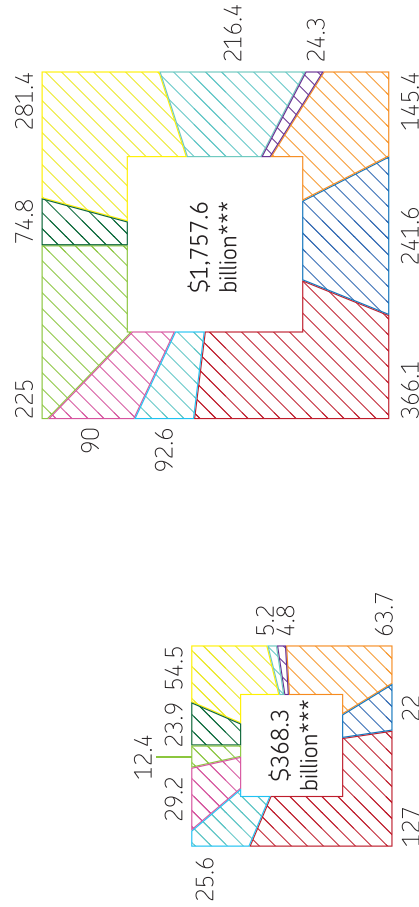
GLOBAL MARKETS OF FACTORIES OF THE FUTURE

-  Design and engineering services market
-  Accelerated certification system and services market
-  Educational services market**
-  Russia's share of the design and engineering services market



GLOBAL MARKETS OF ADVANCED MANUFACTURING TECHNOLOGIES

-  Digital design and simulation
-  CNC machine tools
-  Additive technologies
-  Hardware, including High Performance Computing (HPC)
-  New materials
-  Industrial robotics
-  Manufacturing Execution Systems (MES) and Industrial Control Systems (ICS)
-  Enterprise Application Software (EAS)
-  Big Data
-  Industrial Internet



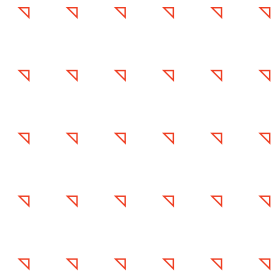
* Calculations based on estimates by the NTI's Technet Working Group of the average share of design and engineering in investment expenditures by the manufacturing sector (7%). Investment expenditures are estimated at 134.5 billion rubles, or \$2.2 billion (average weighted exchange rate for 2015 under IFRS; 1 USD = 60.96 RUB). According to the Russian Federal State Statistics Service, investment expenditures across all sectors of the Russian economy totaled 14.6 trillion rubles in 2015.

** Figures apply to Russia only.

*** Total based on data from CIMdata, Eurasian Economic Commission, Gardner Business Media, Wohlers Associates, IDC, PR Newswire, BusinessWire, Sanford L. Moskowitz, WinterGreenResearch, MarketsandMarkets, Gartner, Allied Market Research, Skoltech.

7

FACTORIES OF THE FUTURE. TESTBEDS



To create Factories of the Future by selecting and combining various cutting-edge technologies with proprietary cross-industry know-how, there needs to be a place where they could be tested in a real-life environment. For these purposes, the Technet Roadmap provides for the establishment of three testbeds in 2017-2019:

- testbed for the generation of Digital, Smart, Virtual Factories of the Future hosted by Russia's first Institute of Advanced Manufacturing Technologies at St. Petersburg Polytechnic University (SPbPU IAMT) with the participation of the CompMechLab group;



-
- testbed for the Factory of the Future hosted by UEC-Saturn;



