Mixed Reality

Improving Energy Efficiency and Compact Design Will Boost Sales

~$220 Billion+ Opportunity

Cumulative Market Size (2016-2020)

AR initially was a major revenue generator in the MR space with very little contribution from VR. However, recently, with several VR product launches from big participants, the MR space is rapid growing and offering new opportunities for application developers.

Companies to Bet On

- Magic Leap, US
- Samsung, South Korea
- Oculus VR, US
- Avegant, US
- Qualcomm, US
- Microsoft, US
- Sony, Japan
- MindMaze, Switzerland

Business Models to Think Of

- MR glasses are a major area of development, but challenges include a lack of efficient battery technology, effective content management, and advanced material technologies. These areas are gaining attention from developers to deliver more compact, lightweight MR glasses that can seamlessly access content while being energy efficient.

MR Will Disrupt Mobile Computing

- *MR will go beyond smartphones to immerse users in technologies that blur the line between the physical and virtual worlds.*

Smartphones have drastically improved customer engagement through improved user experience. MR wearables are expected to bring in a more immersive experience to this engagement.

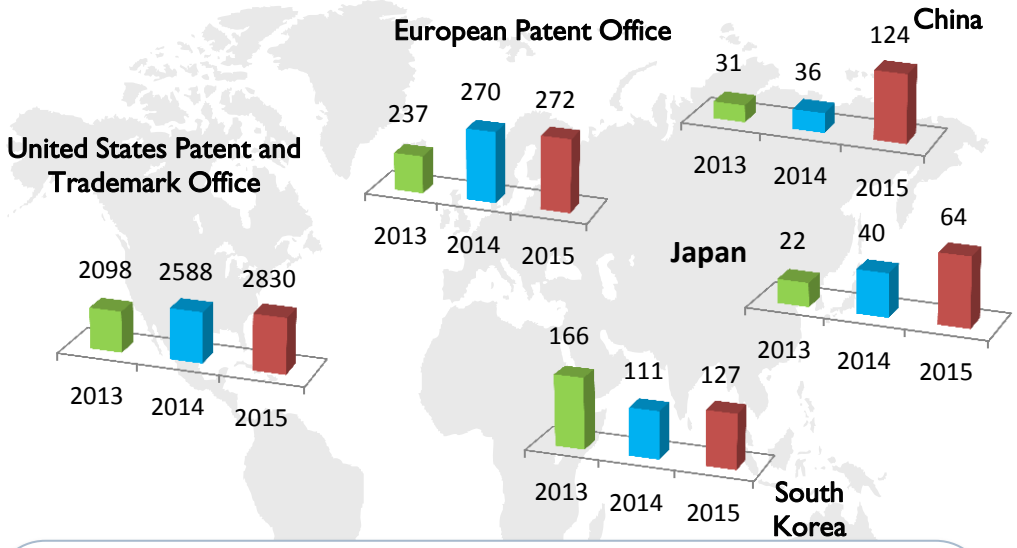
Factors Critical for the Target Industry

- Enriched user experience and cost effectiveness of MR glasses are 2 key areas of concern for MR adoption.
- Lack of standardization and legal aspects will hinder its adoption in industries such as healthcare and defense.
- The framework of easy compatibility will boost technology development.

Acquisitions Will Be Prominent

A market with several big participants focusing on hardware development and start-ups with software innovations is likely to experience several acquisitions in the coming years.

Venture Funding Primarily Driving Innovations across the Globe



Patent Growth

Across the 5 major patent offices, a total of about 9,000 patents have been granted in the last 3 years of which more than 7000 have been granted in USPTO alone.

Microsoft

Microsoft is the major patent holder in the MR space with over 500 patents, followed by Canon, Google, IBM, Panasonic, Sony, Nant Holdings IP, and Qualcomm.

North America

North America, specifically the United States, is the key region for technology development. A majority of the top development firms are based in the region. China also has been showing rapid growth in recent years.

