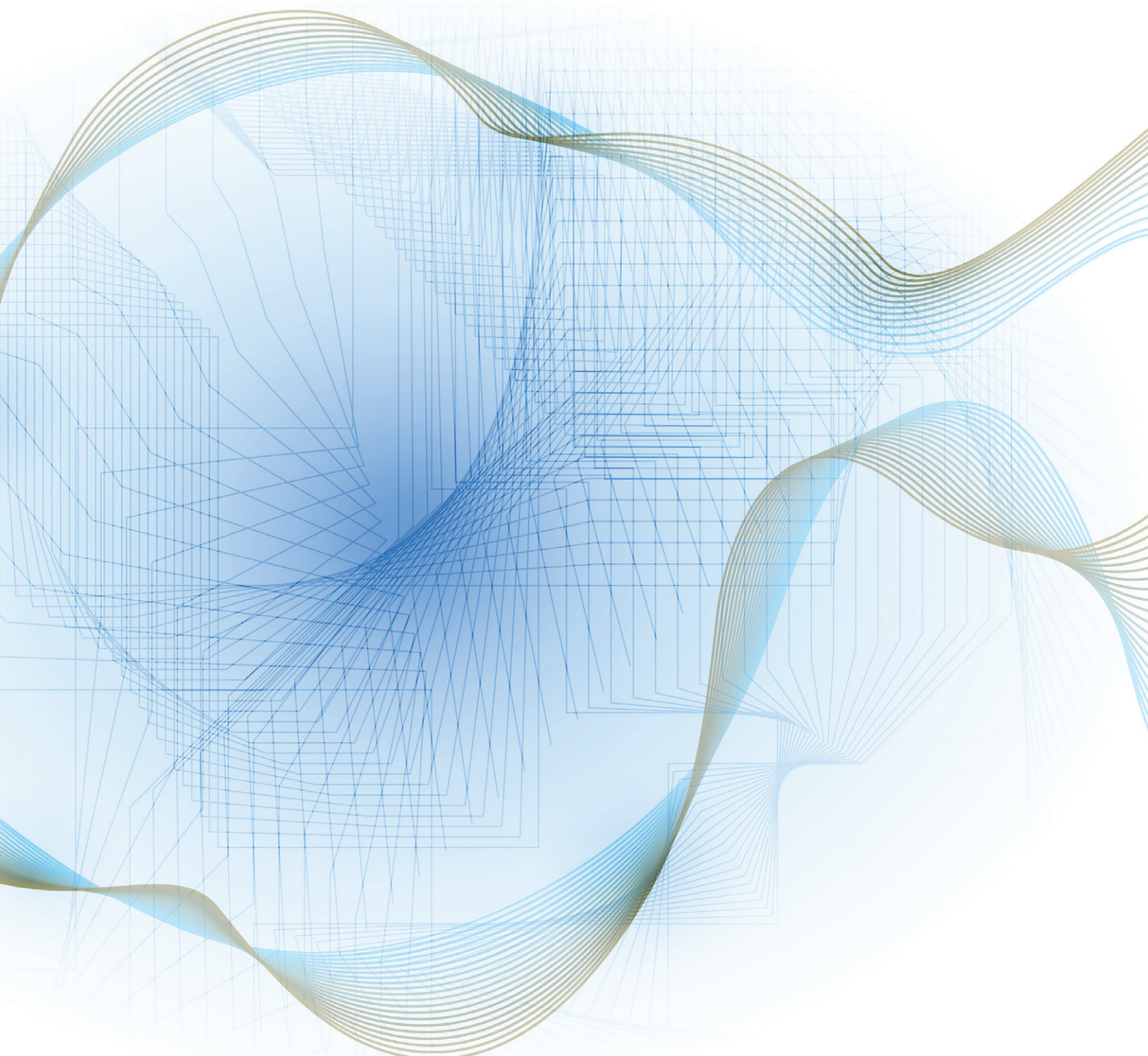


Industry 4.0 Testlabs in Australia

Preparing for the Future

A report of the Prime Minister's Industry 4.0 Taskforce
– Industry 4.0 Testlabs Workstream

Foreword by Professor Aleksandar Subic



Australian Government

The Prime Minister's
Industry 4.0 Taskforce



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Publisher

Swinburne Research
Swinburne University of Technology
PO Box 218 Hawthorn Vic 3122 Australia

ISBN

978-0-9875930-9-2 (print version)
978-0-9806708-6-8 (electronic version)

Date of Publication

August 2017

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Cover image: Nongkran_ch



Foreword



We have embarked on a major industrial transformation known more broadly as Industry 4.0. This is a complex framework based on full integration of cyber-physical production systems (CPPS), where intelligent products, machines, networks and systems are securely interconnected based on common standards, independently communicating and cooperating with each other over the entire manufacturing process – all with minimal or no human intervention.

The adoption and deployment of Industry 4.0 within Australia has the potential to significantly improve the competitiveness of our SMEs and the advanced manufacturing sector. In 2016, the Prime Minister's Industry 4.0 Taskforce was announced with the support of the Australian Government. The Taskforce's initial role was to connect Australian and German industry leaders to collaborate and share information on Industry 4.0.

Being a member of this Taskforce and leading its Industry 4.0 Testlabs Working Group I have had the privilege to discover how important it is to establish innovative learning platforms and facilities in support of this objective. Industry 4.0 Testlabs will enable our SMEs, students and workforce to embrace this transformation and learn about Industry 4.0 within supportive and non-competitive cooperative environments. At its most fundamental, Industry 4.0 is about digitalization of the entire manufacturing process. Yet I have no doubt that the success of this industrial transformation will depend equally on how successful we are in facilitating and supporting workforce transformation.

This report provides a detailed overview of the relevant resources, findings and recommendations resulting from the work of the Industry 4.0 Testlabs Working Group of the Prime Minister's Industry 4.0 Taskforce during 2016–2017. The report aims to bring together in one resource the key intents, concepts and recommendations associated with the development and deployment of Industry 4.0 Testlabs in line with the Taskforce objectives. The report further aims to support broader participation of Australian education and industry sectors and other stakeholders in Industry 4.0 initiatives through co-creation based on a “learning by doing” approach.