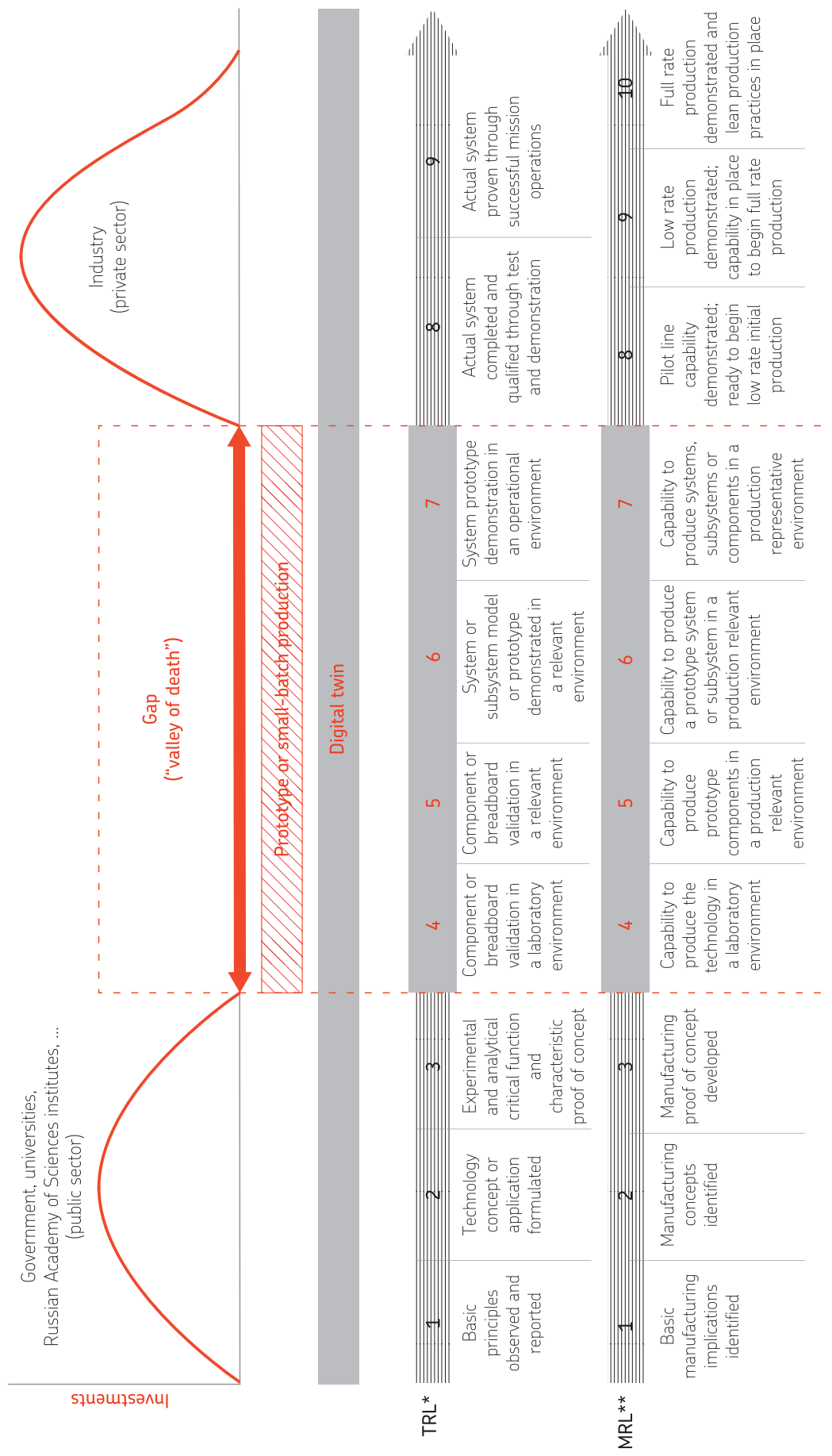
-
- centers for digital experiment based certification hosted by the Skolkovo Institute of Science and Technology (Skoltech) and Lomonosov Moscow State University (MSU).



LOMONOSOV MOSCOW STATE UNIVERSITY

FUNCTIONS OF TECHNET TEST BEDS

National Technology Initiative



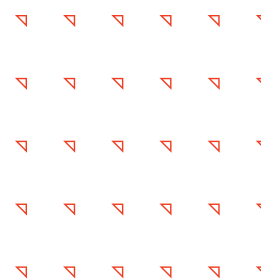
* Technology Readiness Level.

** Manufacturing Readiness Level.

Source: St. Petersburg Polytechnic University's Institute of Advanced Manufacturing Technologies based on Advanced Manufacturing Partnership and NASA data

8

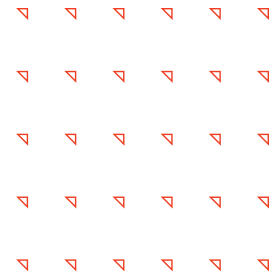
PRIORITY ACTIONS FOR THE IMPLEMENTATION OF THE TECHNET ROADMAP IN 2017-2019



1. Create five Factories of the Future in high-tech manufacturing industry.
2. Establish a national center for testing, verification and validation of software in the field of computer and supercomputer engineering, a national networked center for reverse engineering and prototyping, and two centers for AMT transfer, research, training and Technet export support (in China and Europe).
3. Launch an accelerator program aimed at supporting and promoting businesses that develop new solutions or competencies in advanced manufacturing (accelerator program supported by St. Petersburg Polytechnic University's Institute of Advanced Manufacturing Technologies, UEC-Saturn, Skolkovo Foundation, RVC, other development institutions and universities).
4. Submit a set of recommendations to amend provisions on advanced manufacturing in government-led programs.
5. Promote advanced manufacturing technologies.
6. Form a Russian nationwide Technet association, etc.

9

NTI TECHNET WORKING GROUP



Alexey Borovkov

Leader (co-head) of the Working Group,
Vice-Rector for Advanced Projects
of St. Petersburg Polytechnic University



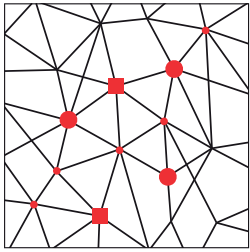
Vasily Osmakov

Co-head of the Working Group,
Deputy Minister of Industry and Trade
of the Russian Federation

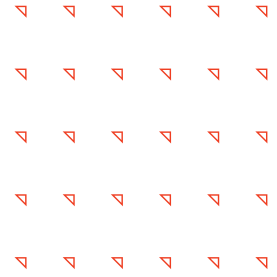


ORGANIZATIONS PARTICIPATING IN THE WORKING GROUP:





NOTES



Technet

National
Technology
Initiative

Technet:
the mesh- and network-
inspired brand identity

The core of the brand identity is a finite element mesh used to develop finite element models. The finite element method is a de facto global standard in digital design and simulation, a cross-cutting technology whose application is the starting point for the creation of globally competitive products for the markets of the future and high-tech manufacturing industry. The nodes of the finite element mesh symbolize the distributed system of Digital, Smart, Virtual Factories of the Future which can be dynamically formed from advanced manufacturing technologies and world-class competencies. The logo visualizes the evolution from the finite element mesh to the distributed network of Factories of the Future.

www.nti.one
www.rvc.ru/nti
www.technet-nti.ru

Prepared and printed with the support of
PJSC UEC-Saturn and the CompMechLab group