American Journal of Information Science and Technology
2024, Vol. 8, No. 3, pp. 73-83
https://doi.org/10.11648/j.ajist.20240803.13

Review Article

Research on Disruptive Technology and Future Manufacturing Developments

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Abstract

Industrial transformations, that are triggered by disruptive technologies, have the property of persisting over time. They may represent new ways to do existing activities, or they may represent genuinely new activities. In order to occupy a dominant position in future developments, many different countries, around the world, are actively embracing disruptive technologies. This is manifested by the pre-emptive incubation of new industries. The present paper is based upon an extensive literature search. It is argued that disruptive technologies, in particular, those that are associated with synthetic biology, aerospace manufacturing, and zero-carbon manufacturing, have been selected from a strategic perspective. Through a combination of qualitative descriptions and case studies, the significance and importance of the roles played by biomanufacturing, aerospace manufacturing and green/low-carbon manufacturing, in modern life, are elaborated upon. This allows the case to be made about the three modes of manufacturing that are noted above, that they are subverting traditional manufacturing. Indeed, they are gradually (and sometimes quickly) becoming new manufacturing models. In addition, we note that manufacturing based on new energy sources, intelligent (i.e., robotic) manufacturing and virtual (i.e., data based) manufacturing, (delete the space) are also likely to become highly important topics, and they will be worthy of attention in future considerations.

Keywords

Disruptive Technology, Biological Manufacturing, Space Manufacturing, Green and Low-Carbon Manufacturing

1. Introduction

Over history, changes have occurred, from the agricultural age, the industrial age, to the information age, and now the bioeconomic era. Human beings have moved from an agricultural civilization to a modern science-based civilization, where the main factors driving changes are developments in science and technology. The implementation of disruptive technologies is the main force driving human development into new eras.

1.1. Disruptive Technology Development Persists over Time

In general, disruptive technologies can be understood as technologies that reshape the human world and change the course of history. In 1995, the Harvard University Professor, Clayton M. Christensen, first mentioned disruptive technology in his book "The Innovator's Dilemma", which refers to technologies that replace existing mainstream technologies in unexpected ways, and the destructive and transformative ideas contained in them can be traced back to the creative

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Received: 2 January 2024; **Accepted:** 16 January 2024; **Published:** 20 September 2024

destruction proposed by the economist Schumpeter in 1912 [1]. As early as 2013, the McKinsey Global Institute released the research report "Disruptive technology: Advances that will transform life, business, and the global economy", and predicted that twelve technologies such as the mobile internet, artificial intelligence, and the internet of things will be future disruptive technologies. It was also pointed out that a disruptive technology should have the following characteristics: make a great change in the price and performance of products in the industry, have a wide impact on the industry and enterprises, have a significant impact on the social economy, and have the potential to greatly change the status quo of human life [2].

There are generally four paths for the emergence of a disruptive technology: first, breakthroughs in basic major scientific principles, which will quickly become the consensus after the emergence of such technologies, with the effect of subverting research, for example by curing existing genetic diseases, using the new technology of gene editing. The second is the technology generated by innovation, which has the characteristics of multidisciplinary, multi-domain and multi-technology cross-integration. This can create new value, such as new manufacturing, based on synthetic biotechnology. Third, a new application of an existing technology can amount to emergence of a disruptive technology. An example of this is the internet, which has become a key mode of interpersonal communication, breaking the boundaries of physical space through interconnection, and realizing barrier-free communication. The fourth is to solve problems with novel ideas and promote the production of a disruptive technology. An example is SpaceX using innovative thinking to invent the Falcon 9 technology of reusable rockets, making space travel enormously less expensive.

1.2. Disruptive Technologies Have a Positive Impact on the Future Global Economy

In previous eras, disruptive technologies have played a positive role. By aiming to provide for the future, each country participates in foresight activities and lays out various industries spawned by cutting-edge technologies. Disruptive technologies give rise to innovative industries that can help countries seize the leadership/first-mover advantage, and promote rapid economic development. In the McKinsey report "Disruptive technology: Technological Advances Transforming Lives, Business, and the Global Economy", 12 disruptive technologies are presented that are forecast to determine the economy in 2025. The forecast data express the positive impact of technology on future human life and global economic development (Table 1).

Table 1. *Outlook 2025: 12 Disruptive technology Shaping the Future Economy [2].*

Industry Field	Estimated upper and lower limits of potential economic impact by 2025 and key data	Main Technologies
Mobile Internet	\$3.7~10.8 trillion; Remote health monitoring reduces healthcare costs by 20%	Wireless devices, computing and storage
Knowledge work automation	\$5.2~6.7 trillion; Increase the full-time labour force by 110 ~ 140 million	Artificial intelligence, machine learning
Internet of Things	\$2.7~6.2 trillion; Manufacturing, health care, mining operating costs savings of up to \$36 trillion	Sensors, wireless communication
Cloud	\$1.7~6.2 trillion; Increase productivity by 15%~20%	Cloud management software, data centre hardware
Advanced robotics	\$1.7~4.5 trillion; Improving the lives of 50 million people with reduced mobility	Wireless technology, machine vision
Autonomous cars	\$0.2~1.9 trillion; Saved 30,000~150,000 lives	machine-to-machine communication
The next generation of genomes	\$0.7~1.6 trillion; Extend life expectancy by 75%	DNA sequences, big data analysis
Energy storage technology	\$0.1~ 0.6 trillion; 40%~100% of new cars are electric or hybrid type	Battery technology, mechanical technology
3D printing	\$0.2~0.6 trillion; Save 35%~60% of the cost	Laser sintering, fused deposition
Advanced materials	\$0.2~0.5 trillion; increased 20 million new cancer-targeted drugs	Graphene, carbon feeding tubes
Advanced oil and gas exploration and production	\$0.1~0.5 trillion; An additional 3.2 ~ 6.2 billion barrels of crude oil	Horizontal drilling, hydraulic fracturing