Funding Trends

Funding deals for start-ups have increased significantly since Q4 2014. In the first 2 quarters of 2015, around 40 deals have been closed in the MR space.

Government MR initiatives have not been significant, except a few, such as Khazanah Nasional Berhad (the investment fund of the Malaysian government) that invested $54 million in Blippar, the AI-based AR technology start-up.

The key areas of investment are for the development of healthcare applications, mobile applications, and supporting hardware development.

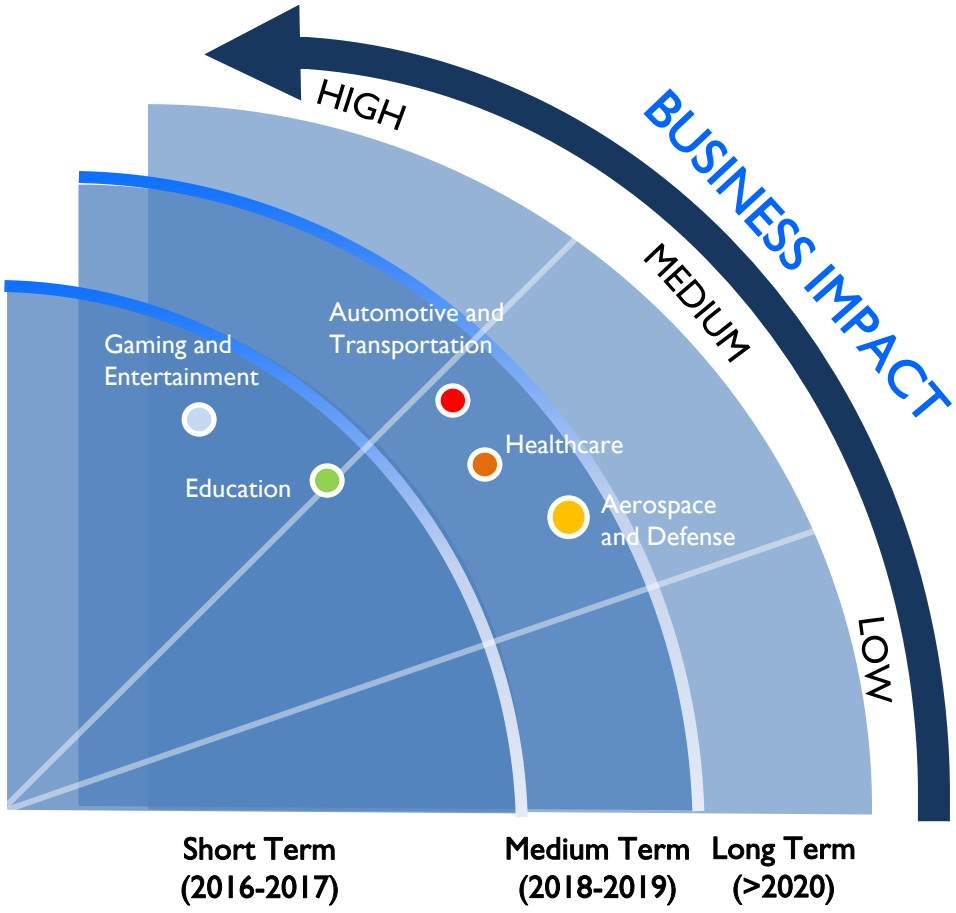
$542M

Series B funding received by Magic Leap in Q4 2014

One of the largest funding deals for the VR space, led by Google, Qualcomm Ventures, and KKR and other investors, is focused on development of the prototype.