The work presented in this report evolved through close collaboration between the Australian Industry 4.0 Testlabs Workstream and the German Labs Network Industrie 4.0, the key organisation driving the development and deployment of Industry 4.0 Testbeds in Germany. This collaboration builds on the Memorandum of Understanding formalised in Hannover this year between the Prime Minister's Industry 4.0 Taskforce and Plattform Industrie 4.0 for cooperation on Industry 4.0 and future of manufacturing between Australia and Germany.

The activities of the Industry 4.0 Testlabs Workstream were supported by the Department of Industry, Innovation and Science, the Australian Industry Group (Ai Group) and the Australian Advanced Manufacturing Growth Centre (AMGC). I want to thank research institutions across Australia for their helpful contributions on respective Industry 4.0 use cases.

Professor Aleksandar Subic

Chair of Industry 4.0 Testlabs Workstream, Prime Minister's Industry 4.0 Taskforce

Deputy Vice-Chancellor (R&D), Swinburne University of Technology

“Industry 4.0 is emerging as a unifying vision across our diverse industry sectors, giving us a clearer focus and a roadmap for digital transformation of advanced manufacturing in Australia. We hope that this Report will serve as a useful resource for industry, education and research organisations that are engaged with the Industry 4.0 agenda.”

Industry 4.0 Testlab Guiding Principles

Platform for industry transformation

Industry 4.0 Testlabs are a strategic initiative of the Prime Minister's Industry 4.0 Taskforce. Located across Australia at leading research organisations in partnership with industry, Industry 4.0 Testlabs will play a central role in improving the competitiveness of Australian manufacturing industries through adoption of Industry 4.0 technologies and workforce transformation. Testlabs will work with stakeholders from companies, industry and peak bodies, government, academia, professional societies and labour organisations, and the wider community to advance Industry 4.0. Industry 4.0 Testlabs will connect with similar labs and activities worldwide. Industry 4.0 Testlabs will help transform Australian industry in three ways.

1. Industry 4.0 Showcase

- **Technology showcase** – Testlabs demonstrate technology and standards aligned to German VDMA Guidelines, Lab Network Industrie 4.0, and RAMI 4.0 architecture.
- **Solutions showcase** – Industry 4.0 strategies, concepts and solutions are familiarised, made accessible and realised for stakeholders/partners.
- **Showcases** will follow a use case centric approach, e.g. future manufacturing scenarios provided by industry.
- **Test bed** – Users will gain experience with state-of-the-art Industry 4.0 processes, and be able to test new technologies to inform manufacturing strategies and business models.
- **Outreach and engagement** – Testlabs will actively engage a range of stakeholders for open access, visits, meetings, training, workshops, and thought leadership.

2. Innovation platform

- **Research, innovation and knowledge translation** – Each Testlab will pursue research and innovation in specialist areas relevant to their expertise and industry application, in partnership with industry, and aimed at practical outcomes.
- **Network** – The Testlab network across Australia is a conceptual platform for distributed production, able to simulate transfer of production parameters to other demonstration sites.
- **Education and training** – Testlabs will develop skills training and education programs for TAFE, higher education, research and life-long learning.

3. Transformation catalyst

- **Workforce transformation** – Testlabs will be education and training platforms to develop Industry 4.0 relevant capabilities and advise on future skills requirements for universities, employers, unions, peak bodies, etc.
- **Industry networks** – Each Testlab will establish an industry advisory board chaired by an industry representative, and organise Industry 4.0 forums, connecting industry and companies.
- **Value-creation** – SMEs will cluster around the production lifecycle at a Testlab, helping inform how they will create value from Industry 4.0.
- **Regulation** – Testlabs are regulated and managed against common principles and values to ensure a consistent uptake of Industry 4.0 across Australia.
- **Strategic asset** – Testlabs represent a low-risk, practical, easy access entry point for companies to trial Industry 4.0 innovations. They provide a collaborative and non-competitive environment for all stakeholders, such as SME clusters.
- **Open access** – Testlabs in Australia and internationally will collectively showcase shared experiences and produce joint use cases around Industry 4.0.
- **Policy** – Testlabs inform and shape industry standards and government policy around Industry 4.0.

Context

Australia has world-class manufacturing strengths in several high-value industries, including medical technologies and aerospace. Australian SME manufacturers are well placed to benefit from alignment to these strategic niches within global value chains. Indeed, as indicated in the Australian Manufacturing Growth Centre *Sector Competitiveness Plan* the future of Australian advanced manufacturing largely depends on the competitiveness of the SME sector.

Industry 4.0 represents the most significant disruption to advanced manufacturing in half a century. The promise of fast, flexible, high quality and efficient production will be realised as the true power of Industry 4.0 is unleashed. It is not a coincidence that both the AMGC and the Australian Industry Group strongly support the uptake of Industry 4.0 strategies and practices. The three factors AMGC has identified as drivers of competitiveness in manufacturing – reduce costs, improve value, and increase market value – align closely with the potential benefits of Industry 4.0.

Advanced economies globally are embracing Industry 4.0 and related technology initiatives, led by manufacturing powerhouse Germany. The German government established Plattform Industrie 4.0 to support German SMEs by helping them understand and exploit Industry 4.0 strategies and opportunities, particularly in the areas of standardisation and norms, security, legal frameworks, research, and workforce transformation. Labs Network Industrie 4.0 (LNI4.0) is a German association connecting SMEs to a network of companies and Testlabs utilising Industry 4.0.

Australia must be at the vanguard of this fourth industrial revolution and support its SMEs and advanced manufacturing sector to increase its competitiveness. In 2016, the Australian Government supported a special initiative – the Prime Minister's Industry 4.0 Taskforce – to connect Australian industry to German and US industrial leaders.

The objectives of the Industry 4.0 Testlabs Workstream are:

- To establish an informed platform for the development of a national network of Industry 4.0 Testlabs in consultation with LNI4.0,
- To introduce a broad range of organisations across sectors to Industry 4.0 strategies and approaches,
- To develop the principles guiding Industry 4.0 testlabs/testbeds for training, education and research, and
- To enable and foster dialogue and collaboration among all stakeholders across the advanced manufacturing ecosystem in support of workforce transformation.