Industry Field	Estimated upper and lower limits of potential economic impact by 2025 and key data	Main Technologies
Renewable energy	$0.2~0.3 trillion; Reduce carbon emissions by 1 ~ 1.2 billion tons per year	Photovoltaic cells, wind turbines

Note: The estimated upper and lower limits of potential economic impact by 2025 include consumer surplus, mean predicted value earned as a result of innovation.

1.3. Disruptive Technologies Bring Opportunities for Future Industrial Development

The opportunities brought by disruptive technologies to future industrial development are mainly reflected in the following two aspects. First, the major innovative characteristics of disruptive technologies, themselves, will give birth to new future industries. In particular, revolutionary disruptive technologies have their own technological development paths, product forms, and business models, which inevitably are different from traditional technologies. As a consequence, new products, new formats and even new industries will emerge. Second, major breakthroughs in disruptive technology can help reduce the uncertainty of future industrial development and promote its rapid development. The reason why it is called "future industry" is very important because an industry, in the early stage or even embryonic stage of industrial development, needs to be nurtured and developed for a long time. During this process, once the relevant disruptive technology achieves breakthroughs, it is expected to change the development cycle of future industries, push them from theoretical ideas to the stage of technology industrialization and industrial scale, and may even grow into a leading industry of the national economy.

2. The Developmental Trend of Disruptive Technologies

As a dynamical phenomenon, the success of disruptive technologies is difficult to predict with uniform criteria. In terms of a significant impacts on real life, we note the following. Synthetic biotechnology subverts traditional biotechnology and pushes the development of biological science to a new stage. Aerospace technology is no longer out of reach, and has become a practical technology in people's daily lives. Zero-carbon technology will determine the future of life. From the perspective of national strategy, the above technologies are among the strategic deployments of major countries, which is enough to show their importance. Here, the development of synthetic biology, aerospace technology and zero-carbon technology are summarized.

2.1. Synthetic Biotechnologies

We are in the third biotechnological revolution, after the discovery of the double helix structure of DNA, and the successful outcome of the Human Genome Project, the development of synthetic biology is more in the middle and lower reaches of the industrial chain, but it can achieve the effect of bringing economic increments to social development. According to statistics [3], the economic impact of synthetic biology and biomanufacturing is expected to reach $100 billion by 2025. As far as China is concerned, 18 provinces have included synthetic biology in the 14th Five-Year Strategic Development Plan [3]. China has generally planned the development path of synthetic biology from the aspects of platform construction, technological breakthroughs and industrial applications.

2.1.1. Cutting-Edge Technologies in Synthetic Biology Are in the Ascendant

Development of Synthetic biology is based on the integration of disciplines and technical fields. The underlying development is based on basic technologies such as DNA design and synthesis, gene sequencing and gene editing. The progress and application of underlying technologies are rapidly promoting the development of the industry, such as DNA synthesis and assembly technology, to quickly and efficiently construct complex genetic building blocks. Biocomputer-aided design and manufacturing tools facilitate the process of designing and building biological systems. The emergence of synthetic biology foundries has made it possible to build, test, and optimize living organisms in rapid and high-throughput quantities.

At the same time, with the continuous development of computational biology, omics technology, artificial intelligence, 3D bioprinting and precision fermentation, synthetic biology research, especially applied research, has entered a stage of rapid development.

2.1.2. The Cross-Field Integration of Synthetic Biology Is Developing Rapidly

Based on the development of the underlying technology and research tools, synthetic biology has shown great application potential, giving birth to a large number of product-oriented companies. Research products have been commercialized in the fields of medical health, agriculture, food, consumer goods, chemical materials and other fields. The following highlight the development of synthetic biotechnology applications in healthcare, agriculture and food (Table 2).

Table 2. *Application development of synthetic biotechnology in healthcare, agriculture and food [4].*