Gaming, Entertainment, and Education will Experience Maximum Impact in the Short Term

- Gaming and Entertainment – The industry is experiencing the earliest impact of MR technology to enrich user experience. Following the commercialization of affordable VR-based gaming consoles, this industry is likely to be hugely impacted by this technology in the short term.
- Education – The industry will have potential benefits of VR, leveraging simulated knowledge environments delivering better insights and engagement in training processes. There will be a medium impact in this space in a medium term.
- Automobile and transportation – MR technology will have a medium impact on the industry. Virtual simulation will aid in design to achieve perfection. It is expected to face convergence in the medium term. AR will help in enhancing the infotainment features in vehicles.
- Aerospace and defense – The industry can leverage VR in simulating training programs. VR will help in delivering the best simulations with real-life scenarios and augmenting information for better learning processes. MR will also help improve customer service through in-flight entertainment applications. Considering the strict regulatory standards for screening technology accuracy levels in this industry, large-scale adoption would be in the long term.
- Healthcare – This industry will have an impact in the medium term through the implementation of training applications. However, further enhancement of the technology could also help MR to penetrate critical application areas such as real-time remote surgeries.



North American and Asian Countries Will Experience Rapid Penetration

Disruptive Index

8/10

TechVision analysis notices a high disruptive index for MR. This signifies that AR and VR services are bringing in significant ***Step-Changing*** innovations across sectors of economic activity.

MEGA TREND IMPACT

- "Smart" is the New Green
- Bricks and Clicks
- Health, Wellness, and Well-Being
- Connectivity and Convergence
- Future of Mobility
- New Business Models

6

MR directly impacts 6 Mega Trends as identified by Frost & Sullivan

Most Revenue Generating Market

- The United States has been exhaustively working on innovative R&D projects on MR solutions. Several universities and research institutes have been actively exploring new dimensions in this space. Supported by federal bodies, such as the National Science Foundation, these research projects are focused on applying AR and VR in various fields, such as healthcare, defense, and education. This region is home to several top technology developers in this space.

Enabling Technologies from the Region Facilitating Adoption

- The region is primarily focusing on developing enabling technologies. The European Union is leading the space in research in VR. The EMOSPEECH project has been extensively working on integrating speech-based emotions in VR. The German company SensoMotoric Instruments GmbH is researching the implementation of eye tracking technologies to VR, making it more responsive. However, this region is focusing on the highest revenue-generating hardware segment for AR and VR that will facilitate adoption considerably across the globe.

Growing Fast and Pushing Hard to Commercialize Products

- Japan is actively looking into VR. Companies such as Nintendo and Sony are making huge investments in R&D as well as acquisitions to make a mark in the global MR market. Another company, Capcom (originally a gaming company), has started an initiative to implement VR into gaming and entertainment. Another key country is South Korea, which is actively participating in the MR space. Innovators such as Samsung and LG along with many start-ups are pushing hard to commercialize their products.

Technology Licensing is the Key Strategy for Expansion among Large Corporates

Microsoft is the pioneer in MR research

- Microsoft HoloLens is a classic example of MR that leverages a set of sensors, stereoscopic 3D head-mounted display (HMD), and spatial sound technology to interact with AR applications through natural user interfaces. Microsoft has also launched the HoloStudio application for 3D modeling.

Magic Leap is revolutionizing VR and AR

- The US-based start-up is utilizing its huge rounds of funding from top ventures such as Google and Alibaba toward development of a cinematic VR device. The Magic Leap device eliminates the need for VR glasses; instead, it uses a head-mounted virtual retina display to project objects directly in the eyes of users.

Asuka Lab Inc. is innovating applications

- The research lab from the University of Tokyo is working toward the development of a cross-platform software library for application development. The platform is offered as an SDK to application developers that can be seamlessly integrated into any HMD for MR applications.

Sony is delivering next-generation gaming

- PlayStation VR is a hardware and software integrated system from Sony that uses a VR Gear HMD device along with its standalone application platform to provide a fully immersive experience that can be linked with the PlayStation platform.