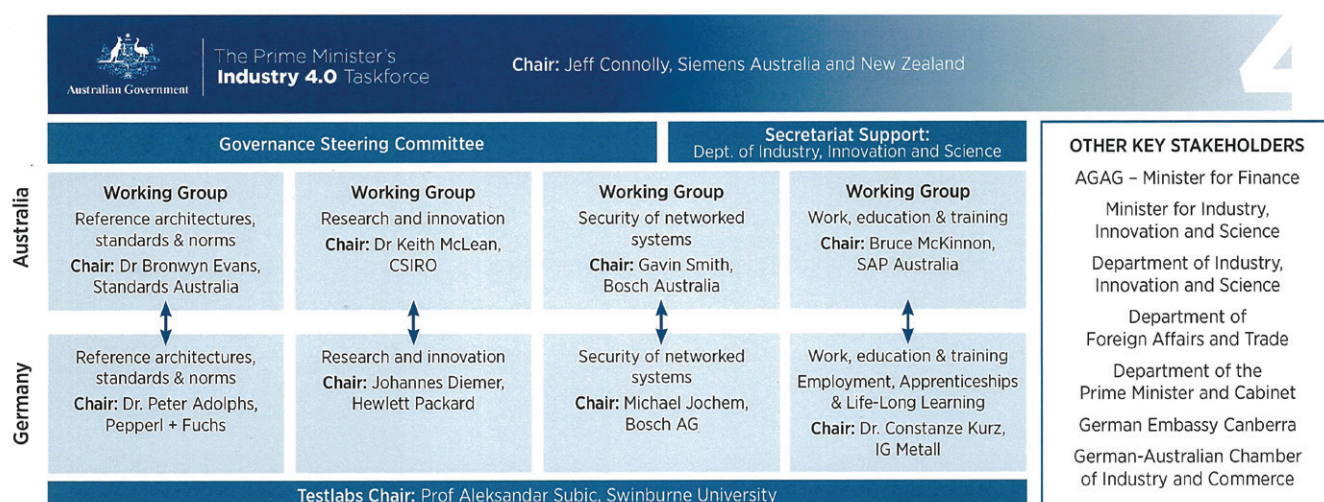
“Without a doubt, the digital transformation of industry demands cooperation at all levels – between companies, industries and institutions. And cooperation across national borders and across the respective emerging digital platforms. Together with other companies, research institutes, industry associations (e.g. VDMA, ZVEI, Bitkom) and public authorities we specifically established a ‘Labs Network Industrie 4.0’ – which is particularly valuable for SMEs as it offers various vendor-neutral testbeds. Labs Network Industrie 4.0 is proud to cooperate with similar initiatives around the world – and with Australia and Swinburne University, we have had one of our first international testbeds!”

Thomas Hahn, Chairman of Labs Network Industrie 4.0 (LNI 4.0), Germany

Context

Siemens Australia & New Zealand CEO, Jeff Connolly, chairs the Prime Minister's Industry 4.0 Taskforce, which is organised in several Working Groups: Reference architectures, standards & norms; Research & innovation; Security of networked systems; Work, education & training and Industry 4.0 Testlabs.

The Taskforce will establish a network of Industry 4.0 Testlabs that span the working groups, as shown below. This taskforce directly supports the National Science and Innovation Agenda.



"With SMEs playing such an important part of manufacturing, testlabs and 'use cases' are a strategic necessity to help SMEs test Industry 4.0 applications with world benchmark automation and digitalization technologies. The work already done between Australia and Germany as part of the Prime Minister's Industry 4.0 Taskforce has been well received including a presentation at the pre G20 conference in Berlin earlier this year. I congratulate Professor Aleks Subic and his team."

Jeff Connolly, Chairman and CEO of Siemens Australia and New Zealand, and Chairman of the Prime Minister's Industry 4.0 Taskforce.

This report is intended as a guide on Industry 4.0 Testlabs in Australia for industry, government, professional societies, labour organisations, research organisations and universities. It captures the fundamental principles of what defines an Industry 4.0 Testlab, regardless of its manufacturing process, industry, application or products.

The guide also describes technologies integral to, and accelerating, Industry 4.0. For companies, this guide is intended as a practical resource to help inform about the opportunities of Industry 4.0 and in partnering with an Industry 4.0 Testlab.

This information guide proceeds in three sections:

- **Section 1** outlines the context and significance of the fourth industrial revolution, the digital transformation that defines Industry 4.0, and introduces Industry 4.0 Testlabs technology, standards and security considerations.
- **Section 2** looks at Testlab developments across Australia and their industry focus with particular use cases of Industry 4.0 across Australia.
- **Section 3** demonstrates the important role Industry 4.0 Testlabs will play in transformation of Australian manufacturing and provides some practical advice on how workforce and digital transformation leads an organisation towards achieving an Industry 4.0 capability.