Field	Subdivision	Main technology/Application direction	Commercial case
Healthcare	RNA drugs	Oligoglycotide drugs mRNA drugs	The mRNA-1273 developed by Moderna (United States company) completed the sequence design and production of a Covid-19 vaccine in 25 days, and completed the sequence design to the first subject administration in a record-breaking 63 days
	Gene editing	Zinc finger nuclease (ZFN) Transcription activator-like effector nucleases (TALEN) Short palindromic repeats (CRISPR) that are periodically aggregated	Swiss company CRISPR mainly researches CRISPR/Cas9 gene editing technology and its application in the treatment of β thalassemia, haemophilia, Duchenne muscular dystrophy and other diseases; Sangamo focuses on zinc finger protein technology (ZFP), and is a representative company in the world for the application of zinc finger protein technology, with pipeline layout in hemophilia, hemoglobinopathies, central nervous system and other diseases
	Cell therapy	CAR-T technology	Kymriah Novartis, Yescarta and Tecartus developed by Gilead's Kite have been approved by the FDA. In 2020, China Legendary Biotech submitted a marketing application to the FDA for LCAR-B38M CAR-T, the first self-developed cell therapy in China
	In vitro testing	CRISPR/Cas9-based virus detection products	Sherlock, a U.S. company founded by Zhang Feng and others, and Mammoth, a U.S. company founded by Jennifer Doudna and others, both of which have developed test kits for the COVID-19 virus, can provide test results within an hour
Agriculture	Increased crop yields	Increased yield of plant crops Increased livestock production	Pivot Bio, a U.S. company, pioneered the development of microbial nitrogen fixation products for corn crops; Agrivida has developed a new generation of enzyme solutions to meet animal nutrition and health needs, the first product, Grain enzyme phytase, which benefits the livestock industry by improving the digestibility of animal feed and reducing nutritional inhibitors in animals
		Pest control	AgBiome, an American company, is committed to using microbial communities for plant genetic trait analysis and biopesticide research and development, and developing new crop protection products; The British company Oxitec controls and reduces pests by modifying their genetics
Food	Meat and dairy products	Artificial meat technology Fungal proteins	Impossible Foods has long been committed to the research and development of artificial meat technology; Nature's Fynd of the United States ferments and produces fungal proteins by modifying the microorganism Fusarium xanthococcus; Two U.S. companies, Perfect Day and Clara Foods, are targeting milk, egg white, and cheese products to synthesize protein products through synthetic biotechnology
	Beverage	New wines	American company Endless West produces new wines by blending them with grain alcohol by replacing the flavor and aroma molecules contained in traditional wines by using natural plant and yeast extracts
	Food safety, flavorings and additives		Mars collaborated with Thermo Fisher Scientific to design and produce an enzyme that neutralizes aflatoxin; Irish company Miracaculex and U.S. company Milis Bio are developing protein sweeteners; The main products of the Swiss company Evolva are biological vanillin, resveratrol, L-arabinose and steviol glycosides; The main products of China Shanghai Aipu Fragrance Company are vanillin and ethyl marriage

2.1.3. Capital to Help the Transformation of Synthetic Biotechnology Achievements

Even in 2021, when unlisted markets were sluggish, global synthetic biology startups still created a record high in industrialized financing in the field, with a growth rate of $18 billion and a year-on-year increase of 130% [5]. A new set of data [6] shows the following. In the first quarter of 2023, global synthetic biology startups have raised about $2.8 billion, with application areas receiving the most funding, approaching $1.8 billion. Among them, the health and pharmaceutical sector received $1.4 billion, which is the direction that receives the most financing for the application field. In addition, more than 20 synthetic biology companies related to climate technology will emerge in 2023.

2.2. Aerospace Technology

Aerospace technology is mainly composed of two parts: satellite manufacturing and aviation aircraft manufacturing. With continuous breakthroughs of satellite technology, especially the interconnection of a new generation of communication systems, and the gradual development of space energy technology, as the strategic focus of all countries, the use of space has changed from the traditional model of tall, noble and few to the business model of good, small and cheap.

2.2.1. The Commercial Process of Low-Orbit Satellite Communications Has Accelerated

Low-orbit space is the focus of global space development, and the mass deployment of low-orbit satellites has entered a peak period. Because low-orbit satellites have obvious advantages in launch cost and global coverage, and have great durability, low transmission delay and low-power usage, the low-orbit broadband satellite network system has shown a vigorous trend of development in the world. Internationally, the Iridium program, Starlink program, OneWeb constellation program and Amazon Kuiper plan have emerged one after another.

China actively promotes giant low-orbit satellite plan to gain a market competition opportunity. In terms of project promotion, the two major groups of aerospace science and technology and aerospace science and industry, as pioneers in the field of low-orbit communication satellites in China, have respectively launched the low-orbit communication projects Hongyan and Hongyun plans. In 2021, China Satellite Network Group Corporation was established to coordinate the development of domestic low-orbit communication satellites, and “GW plan” is currently the largest low-orbit communication satellite in China. In terms of private investment, the private capital low-orbit satellite company represented by Galaxy Aerospace will effectively promote the commercialization process of China's satellite Internet [7].

2.2.2. Recyclable Rocket Technology Is Maturing

Rocket recovery technology is a disruptive technology that has attracted worldwide attention in recent years. Different countries are exploring this. As the main launch vehicle for space activities, rocket engines were initially disposable consumables, but with the continuous improvement of technology, the cost of rocket liftoff has decreased, which has enabled commercial development. As a pioneer in the field, SpaceX's Falcon 9 completed its first launch as a resalable medium launch vehicle in June 2010 and its first recovery in December 2015. At the same time, SpaceX proposed the Low-orbit Internet Plan in 2014, the Starlink Plan, which plans three phases and will launch nearly 42,000 low-orbit satellites. During the implementation of the Starlink Plan, SpaceX has been committed to reducing the cost of satellite launches, forcing the birth of multiple satellites with one stone technology. In April 2020, the US Space Exploration Technology Corporation used the “One Arrow, Multiple Satellites” technology to use a Falcon 9 rocket to send the seventh batch of 60 satellites of the Starlink program into space, continuing to build a global satellite Internet. In September 2021, SpaceX flew its first purely commercial manned spaceflight mission using the Dragon spacecraft and Falcon 9 rockets, sending four ordinary people into space for the first time.