Facebook is bringing VR to social media

- Acquisition of Oculus VR by Facebook is primarily aimed at developing a new social networking platform leveraging convergence with the virtual environment. Considering the fact that the future of computing and communication will be dependent on mobile and wearable devices, the initiative focuses on new experiences of communication.

Jaunt is focusing on cinematic VR

- Palo Alto-based Jaunt is aiming to innovate the future of the immersive viewing experience through its cinematic VR solution for entertainment. Leveraging advanced algorithms and computational photography, the aim is to bring the VR experience into mainstream entertainment.

Other Innovators:

Qualcomm | Samsung | Oculus VR | MindMaze

Key Questions for Strategy Planning

How can cloud computing improve MR systems ?

With the convergence of cloud and MR systems, most system software and data content can be distributed to the cloud server. This will allow the MR system to fully utilize storage for improved user experience instead of using its processing power and storage space for keeping big amounts of data.

What are the key areas of development to make MR systems more compact ?

Nanotechnology can play a vital role in this aspect. The capabilities of nanotechnology are boundless. The main modification to hardware that nanotechnology can provide is the compact features in a tiny IC or transistor. With the introduction of nanotechnology into MR systems, future HMDs will be extremely compact and lightweight.

Key Questions for Strategy Planning

How can we improve the energy efficiency of MR systems ?

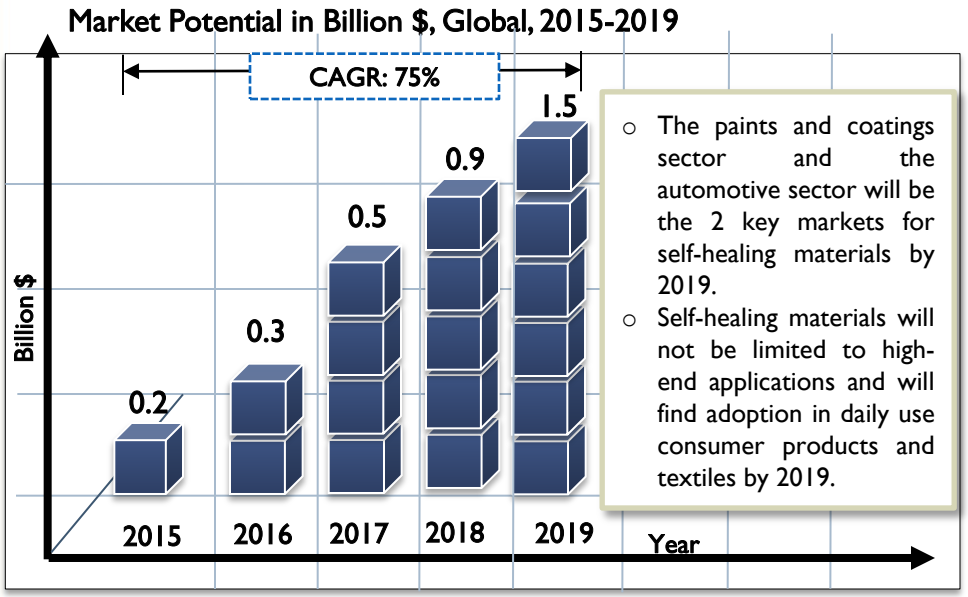
Running VR on a HMD device requires sufficient energy, which is a key challenge with current systems. With the introduction of materials such as graphene, thin-film thermoelectrics for future MR devices can use renewable energy materials that may boost energy harvesting from MR systems.

How can the industry overcome integration challenges for software and hardware?

Standardized frameworks could play a significant role in addressing integration challenges. Initiatives such as the Open-Source Virtual Reality Consortium and Extensible 3D (X3D) by Web3D Consortium could help to bridge the gap. However, there is also a requirement for regulations and policies for system security enhancements.

Self-healing Materials

Need for Materials with Increased Lifespan and Durability



- The paints and coatings sector and the automotive sector will be the 2 key markets for self-healing materials by 2019.
- Self-healing materials will not be limited to high-end applications and will find adoption in daily use consumer products and textiles by 2019.