Section 1

Industry 4.0 Testlab

1.1 What is Industry 4.0?

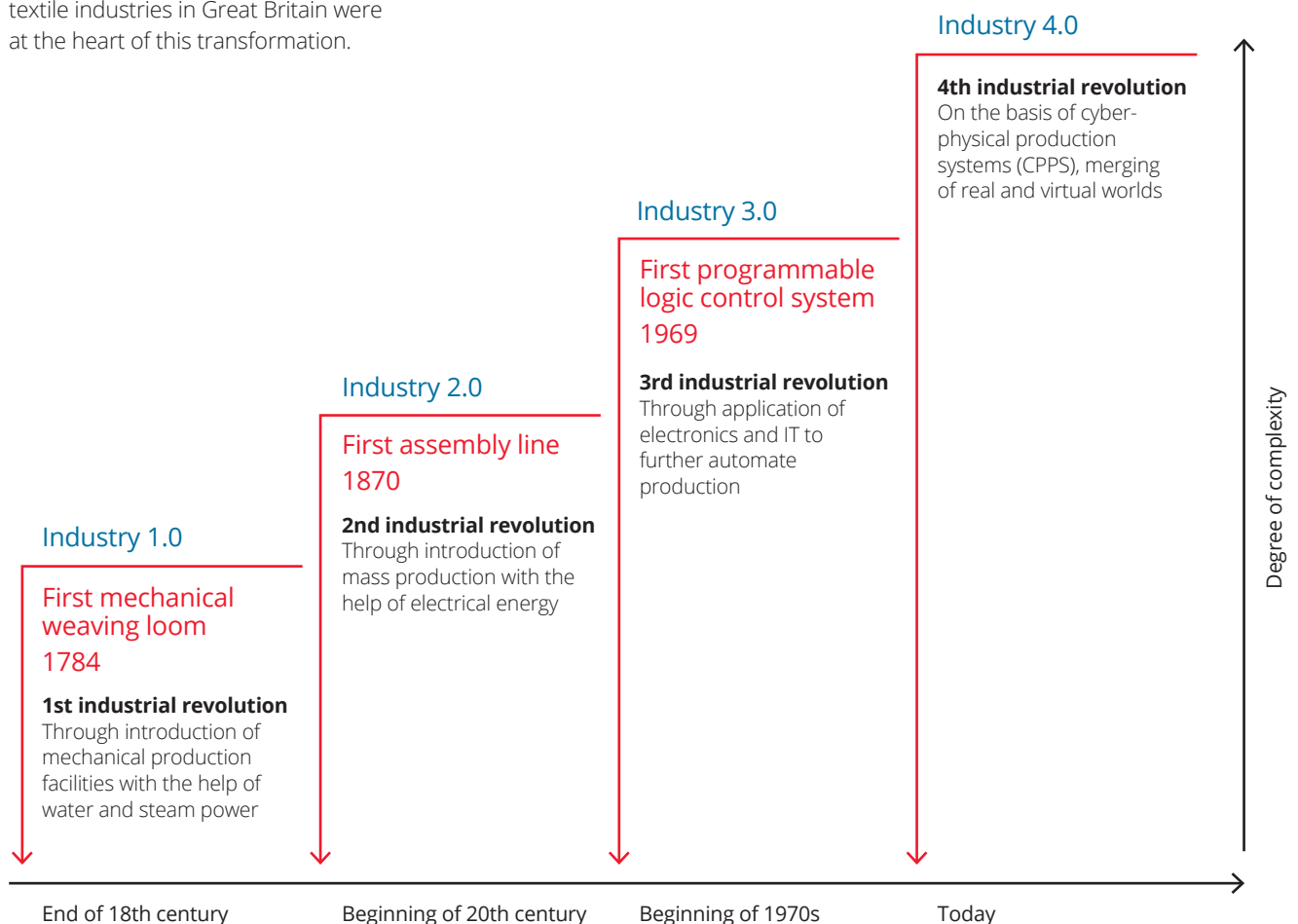
Fourth industrial revolution

In just a little more than two centuries, the industrial revolution has profoundly shaped and transformed the world from an economy largely based on primary industries and around work into the sophisticated civilization we know today. In fact, we have progressed through three industrial revolutions to date. (see figure below)

Around the end of the 18th century, the first Industrial Revolution saw cottage industries and manual labour replaced by mechanical production using water and steam power. The textile industries in Great Britain were at the heart of this transformation.

The second period began in the United States in the 1870s where assembly lines began transforming factories into mass manufacturing using electrical power, and where economies of scale determined success. While Henry Ford did not invent the assembly line, he is recognized as one of its most influential pioneers. In the late 1960s, advances in computing and electronics allowed production to be increasingly optimised and automated, known as programmable logic control systems, leading to greater efficiencies and improvements in quality and the third revolution in production.

We are now at the dawn of a fourth industrial revolution. In the same way that the Internet created enormous value by connecting people virtually, so too will the Internet of Things by interconnecting things. Cyber-physical production systems (CPPS) will lead to smart production, where intelligent products, machines, networks and systems independently communicate and cooperate with each other over the entire manufacturing process – with minimal human intervention.



Implications of digital transformation

Everything is being digitalised and interconnected. High-tech chips and sensors are increasingly being embedded in the things that we use (cars, planes, wearables, machines, etc), each creating valuable data relating to performance, behavior, condition, and so on. Three forces are shaping this digital future.

1. Acceleration

Moore's Law states that the doubling of the number of transistors on a microchip occurs around every two years. Today, similar exponential trends can be seen in everything from solar panels to gene sequencing. Exponential advances accelerate so quickly that they are difficult to fully comprehend: over the next 18 months to 2 years, the advances in digital technology will be equivalent to the *total advances* made since the very beginning of the computer age.

2. Convergence

As everything is digitalised, data will become ubiquitous and connections will be able to be made between everything via clever software. This technology is breaking down barriers converging industries (e.g. information, communication and entertainment), converging disciplines (e.g. genomics, nanotechnology, robotics) and converging, biological, physical and virtual worlds (e.g. cyber-physical systems).

3. Individualisation

The digital identity we create of ourselves online – what we like, who we follow and communicate with, where we click, what we post, what we buy, how we exercise – increasingly allows each of us to be distinguished as an individual. No longer will we accept mass marketing of mass produced goods but we will increasingly expect products and services individualised to our needs and desires. This shift in consumer mindset means companies will increasingly have to meet the expectations of the individual first.

Internet of Things (IoT)

The IoT is the platform that brings together and coordinates information from all diverse sources through a common language for devices and apps. Through secure communication with an IoT platform, data from many devices is integrated. Sophisticated analytics determine the most valuable data (knowledge) with applications that directly relate to specific needs and certain events. By connecting all these devices together their data can be shared allowing them to communicate with each other, thus helping provide a better understanding of how these things work and how they work together. In a factory setting, this means that machines and products communicate with each other cooperatively as everything is interconnected wirelessly through an Internet of Things.

Industry of the future

How will companies thrive in the digital revolution involving the Internet of Things? The digitalisation of the manufacturing industry will catalyse tremendous change and unleash enormous value-creating potential. In the mass manufacturing paradigm of the twentieth century, economies of scale drove profit models. Being *cost-efficient* is still essential but companies now also have to be *flexible* and *fast* – able to scale without additional costs. This is the promise of "Industry 4.0".

Section 1

Industry 4.0 Testlab

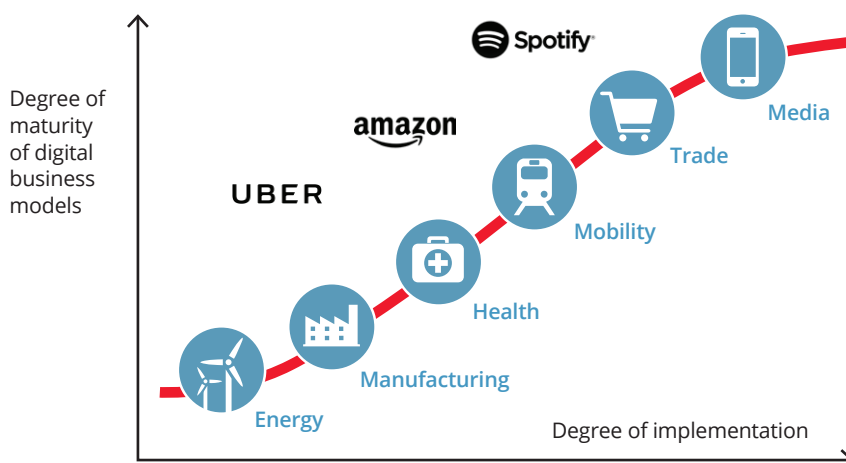
Product lifecycles are becoming increasingly shorter while product variants continue to diversify. Ultimately, Industry 4.0 should be able to produce a batch of one as economically as the large volumes in “Industry 3.0” mass manufacturing – only faster. This means companies will need to undergo a business mindset shift to be:

- **Flexible:** align themselves much more rigorously with customers to meet their needs,
- **Fast:** shorten lead times so that delivery becomes faster,
- **Efficient:** cost-efficient, sustainable manufacturing, and
- **Quality-focused:** enhance the quality of production and products.