At the same time, Europe, Japan, Russia and other countries are making efforts in this field. China has a gap with the United States and other countries in rocket recovery, but with unremitting efforts in recent years, great progress has been made. In addition to the national Long March launch vehicle, private aviation enterprises performed brilliantly. In August 2019, Linker Aerospace successfully achieved the third launch and recovery test of the kilometer-class recoverable rocket RLV-T5. RLV-T5 is currently the largest and most technologically advanced recoverable rocket in China, with novel and practical technology, low test cost, can be reused many times, and rapid iteration. The rocket is mainly for the development of suborbital recoverable rockets and orbit-stage recoverable rockets in the future. In October 2021, Deep Blue Aerospace Nebula-M-1 test arrow successfully completed the 100-meter-class vertical takeoff and landing flight test, with a maximum flight altitude of 103.2 meters. The Nebula-M rocket achieves a new breakthrough in the successful vertical recovery height in the field of liquid oxygen kerosene rockets.

2.2.3. China, Japan and South Korea Focus on Space Energy Technology

In addition to space exploration by rockets and satellites, the rational and effective use of space energy is also the focus of strategic competition among countries. As the main technical means to explore space energy, space solar power station refers to the power system that converts solar energy into electricity in space and then transmits it to the ground through wireless energy transmission [8]. The United States was the first to conduct space solar power plant research and is still the leading country in this technology. In May 2020, the United States launched a reusable orbital test vehicle, and the X-37B assumed the role of using solar power to generate electricity and transmit energy back to the ground. Russia, Europe and other countries are also involved in this field. At this stage, the research focus of space solar power plants has gradually shifted to Asia, with China, Japan and South Korea having the core strength. Japan is a world leader in the research and testing of space energy technology, especially microwave wireless energy transmission technology; South Korea has been paying attention to the development of space solar power plants since 2016, and in February 2019, it first demonstrated its space solar power plant concept K-SSPS, and simultaneously proposed the development plan of South Korea's space solar power plant for 2020-2029.

Since 2008, China has planned the establishment of space solar power plants from a strategic level, and in 2014 put forward the development plan and roadmap of China's space power stations, pointing out that it will strive to start building megawatt-level space solar power stations in 2030, and have the ability to build gigawatt-level commercial space solar power plants by 2050. In terms of specific implementation, at the end of 2018, the world's first full-link, full-system Omega space solar power plant ground demonstration and verification system Day-by-Day Project was launched in Xi'an, and in June 2021, the construction of the country's first space solar power station experimental base was launched, which will provide a space place for the early demonstration of space solar power station, wireless microwave energy transmission and space information network and other technologies [8].

2.3. Zero-Carbon Technology

With an increasingly harsh ecological environment, controlling carbon emissions has become a focus issue for future global development. The Paris Agreement, which came into force in 2016, called for limiting global warming to 1.5℃ above pre-industrial levels and reaching net-zero carbon emissions by 2050. Based on achieving this goal, countries around the world have quickly focused on hydrogen energy technology, electrochemical energy storage and other fields, and companies in various countries have also responded positively to this goal.

2.3.1. Hydrogen Technology Is the Focus of Global Attention

As an alternative energy source, hydrogen energy can not only solve the energy crisis, but also be key for building a clean, low-carbon, energy system that is safe and efficient. In the face of excessive carbon emissions, countries have rushed to propose zero-carbon strategies and actively deploy hydrogen energy development. As the first country to deploy hydrogen energy, the United States took the lead in proposing a “hydrogen economy”. The EU also laid out hydrogen energy research very early, especially for fuel cells and hydrogen energy technology [9].

China, Japan and South Korea, as major carbon emitting countries, are fully cooperating with international carbon control measures to carry out the research and development and application of hydrogen energy technology. Japan has an earlier layout in hydrogen energy research and development, so it has strong technical research and development strength, not only has a strong R&D team in some key hydrogen energy technology fields, but also has rich experience in hydrogen energy applications. South Korea has increased its investment in industrial by-product hydrogen and high-efficiency electrolysis of water to produce hydrogen, and actively participates in international hydrogen trade. At present, China is the world's largest hydrogen producer, with the continuous reduction of the cost of renewable energy hydrogen production, hydrogen storage and hydrogen use, as well as the comprehensive application of fossil energy hydrogen production + Carbon Capture and Storage, China will have a broad market space in the future whether it is hydrogen energy supply or hydrogen energy application [10].

2.3.2. Electrochemical Energy Storage Has Entered the Commercialization Stage

In order to meet the growing energy demand and solve environmental problems, electrochemical energy storage technology has gradually become an important solution. Electrochemical energy storage technology will improve the conversion and utilization rate of energy. In this, electric energy is converted into chemical energy, and then stored for emergency needs while ultimately achieving sustainable energy development. Lithium-ion batteries, sodium-ion batteries, nanoporous batteries and other technologies are all important branches in electrochemical energy storage technology, and lithium-ion batteries are currently one of the most commonly used batteries; Sodium-ion battery is a new type of battery technology, compared with lithium-ion batteries, sodium-ion batteries have higher capacity and lower cost. Nanopore batteries are a new type of supercapacitor with high energy density, high power density and long cycle life. In recent years, great progress has been made in the research of nanoporous batteries, such as the discovery of new nanoporous materials, which improve the energy density and cycle life of batteries. Electrochemical energy storage technologies such as lithium-ion batteries, sodium-ion batteries, and nanoporous batteries continue to develop and improve, and will play an increasingly important role in the future energy field.