BENEFITS AND DRAWBACKS

- Minimizes production cost of processes required for damage repair
- Prolonged life of materials
- Improved efficiency of materials due to the ability for quick repair of damages/faults/cracks on the surface
- Minimizes need for repair in inaccessible locations such as high-rise buildings and wind turbines

- Scalability issues
- Absence of standards
- Availability and cost

Trending Now

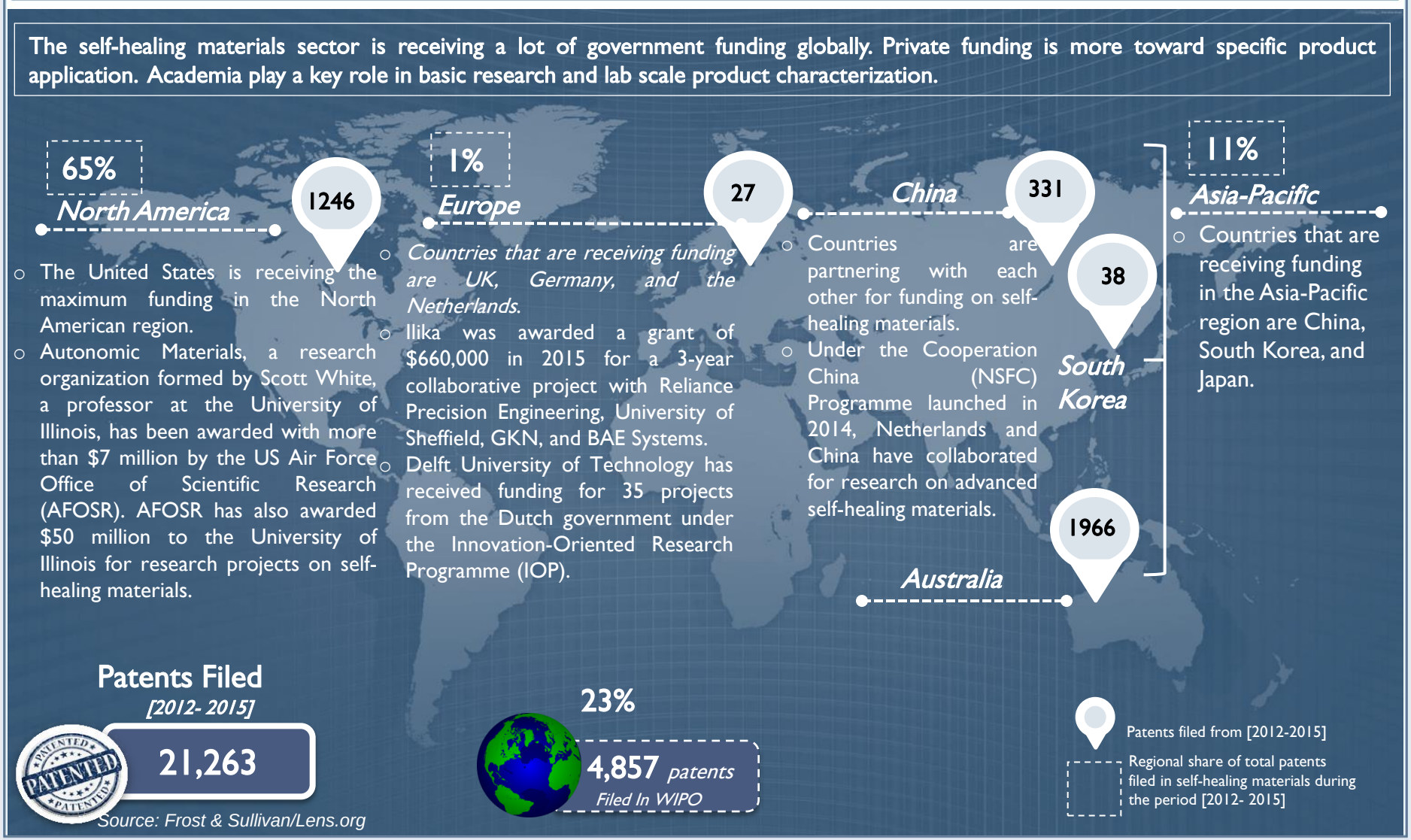
- NASA and the University of Michigan have developed a material that can heal itself in seconds. It can self-heal even bullet holes.
- Apple has developed a self-healing elastomer for making its phones waterproof.