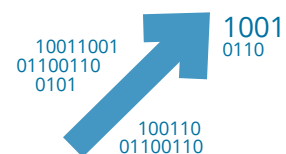
According to RnR Market Research, the overall Industry 4.0 market was valued at \$66.67 billion in 2016 and is expected to reach \$152.31 billion by 2022, at a CAGR of 14.72% between 2017 and 2022. Some of the major players in the Industry 4.0 market are companies such as GE, IBM, Cisco (US), Siemens (Germany), Samsung (Korea), and Mitsubishi Electric (Japan).

To begin aligning to Industry 4.0, companies must undergo digital transformation. That means digitalising, automating and interconnecting all machines and processes – starting within the company and eventually along the entire value chain and value network, using uniform standards.

The aim of a company's digital ecosystem will be to seamlessly connect customers and business partners. The goal is to make all relevant data available anytime and to be able to control the whole network of value creation in real time, from product planning, development, production, logistics, service, and replacement. Synchronising physical and digital value streams will not only increase productivity, efficiency, and quality, but also enhance a company's ability to be innovative and succeed. Data security is thus of utmost importance.



We are seeing increasing digitalisation of industries



Source: Accenture – assessment based on the 3 dimensions (business models, value creation processes and products)

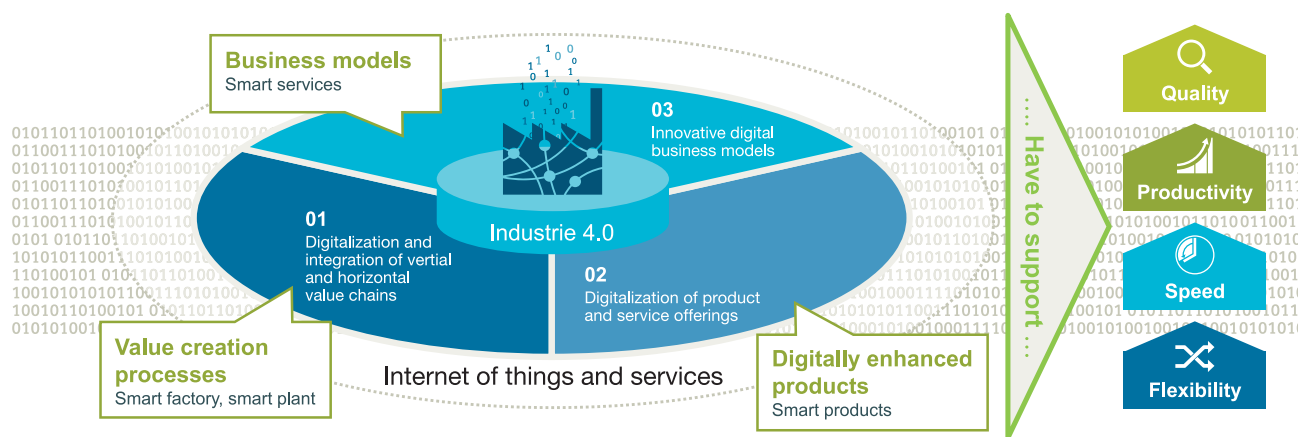


Industry 4.0

Industry 4.0 is often described as digitalisation or full-scale automation. Also, it is sometimes defined in relation to emerging technologies – advancements in IoT, big data and data analytics, robotics, autonomous systems, sensors and automation, and production methods such as 3D printing. Yet while digitalisation has given rise to Industry 4.0, it is not enough to define and describe Industry 4.0 from a purely technological perspective. Because of convergence, enterprise transformation – through changes in business models, organisation and culture – is just as integral to Industry 4.0 as technology.

Industrie 4.0 is the “real-time, high data volume, multilateral communication and interconnectedness between cyber-physical systems and people”

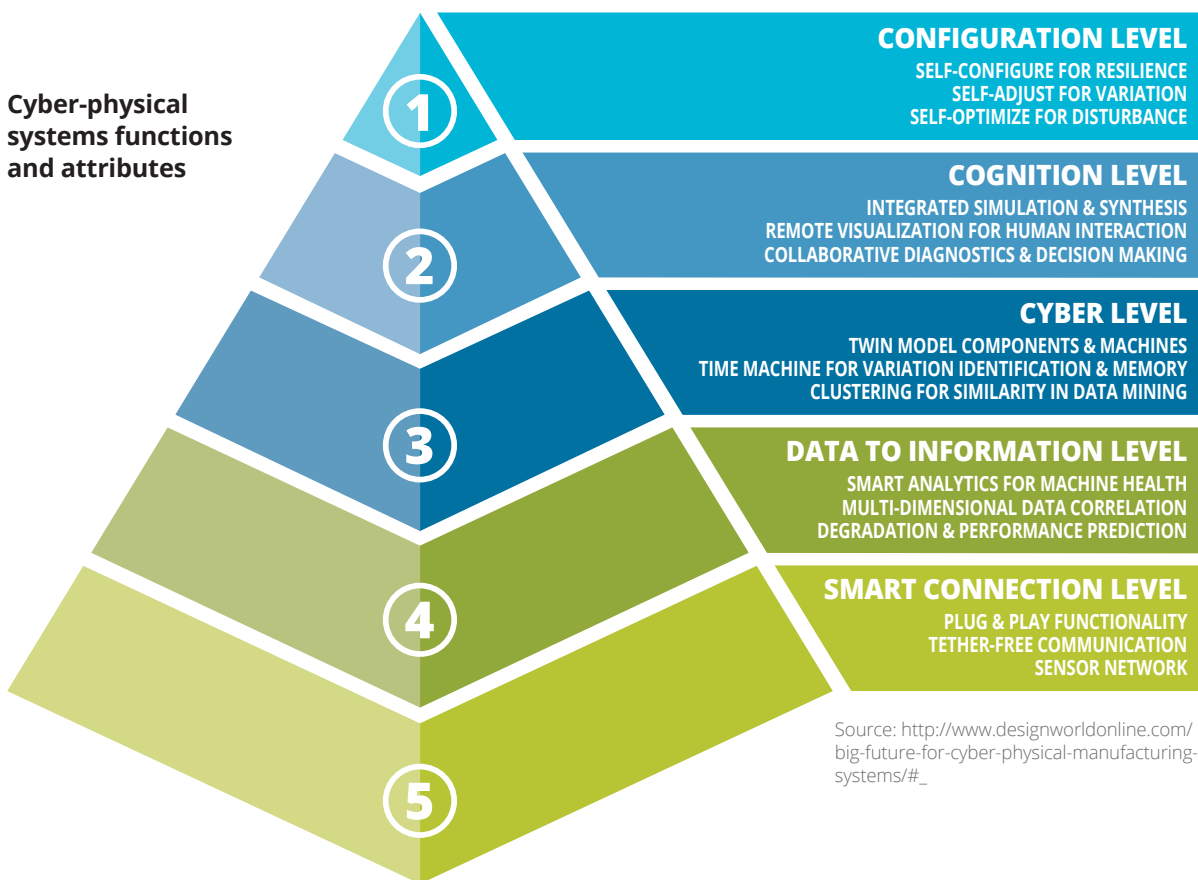
acatech, German National Academy of Science and Engineering