At this stage, electrochemical energy storage systems have been widely used and promoted in the fields of power systems, new energy, and transportation. In terms of power system, electrochemical energy storage system has become an important technology in power systems, in terms of power grid peak shaving, backup and balance. In terms of new energy, by storing renewable energy such as solar and wind energy, it balances the supply and demand relationship of the power grid and improves the utilization efficiency and reliability of new energy. In transportation, electrochemical energy storage systems can be used in electric vehicles to provide a clean and sustainable energy supply, while also easing the pressure of electric vehicles on the grid. Electrochemical energy storage has begun commercial operation in the power system and has formed a market size. At the same time, in the fields of new energy and transportation, the commercialization of electrochemical energy storage systems is also gradually realized [10].

2.3.3. Domestic and Foreign Enterprises Are Actively Responding to the Zero-Carbon Strategy

Zero carbon is referred to in China as “carbon neutrality”. The People's Daily article “Carbon Peaking and Carbon Neutrality-The Only Way to Green Development” has the following definition of carbon neutrality: for a period of time, carbon dioxide produced by specific organizations or entire social activities is absorbed and offset by natural and man-made means such as afforestation, marine absorption, and engineering storage, so as to achieve relatively zero emissions of carbon dioxide from human activities. As the main body of production and manufacturing, foreign enterprises, especially many leading enterprises, not only put forward the zero-carbon goal of self-development (Table 3), but will also use this as an opportunity to form a zero-carbon industry and drive enterprises to improve quality and efficiency. Taking companies, such as Apple as an example, that pay attention to brand reputation and social responsibility, the carbon neutrality goal is quite clear, proposing to achieve carbon neutrality by 2030, and also requiring suppliers such as Foxconn to provide carbon data during the cooperation process. Microsoft's carbon reduction goals are quite ambitious, and the concept of historical carbon neutrality is proposed, that is, in 2050, the 75th anniversary of the establishment of Microsoft, all the carbon emitted since its establishment should be calculated and carbon neutral. In addition, other leading international companies have strategies.

Table 3. *A list of representative leading enterprises of the “carbon reduction plan” proposed abroad.*

Enterprise	Carbon reduction plans	Enterprise	Carbon reduction plans
Apple	Carbon neutrality by 2030	Microsoft	2030 negative emissions
L'Oréal	Reduce emissions by 25% by 2030	BOSCH	Carbon neutrality in 2020
ExxonMobil	Carbon neutrality by 2025	Unilever	Carbon neutrality by 2030
IKEA	Carbon neutrality by 2030	Amazon	By 2030, half of all transport will be zero-carbon
Schneider	Net emissions at the operational level by 2030 are zero By 2050, the supply chain has zero net emissions	Benz	Achieve carbon neutrality in vehicles by 2039
Volkswagen	Achieve zero vehicle emissions by 2050	Danone	The whole industry chain is carbon neutral
Nestle	Net zero emissions by 2050	Shell	Reduce carbon emissions by 50% by 2050
Google	Carbon neutrality by 2030		

The pace of carbon neutrality by domestic companies has been relatively slow, but encouraged by the strategy, many local Chinese companies have stepped forward, especially Internet giants, who have set up their own carbon neutrality groups. A representative company is Baidu, which has clearly stated that it will achieve carbon neutrality by 2030, a goal that aims to equal Google's carbon reduction goals. In terms of energy, the 2022 Corporate Climate Action Case Book, officially released at the 27th United Nations Climate Change Conference (COP27) at the end of 2022, was selected as the world's first battery zero-carbon factory by the Chinese battery company CATL Yibin Factory [11].

As a representative of domestic brick-and-mortar retail, Beijing Hualian (SKP) has been benchmarking against Harrods in London, UK. Since the carbon neutrality initiative, SKP has been exploring, for a long time, through rigorous calculation, and multiple measures to reduce carbon emissions, and has explored a set of carbon neutrality models for the retail industry that suits SKP's own characteristics. In November 2021, SKP explicitly announced that it would become the first brick-and-mortar retail mall in China to achieve carbon neutrality, with SKP Beijing, SKP Xi'an and SKP-S (Beijing) fully carbon neutral. Industry insiders said that SKP's top-down thinking, clear development goals and scientific task arrangements in the field of carbon neutrality reflect the responsibility of Chinese enterprises in promoting global climate governance.

3. Development Trends of Future Manufacturing

Driven by technological change, manufacturing industry has gradually departed from traditional models. For example, biomanufacturing, led by synthetic biology, may become the main mode of future manufacturing, while space manufacturing has also entered a new round of development cycle and is expected to be commercialized. Additionally, low-carbon manufacturing has become a current trend, and all manufacturing models will be based on the premise of green environmental protection.

3.1. Biomanufacturing

Biomanufacturing refers to the application of the achievements of biological science and engineering to the field of industrial manufacturing. This uses renewable biomass resources as raw materials, developing manufacturing routes for new products, and mass-producing chemicals and polymer materials needed by humans. Biomanufacturing is significantly different from traditional manufacturing and will lead the future of manufacturing as a disruptive model.