Key Innovators

acciona
GKN AEROSPACE
Encore COATINGS
GARMOR
INNOVATIVE SOLUTIONS. ADVANCED PRODUCTS.
AñCatt
atfi
Surface Science Solutions
IASS
2-DTECH
NANTO PAINT
NEI
NEI Corporation
Autonomic Materials™
SCS
Sensor Coating Systems Ltd
CRITICAL MATERIALS
TU Delft
Delft University of Technology
UNIVERSITY OF BATH
UNIVERSITY OF CAMBRIDGE
CARDIFF UNIVERSITY
University of BRISTOL
九州大学
KYUSHU UNIVERSITY
THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Mix of Private and Public Funding with Improving Performance and Durability as Key Focus Areas

The self-healing materials sector is receiving a lot of government funding globally. Private funding is more toward specific product application. Academia play a key role in basic research and lab scale product characterization.



Paints & Coatings and Construction Markets to Be Highly Impacted in the Next 5 Years

SELF-HEALING MATERIALS

	A	B	C	D
Key Materials	Embedded healing agents	Microvascular materials	Shape-memory materials	Reversible polymers
Features	Reduced maintenance and replacement cost	Reduced machine downtime	Increased productivity	Enhanced product performance

Sectors of Impact

Aerospace

- Fiber-reinforced composites with liquid self-healing materials can be used in the aviation industry.
- University of Bristol, UK, has developed a "bio-inspired" vascular system, which could be used in high-performance composite polymers. These polymers can replace metal in the aerospace industry.

Consumer goods

Self-healing materials can be used in various consumer products, such as the packaging of cosmetics, sporting goods, sportswear, and home appliances.

Military

Self-healing glass can be used in the armored windscreens of military vehicles and exterior body panels of military jets.

Marine

Self-healing coatings can be used on marine assets, such as ships and docks, to protect metal beneath the sea from corrosion.

Oil & Gas

Self-healing coatings can reduce the maintenance period and increase the lifespan of oil rigs and pipelines and refineries by reducing corrosion.

Paints & Coatings

Self-healing materials in the microcapsule systems can be used in coatings, paints, and adhesives, which can be further used across industries such as marine, oil and gas, buildings, and automotive.

Electronics

Self-healing materials can be used in conductors, semiconductors, stretchable sensors, and soft robotics.

Construction

Self-healing concrete for buildings and self-healing coatings for metal structures in bridges are being adopted in the construction sector.

Automotive

- Self-healing materials can improve asset life and reduce maintenance and overall cost.
- Nissan Motor commercialized the world's first self-healing clear coat for car surfaces.