Source: ZVEI following PwC

Cyber-physical production systems (CPPS)

CPPS are the enabling technologies bringing the virtual and physical dimensions together in manufacturing to create a truly networked domain in which intelligent objects communicate and interact with each other. CPPS architecture has five levels.



Industry 4.0 refers to the “suite of digital technologies augmenting industrial processes, including 1) the rise of data volumes, computational power and connectivity; 2) emergence of business intelligence capabilities; 3) new forms of human-machine interactions; 4) improvements in transferring digital instructions to the physical world, e.g. 3D printing.”

Australian Manufacturing Growth Centre



Industry 4.0 manufacturing

Akin to social networks for humans, cyber-physical production systems (CPPS) are networks of social machines; the scaffolding of Industry 4.0. The information protocols within CPPSs facilitate the exchange of information over the entire lifecycle of a product, as data transfers seamlessly from system to system. Machines monitor one another and make *decentralised* decisions about production and maintenance, with *centralised* storage of all data generated in cyber versions of the physical thing, known as “digital twins”.

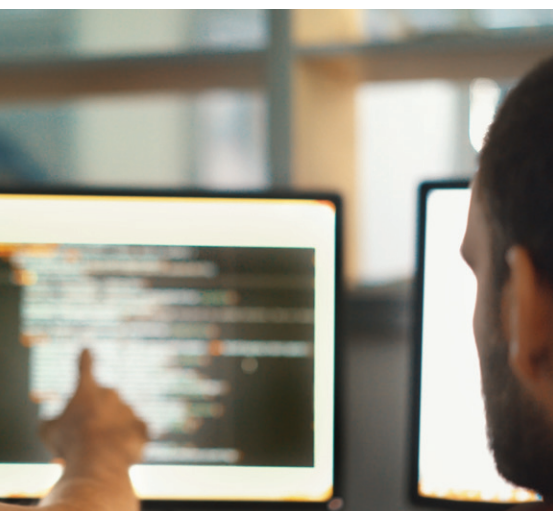
Industry 4.0 manufacturing is defined as an intelligent, self-regulating, automated manufacturing process on cyber-physical production systems, producing one or more products simultaneously. Products find their way independently through the product lifecycle via the CPPS – all without direct human intervention.

Industry 4.0 manufacturing is distinguished by its modularised and decentralised structure where three distinctive processes/features drive the digital manufacturing process:

- 1. Decentralised information** – the product to be manufactured contains all necessary information on its production requirements. The product manufacturing instructions are decentralised in each module with the instructions for each work step carried on the product, e.g. in RFID chips.
- 2. Self-organisation** – production modules are able to self-organise over the entire manufacturing process. Each module is self-controlled as it knows what to do without having to communicate with a central hub.
- 3. Communication and cooperation among modules** – flexible decision making on manufacturing process based on current real-time situation. Each of the modules are able to communicate with each other so the partially-completed product can be passed on to the next module.

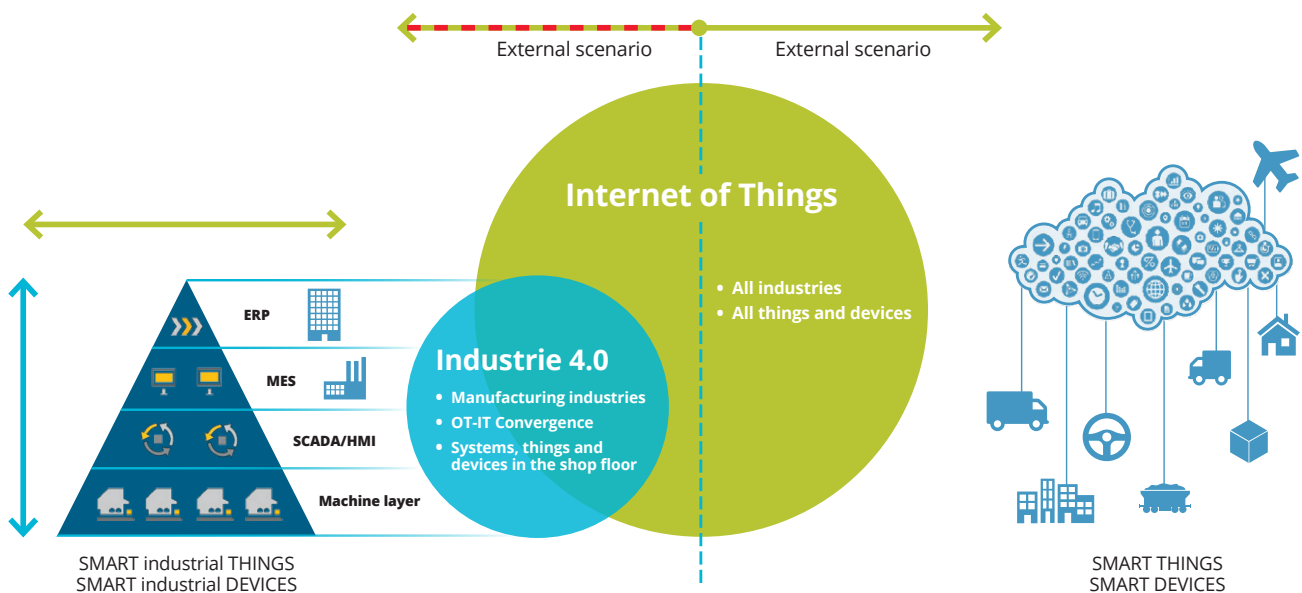
All the information on the product therefore creates an intelligent and self-organised ensemble of the modular components of the smart factory. This process is significantly more efficient than traditional “Industry 3.0” manufacturing as each intelligent component can make real time decisions as opposed to all components requiring a hub to make centralised decisions. The decentralised control function results in a significantly shortened communication path, and greatly increases flexibility.