3.1.1. The Implementation of International Biomanufacturing Strategy Is in Full Swing

For now, the continuous reduction of traditional resources such as land, water, and fossil fuels have made human beings pay attention to biological manufacturing based on artificial life. Some countries have prepared for this. As early as 2015, the National Research Council of the United States issued the Roadmap for Biological Industrialization: Accelerating the Advanced Manufacturing of Chemicals, which put forward a development vision for the manufacturing of biosynthetic and bioengineering chemicals to reach the level of chemical synthesis and chemical engineering production in the future. Subsequently, the US Department of Energy, the Department of Agriculture, the Department of Defense, along with some other countries, continued to invest heavily in research and development projects in the field of biochemicals and biofuels, and launched the Agile BioFoundry (ABF) alliance program, and established a new bioindustrial manufacturing and design ecosystem in 2020 to promote the development of non-pharmaceutical bioindustrial manufacturing in the United States. In 2013, the EU published its first Strategic Innovation and Research Agenda for bio-based industries, and in 2019 developed a European Chemical Industry Roadmap for the Bioeconomy, proposing to increase the share of bio-based products or renewable raw material substitutions to 25% by 2030; and continued to fund research and development of biomanufactured products through the Bio-based Industry Alliance Program. In 2018, the UK formulated and released the National Bioeconomy Strategy, for the period up to 2030, focusing on the development of the transformation and application of synthetic biology research, establishing and improving the innovative network layout of the synthetic biotechnology industry, and promoting the implementation of the national industrial strategy. In Asia, Japan released its Biostrategy 2019, proposing to build the world's most advanced bioeconomy society by 2030.

3.1.2. The Biomanufacturing Market with Synthetic Biology as the Core, Is Growing Rapidly

In recent years, the world's major developed countries have vigorously developed biological manufacturing industry; the industrial scale has continued to expand, and the contribution of economic growth has continued to increase. It seems clear that synthetic biology, as a key technology, has made an indispensable contribution to this. According to BCC Research, the market size of synthetic biology in the medical field will reach $5 billion in 2024, and will grow at a compound rate of 18.9% [12]. The fastest growing sector is in food and agriculture, with a Compound Annual Growth Rate of around 64% for the period 2019-2024. At the current stage of biomanufacturing, which is dominated by synthetic biology, according to McKinsey, the economic impact of synthetic biology and biomanufacturing is expected to reach $100 billion by 2025.

In addition, synthetic biology will also change the development form of manufacturing to achieve green and low-carbon manufacturing. The Organization for Economic Co-operation and Development (OECD) has predicted that by 2030, OECD countries will form a bioeconomy based on renewable resources, and the economic and environmental benefits of biomanufacturing will surpass bioagriculture and biomedicine, contributing 39% in the bioeconomy [13]. As a result, the development of the synthetic biology industry will have a growth spurt in the next few years.

3.1.3. Future of Biomanufacturing will Have a Transformative Impact on Multiple Fields

In addition to the rapid expansion of the market scale, biomanufacturing, promoted by synthetic biotechnology, will also enter a sophisticated development stage due to the continuous upgrading of gene editing, fermentation and metabolism technologies.

First of all, the underlying technology and key technologies related to biomanufacturing have made continuous breakthroughs, which has rapidly advanced related research to the stage of industrialization. In biopharmaceuticals, taking the production of antimalarial drug artemisinin as an example, traditional planting methods not only require large areas of land, manpower and other resources, but also face the problems of uncertain growth and a long natural growth cycle, before the extraction and research stage. However, using advanced synthetic biotechnology, large-scale production of artemisinin can be achieved in just a few weeks by constructing artificial yeast and industrial fermentation. At present, the Institute of Process Engineering of the Chinese Academy of Sciences has solved the technical bottleneck restricting the large-scale production of artemisinin, which has been promoted and used by Henan Yuzhou Tianyuan Biological Company to complete the production of artemisinin in one year [14].

Secondly, the related technologies of biomanufacturing can realize the replacement of chemical raw materials and processes, which is expected to revolutionize future material processing and production mode. From the perspective of material processing, materials such as non-food biomass, organic waste, and even industrial waste gas, and carbon dioxide, which are generated by biological manufacturing, can continue to produce energy and chemical products through recycling technology. These include basic chemical raw materials, chemical intermediates, and bio-environmental protection materials and preparations such as plastics and nylon, which will drive the next round of production and manufacturing into a green, low-carbon, sustainable development stage. From the perspective of the supply mode, the process of producing starch, protein, oil and other food ingredients through biomanufacturing technology will completely subvert the production and supply of agricultural products. The research team of the Tianjin Institute of Industrial Biotechnology, Chinese Academy of Sciences has realized, for the first time, that the de novo synthesis of starch, from carbon dioxide, is the key link to complete the transformation of starch production from traditional agricultural plant methods, to industrial workshop production mode [13].

3.2. Space Manufacturing

As mentioned earlier, the accelerated commercialization of low-orbit satellites, the increasing maturity of recoverable rocket technology, and the active promotion of space energy technology, by various countries, have made space manufacturing accessible. Based on space microgravity, such manufacturing provides a unique environment that is difficult to achieve on Earth, for the development and production of cutting-edge technologies such as 3D printing and stem cell manufacturing. The increasing maturity of the above conditions has laid a feasible foundation for the construction of a space factory by the United States and Europe.