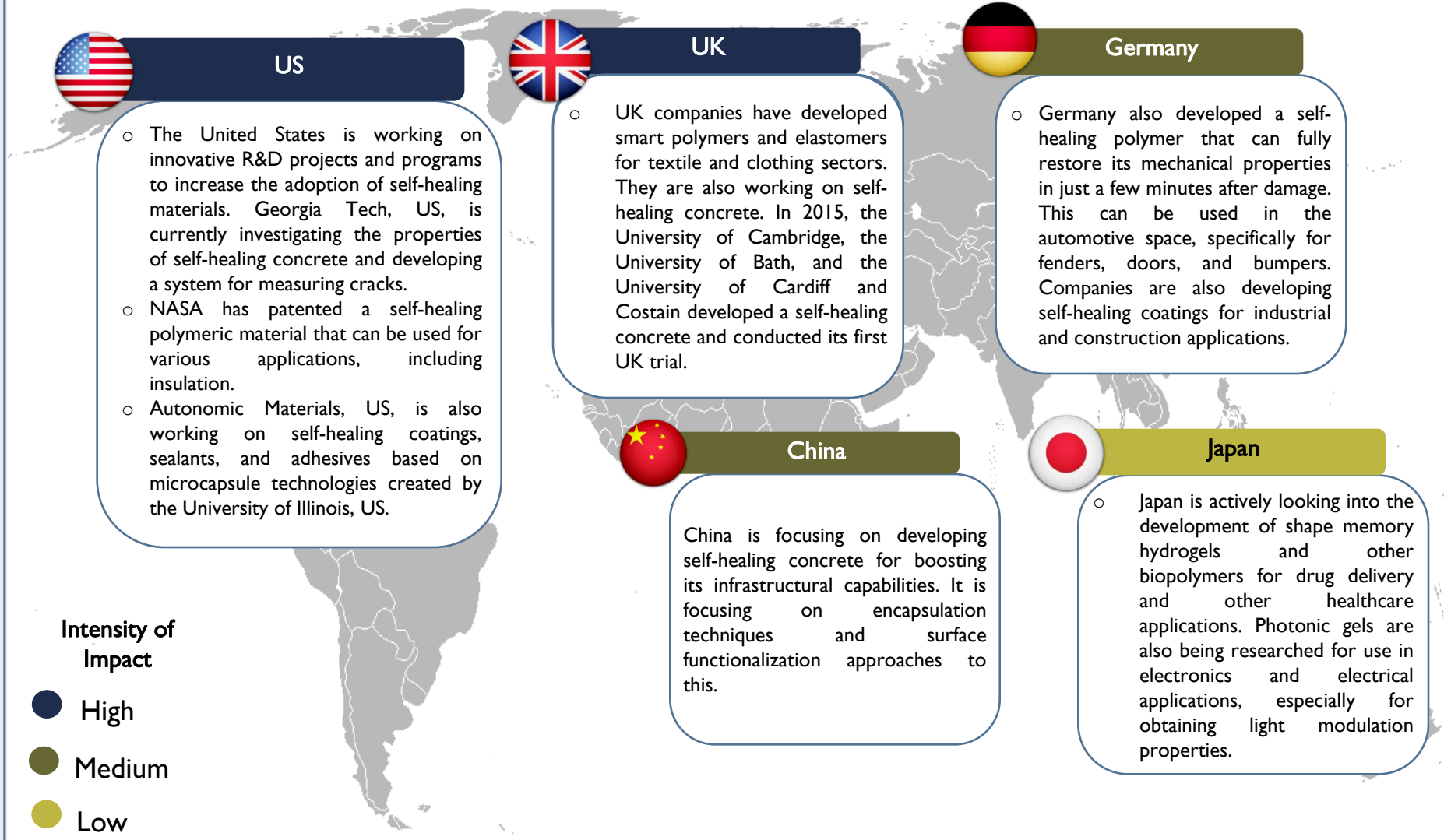
Healthcare

Biocompatible self-healing composites can be used in artificial bones and teeth to increase their life.

Energy

Self-healing materials can be used in wind turbines to increase their service life and decrease maintenance cost.

United States Leading in Technology Adoption While UK and China Accelerate R&D Efforts



US

- The United States is working on innovative R&D projects and programs to increase the adoption of self-healing materials. Georgia Tech, US, is currently investigating the properties of self-healing concrete and developing a system for measuring cracks.
- NASA has patented a self-healing polymeric material that can be used for various applications, including insulation.
- Autonomic Materials, US, is also working on self-healing coatings, sealants, and adhesives based on microcapsule technologies created by the University of Illinois, US.