See Appendix 1 for more insight on strategic considerations of Industry 4.0.



Industry 4.0 vs Internet of Things

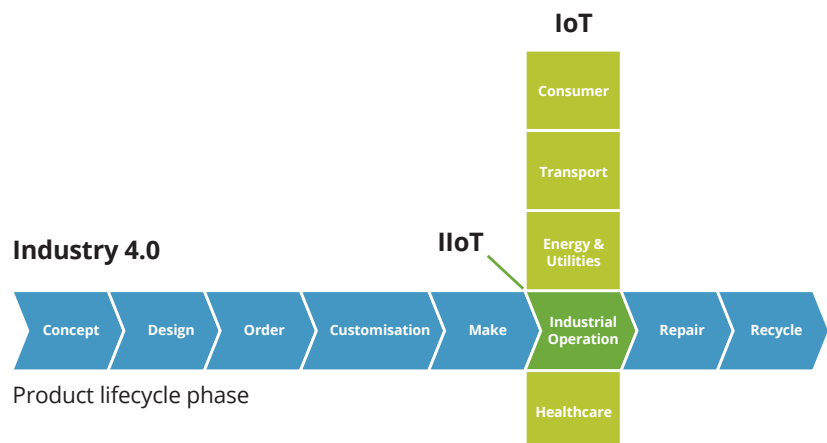
Industry 4.0 is a significant subset of the Internet of Things. The IoT spans both internal industrial and external scenarios, respectively described as encompassing smart industrial things and devices, and smart things and devices.



Source: SAP

Industry 4.0 vs Industrial Internet of Things (IIoT)

Whereas Industry 4.0 describes a new manufacturing process based on digitalisation, the IIoT describes systems that connect and integrate industrial control systems with enterprise systems, business processes and analytics. The aim of IIoT is to optimise operations across asset types, fleets, suppliers and customers worldwide. The Industrial Internet of Things is where Industry 4.0 meets the Internet of Things – in the operation phase of the lifecycle of a product.



Source: Jonas Berge

Main Industry 4.0 consortia

Germany

To advance Industry 4.0 for the long-term benefit for society as a whole, Germany has three Industry 4.0 initiatives all working in complement with one another.

1. Plattform Industrie 4.0 is a German strategic initiative, defining the cyber-physical systems that will revolutionise manufacturing industries. The guiding principles of Industrie 4.0 are:

- **Customer benefits first “C2B”** – mindset shift for industry from making products to creating solutions that generate customer benefits (individualisation).
- **Build on, augment and enhance core competencies and strengths.** Digitalisation must enhance our profound understanding of physical world and manufacturing processes.
- **Unique approaches** – one size does not fit all.

Plattform Industrie 4.0 brings together the private sector, academia, politics, trade unions and professional associations. It provides support for the coordinated and organised transition to the digital economy in Germany through guidance on what needs to be translated into practice.

2. Labs Network Industrie 4.0

(LNI4.0) supports German industry in testing the practical use of Industry 4.0, described as a “one-stop shop for the coordination of different Industry 4.0 approaches”. It supports companies in a risk-free environment in the initiation of Industry 4.0 projects, pooling results from testbeds to inform standardisation and international cooperation.

Labs Network Industrie 4.0 is particularly valuable for SMEs as it offers various vendor-neutral testbeds with easy access to distributed infrastructure at test environments.

LNI4.0 connects and networks across Germany a multitude of “Testbeds” – projects where small and medium-sized mechanical and plant engineering companies are developing new components for Industry 4.0. Testbeds allow SMEs to test:

- their latest developments in a realistic environment to prepare them for production, and
- innovative system approaches and networked business models before bringing them to market.

These Testbeds test, develop and refine complex production and logistics systems under realistic conditions in specialist centres at universities and research institutions. Importantly, companies can work on solutions that can later be commercialised as their own products and application solutions with low risk and minimal investment of their own resources.

3. Standardization Council

Industrie 4.0 (SCI 4.0) was established to provide access for all companies to standardisation bodies on Industry 4.0. SCI 4.0 works in close relation with LNI4.0 and Plattform Industrie 4.0 to help progress Industry 4.0, especially in assisting SMEs to get access to the international **Standardisation Organisation**. SDO is a consensus-based organisation similar to the DIN/IEC or consortia-based organisation such as OPC-F/OM/W3C.

USA

Industrial Internet Consortium

The Industrial Internet Consortium (IIC) is an organisation focused on transforming business and industry by accelerating the Industrial Internet of Things (IIoT). Its mission is to deliver a trustworthy IIoT in which the world's systems and devices are securely connected and controlled to deliver transformational outcomes.

The IIC has published the Industrial Internet Reference Architecture. Known as the IIRA, this standards-based architectural template and methodology enables Industrial Internet of Things (IIoT) system architects to design their own systems based on a common framework and concepts.

America Makes is the National Additive Manufacturing Innovation Institute, based in Youngstown, Ohio. America Makes is the leading and collaborative partner in additive manufacturing (AM) and 3D printing (3DP) technology research, discovery, creation, and innovation. Structured as a public-private partnership with member organisations from industry, academia, government, non-government agencies, and workforce and economic development resources, America Makes works to innovate and accelerate AM and 3DP to increase American global manufacturing competitiveness.