3.2.1. Developed Countries Led by the United States Are Facing up to Space Industry and Space Manufacturing

As a leader in space exploration, the United States has regarded space resources as an industry and has begun to advocate the creation of economic value by facing up to space manufacturing. This view is due to the fact that since 2020, the US Department of Defense Innovation Group, together with the US Space Force and the Air Force Joint Laboratory, have released the “State of the Space Industrial Base” report for three consecutive years [15]. The theme of the three reports is basically the same, emphasizing the layout of space exploration programs, and actively seize space dominance, in order to lead China in this field. Space is the key to winning the future and needs to be defined by a new public discourse. The three reports hold that space is an economic and strategic field, and a key to US soft power, which directly affects the development of hard power, and the competitive advantage of the United States. Space is also a critical infrastructure, i.e., a means of transportation, and the key to combating climate change. Space is a source of new industries, jobs, technological innovation and economic growth, and an investment rather than a bill. The report also identifies a number of space-based areas that are suitable for future development, including space manufacturing and resource extraction.

In Europe, Airbus Europe, the world's largest aircraft manufacturer, has launched a two-year Period project funded by the European Commission's Horizon 2020 program. The 3 million euros A/B1 phase research contract focuses on assembling and manufacturing satellites in orbit, with the goal of validating the program. The project also has a bold initiative of realizing the construction of a space factory. In the first few years of the Period project, the company Airbus, with the support of the European Space Agency, has invested 40 million euros in the development, production and launch of the Bartolomeo platform, which is the underlying technology for the construction of the space factory [16].

3.2.2. The Construction of Space Factories, Advocated by Developed Countries, Is Expected to Be Realized

The feasibility of building a pace factory will ultimately be determined by the degree of development of technology. American start-up Made in Space has long been committed to space 3D printing. This includes planning to print and assemble industrial products and space equipment in space, achieve the first 3D printer on the space station, and later bring the plastic recycling device with a spacecraft, onto the International Space Station, and carry out 3D printing operations on the spot, thereby accumulating background for manufacturing in space. Today, Made in Space is targeting a promising product, namely a special optical fiber called ultra-pure fluoride (ZBLAN). This material has higher infrared transmission than silicon and is mainly used in high-end lasers, fiber optic cables, medical products and other fields. In the environment of the earth's gravity, the traditional method of producing this material is to melt it at high temperatures and let it drop from a high place, in a process of stretching. The disadvantage is that the density of different components contained in this material is heterogeneous, and the material will form microcrystals during the cooling process, which will affect its application in areas such as communications. However, in microgravity, material density separation and crystallization can be avoided, resulting in better quality ZBLAN. As early as the 90s of the 20th centuries, the US Air Force artificially created a microgravity environment through parabolic flight, proving that it is beneficial to manufacture ZBLAN in a microgravity environment [17].

In addition to 3D printing, stem cell technology in the field of biomedicine can also be fully applied in the space environment. The principle is that the vacuum and microgravity environment of space naturally provides conditions for delaying stem cell differentiation, and experimenters can use this time window to conduct experiments, such as organ manufacturing and drug development. In short, space manufacturing as a future manufacturing is worth exploring.

3.3. Green and Low-Carbon Manufacturing

The future development of production and manufacturing to green and intelligent has become a general trend. There are four effective measures to help accelerate the transformation and upgrading of green manufacturing in traditional industries: (i) using green technology to change traditional industries, (ii) establishing the green information industry, (iii) advocating resource recycling and the development of the remanufacturing industry, (iv) building green factories and establishing a green supply chain.

3.3.1. Using Green Technology to Accelerate the Upgrading of Heavy and Polluting Industries

In traditional manufacturing fields, especially in heavy industries associated with serious pollution, such as those of steel, nonferrous metals and chemicals, green technology is urgently needed to upgrade the industry. For example, the conscious use of technologies or processes that reduce pollution, recycling waste and the use of harmless treatments in the manufacturing process. Cost permitting, the replacement of traditional equipment is completed by using advanced equipment such as high-efficiency motors and boilers, and the green upgrade of the production process will also be completed by this process.

3.3.2. Developing a Green Information Industry to Reduce the Pollution of Traditional Electronic Information Products

During the production, use and operation of traditional electronic information products (e.g., batteries, computers), a large number of toxic and harmful substances such as lead, mercury and cadmium are produced. This is one of the main factors causing irreversible and serious pollution of the ecological environment. To reasonably solve the above problems, high pollution and high carbon emissions can be mitigated or even improved by promoting lead-free production processes, as well as green material-saving process technologies such as near-net forming, rapid prototyping, and surface engineering.

3.3.3. Advocate Resource Recycling and Vigorously Develop the Remanufacturing Industry

Resource reuse is one of the effective ways to achieve green production and manufacturing, and the development of remanufacturing industry is a reasonable export for resource reuse. In-service remanufacturing for old or low-performance in-service mechanical and electrical equipment with frequent failures. For traditional mechanical and electrical products, etc., intelligent remanufacturing is implemented through green information technology; High-end remanufacturing of large equipment such as aero engines. Based on the above various remanufacturing work, the identification of remanufactured products can be considered, so as to further standardize the production of remanufactured products, and guide the consumption of remanufactured products in a timely manner, and then establish an international mutual recognition mechanism for remanufactured products, and finally form a closed-loop of sustainable, healthy and orderly development of the remanufacturing industry.