UK

- UK companies have developed smart polymers and elastomers for textile and clothing sectors. They are also working on self-healing concrete. In 2015, the University of Cambridge, the University of Bath, and the University of Cardiff and Costain developed a self-healing concrete and conducted its first UK trial.

Germany

- Germany also developed a self-healing polymer that can fully restore its mechanical properties in just a few minutes after damage. This can be used in the automotive space, specifically for fenders, doors, and bumpers. Companies are also developing self-healing coatings for industrial and construction applications.

China

China is focusing on developing self-healing concrete for boosting its infrastructural capabilities. It is focusing on encapsulation techniques and surface functionalization approaches to this.

Japan

- Japan is actively looking into the development of shape memory hydrogels and other biopolymers for drug delivery and other healthcare applications. Photonic gels are also being researched for use in electronics and electrical applications, especially for obtaining light modulation properties.

Intensity of Impact

- High
- Medium
- Low

Highly Disruptive Technology with Wide Application Potential

Disruptive Index

7/10

TechVision analysis provides a high score to self-healing materials for disruptive index. This signifies that self-healing technology is bringing in ***Game Changing*** innovation across sectors of economic activity with the potential to replace existing materials in various industries.

Smart Is the New Green | Future of Mobility | Urbanization —City as a Customer | Health, Wellness, and Wellbeing | Future Infrastructure Development | Innovating to Zero

6

Self-healing materials directly impact 6 Mega Trends as identified by Frost & Sullivan due to wide application potential and high performance characteristics.

Competitive Landscape

Most Lucrative Markets

- North America is leading in terms of market potential for self-healing materials. It is the most lucrative market for investment in the short to mid term with various research and funding activities are happening in the region.
- In the long term, Europe (Germany, Netherlands) and Asia-Pacific (China, Japan) could be the target markets for investment.

Industries to Watch Out For

- The segments that will be impacted the most in the short to mid term are paints & coatings, construction, and automotive. This is because corrosion is a huge problem across the globe, and countries spend huge amounts of money on maintenance.
- Other industries that will be impacted include aerospace, marine, and oil and gas.

Emerging Markets

- While the United States and Germany can be considered attractive markets in the near term, Asia-Pacific is one of the fastest growing markets in the adoption of self-healing materials with the construction industry being foremost.
- Other countries that will actively adopt this technology in the near to mid term include Japan, South Korea, and Australia.

Key Questions for Strategy Planning

What are the major applications that would be impacted in the near term?

The development of micro capsulated coatings (e.g., anti-corrosion coatings that can repair on their own) will impact the market in the next 1 to 2 years. Another market that will be impacted in the short to mid term is the building and construction industry, with self-healing concrete being investigated across the world.

Should I be concerned about the disruption potential of self-healing materials?

Self-healing materials could have a high degree of disruption potential because they find applications in innumerable sectors such as paints, aerospace, oil and gas, consumer, automotive, and healthcare. One of the main reasons this will be disruptive is that its use will not only be limited to high-end applications, but also in products required for everyday life.

Key Questions for Strategy Planning

Where does the long-term potential of self-healing materials reside?

In the long term (3 to 5 years), high performance composite polymeric materials will hit the market. They will find use in the aerospace industry for removing tiny cracks on aircraft's wings and fuselage. This will materialize in the long term because of the high standards of product testing required for the aerospace industry. Other industries that will be impacted are consumer, oil and gas, and healthcare.

In-house R&D or Technology Acquisition?

Partnerships, mergers & acquisitions, and joint ventures are the main strategies adopted by companies operating in this segment. An example includes the first trial of self-healing concrete done by Costain—a research organization that sponsored the research done by the University of Cardiff, University of Bath, and University of Cambridge. Another example is the development of self-healing coatings based on microcapsule technologies by Autonomic Materials in collaboration with the University of Illinois.