3.3.4. Build a Green Factory and Build a Green Supply Chain

The main place of production and manufacturing is the factory, and the construction of green factory is a measure to ensure green and low-carbon manufacturing from the source. Through the construction of green demonstration factories in key industries, plant intensification, harmless raw materials, clean production, waste recycling and low-carbon energy production and manufacturing can be realized, providing reference for exploring replicable green factory models. More importantly, by building green demonstration factories in key industries, the construction of green supply chains can be quickly driven, and the linkage mechanism of upstream and downstream enterprises to complete the transformation of green production and manufacturing and jointly practice environmental protection, energy conservation and emission reduction can be effectively promoted and formed.

In short, green and low-carbon manufacturing is a re-transformation and construction, that is based on traditional manufacturing. This will be a long and difficult transformation process, but it is an inevitable trend of future manufacturing development.

4. Conclusion

In summary, biomanufacturing, aerospace manufacturing and green/low-carbon manufacturing is developing into mainstream modes of manufacture, and they are injecting vitality into the development of national economies. In addition, new energy manufacturing, represented by new energy vehicles, intelligent manufacturing, represented by robots, and virtual manufacturing, involving data, algorithms and models as the main elements, will also be an important part of the development of new manufacturing in various countries.

They are all worthy of in-depth research.

Acknowledgments

I would like to thank David Waxman, colleagues of Shanghai Library (Institute of Scientific & Technical Information of Shanghai), for helpful discussions and assistance.

Author Contributions

Hua Deng is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Liu, A. R., Li, L., Cao, X. Y. The Strategic Connotation and Policy Enlightenment of the Concept of Disruptive Technology. *Strategic Study of CAE*. 2018, 20(6), 7-13. https://doi.org/10.15302/J-SSCAE-2018.06.002

[2] Mckinsey Global Institute. Disruptive technologies: Advances that will transform life, business, and the global economy. Available from: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/disruptive-technologies [Accessed 1 May2023].

[3] Xinmin.cn. Synthetic biology is in the ascendant, Shanghai has a first-mover advantage, will promote "1+3+1". Available from: news.xinmin.cn/2023/04/13/32359844.html [Accessed 7 June 2023].

[4] Qiu, W. L., Liao, X. L., Luo, W. Analysis on the Development Frontier of Global Synthetic Biology Industry. *Journal of Integration Technology.* 2021, 10(5): 117-127. https://doi.org/10.12146/j.issn.2095-3135.20210427009

[5] Finance.china.com.cn. "Creation for use"—synthetic biology industry leads the global capital investment and financing boom. Available from: finance.china.com.cn//roll/20230221/5944729.shtml [Accessed 7 June 2023].

[6] Shanghai Securities News. The rise of synthetic biology industry in Shanghai. Available from: https://news.cnstock.com/news,bwkx-202305-5066392.htm [Accessed 7 June 2023].

[7] Tencent.com. In-depth research on low-orbit satellite industry: low-orbit constellations are ready to set sail for hundreds of billions of blue oceans. Available from: https://new.qq.com/rain/a/20230302A053FJ00 [Accessed 8 June 2023].

[8] Institute of Scientific & Technical Information of Shanghai. 2021 Global Frontier Science and Technology Hot Spots. [Accessed 9 June 2023].

[9] Jiang, Q. Y. Strategic Thinking of China-Japan-South Korea Energy Cooperation under the Background of Carbon Neutrality. *Energy of China*. 2021(9): 74-79. https://doi.org/10.3969/j.issn.1003-2355.2021.09.012

[10] China Power. Development prospect of electrochemical energy storage. Available from: www.chinapower.com.cn//chuneng/dongtai1/20230404/195296.html [Accessed 12 June 2023].

[11] Thepaper. CATL was selected into the "2022 Corporate Climate Action Case Collection". Available from: https://www.thepaper.cn/newsDetail_forward_20774224 [Accessed 25 June 2023].

[12] Tencent.com. Synthetic biology wind: the scale will exceed 100 billion RMB in 2024, and the compound growth rate of the subdivision track will be nearly 64%. Available from: https://new.qq.com/rain/a/20220914A09ZN800 [Accessed 26 June 2023].

[13] Ma, Y. H. "14th Five-Year Plan" Bio-economic Development Plan Series Interpretation II | Biomanufacturing industry is the key development direction of bioeconomy. Available from: https://www.ndrc.gov.cn/xxgk/jd/jd/202205/t20220510_1324454.html?code=&state=123 [Accessed 29 June 2023].

[14] Chinese Academy of Sciences. Artemisinin achieves green large-scale production. Available from: https://www.cas.cn//jh/202001/t20200113_4731136.shtml [Accessed 29 June 2023].

[15] United States Space Force. United States Space Force, Defense Innovation Unit and Air Force Research Laboratory. State of the Space Industrial Base (2020, 2021, 2022). [Accessed 30 June 2023].

[16] Sohu.com. Made in Space, The era of space manufacturing is coming. Available from: https://www.sohu.com/a/466675920_658106 [Accessed 4 July 2023].

[17] DeepTech. US startups build space factories, NASA heavy financial support, space manufacturing or space dreams? Available from: https://zhuanlan.zhihu.com/p/90065288 [Accessed 4 July 2023].