Section 1

Industry 4.0 Testlab

1.2 What are Industry 4.0 Testlabs?

Based in specialist Industry 4.0 facilities at research and education organisations like universities across Australia, Testlabs are where Industry 4.0 within an Australian manufacturing context is being designed, developed and trialed in partnership with industry and other stakeholders. Industry 4.0 Testlabs will help Australian industry in three ways: Industry 4.0 showcase, innovation platform and catalyst of transformation. These are the guiding principles of Industry 4.0 Testlabs.

Industry 4.0 showcase

Testlabs are where digitalisation and Industry 4.0 become accessible and tangible, being where industry can see firsthand a smart factory prototype. Testlabs show how new technologies, new applications, new products, new services, new security and new processes work together using an Industry 4.0 platform.

Each Testlab will familiarise, make accessible and realise Industry 4.0 strategies, concepts and solutions for stakeholders/partners. The Industry 4.0 showcase extends beyond industry to academia, policymakers, labour organisations (e.g. unions), and broader society.

Innovation platform

Industry 4.0 Testlabs are integrated platforms for: i) R+D, ii) education, and iii) skills development that directly link and relate to training programs in Industry 4.0. Individually Industry 4.0 Testlabs are platforms for open innovation in digital manufacturing. As a network Testlabs are a conceptual platform for distributed production, able to simulate transfer of production parameters to other demonstration sites.

Testlabs will reach out and actively engage a range of stakeholders for open access, visits, meetings, training, workshops and thought leadership. Each Testlab will establish an industry advisory board chaired by an industry representative.



Factory of the Future, Swinburne University of Technology

Catalyst of Industry 4.0 transformation

Testlabs will introduce a broad range of organisations across sectors to Industry 4.0, and help catalyse transformation. Elements include:

Workforce transformation – Testlabs will be education and training platforms to develop Industry 4.0 capabilities and advise on future skills requirements for universities, employers, unions, peak bodies, etc.

Industry networks – Each Testlab will establish an industry advisory board chaired by an industry representative, and organise Industry 4.0 forums, connecting industry, companies.

Value-creation – SMEs will cluster around the production lifecycle at a Testlab, helping inform how they will create value from Industry 4.0.

Regulation – Testlabs are regulated and managed against common principles and values to ensure a consistent uptake of Industry 4.0 across Australia.

Strategic asset – Testlabs represent a low-risk, practical, easy access entry point for companies to trial Industry 4.0 innovations. They provide a collaborative and non-competitive environment for all stakeholders, such as SME clusters.

Open access – Testlabs in Australia and internationally will collectively showcase shared experiences and produce joint use cases around Industry 4.0

Policy – Testlabs inform and shape industry standards and government policy around Industry 4.0.

It is recommended that a wider range of testlabs be distributed nationally across institutions in each state, aligning their area of application with growth industry sectors and respective state industry priorities. These testlabs will collaborate across the national network forming a strategic portfolio of capabilities that support research, education, training and engagement with industry. Each industry 4.0 Testlab would need to meet the Industry 4.0 qualification criteria described in this report and operate in line with the guiding principles.



RMIT Advanced Manufacturing Precinct

Demonstrator of digital transformation

A significant function of Industry 4.0 Testlabs will be to assist/advise SMEs with their digital transformation. To develop explicit knowledge and tacit understanding of digital transformation, Testlabs themselves will follow a similar digital transformation pathway as companies.

The National Academy of Science and Engineering in Germany, acatech, has developed a rigorous approach for the digital transformation of companies. A similar digital transformation approach will guide each Industry 4.0 Testlab in its establishment, as summarised in these two stages:

Stage 1. **Technological feasibility** – resources and information systems

Stage 2. **Enterprise transformation** – business, organisation and culture

Each Testlab will focus on designing, developing and demonstrating its respective technological feasibility in their first stage, and implement these lessons learned in helping companies with their enterprise transformation.

"Australia's leading trading partners and competitors are undergoing a major technology-led industrial transformation to improve their competitiveness and prospects. If we are going to improve our own prosperity, we cannot afford to be left behind either at a national, company or workforce level and investment now and into the future is crucial.

The jobs of future, the industries that provide them and the communities that sustain them are increasingly going to rely on the development, understanding and use of new technologies. Sensors, robotics, automation and data analytics are growing rapidly as part of the workplace.

The more we understand, the more we can all be part of the inevitable change and use it to shape our workforce and community to the advantage of all of us. The Testlabs are a crucial part of developing our knowledge about the challenges and opportunities of now and the future".

Innes Willox, CEO, The Australian Industry Group (Ai Group)

Industry 4.0 Testlabs – Core technology and features

A Testlab is a “minimum Industry 4.0 viable facility” that demonstrates an Industry 4.0 production lifecycle. Technological feasibility requires both the digital transformation of resources (digital capability, structured communication) and of information systems (information processing and integration). The following core technology features, informed by a PwC Germany report, are characteristic of an Industry 4.0 Testlab and support technological feasibility. <https://www.pwc.de/de/digitale-transformation/assets/digital-factories-2020-shaping-the-future-of-manufacturing.pdf>

1 “Digital twin”

The aerospace and defense industry developed the concepts of digital thread and digital twin for military aircraft. The aim was to improve the performance of future programs by applying lessons learned in current programs via these digital versions of physical things. The digital thread and digital twin now find utility with the digital manufacturing and cyber-physical production system of Industry 4.0. <http://www.manufacturing-operations-management.com/manufacturing/2016/04/what-is-the-digital-thread-and-digital-twin-definition.html>

a. Digital thread

The digital thread refers to the communication framework that allows a connected data flow and integrated view of the asset's data throughout its lifecycle across traditionally siloed functional perspectives. The digital thread concept objective is to deliver “the right information to the right place at the right time”.

b. Digital twin of a product or process

The digital twin refers to a digital model of a particular product or process that includes design specifications and engineering models describing its geometry, materials, components, assembly and behavior, but more importantly it also includes the as-built and operational data unique to the specific physical asset which it represents.

c. Digital twin of a production asset

This refers to the digital version of a production asset used for design, virtual start-up and ongoing operation. The asset's operations are simulated to optimise its key parameters, enabling predictive maintenance.

d. Digital shadow of factory

The factory's digital twin/digital shadow is helpful in planning, designing and constructing the physical factory. It is used to support testing and simulate process operation. The digital shadow can show what is happening in the factory at any given moment so that decisions can be based on real data.

Role of Testlabs in developing digital manufacturing platforms

Digital twin	Digital thread
<ul style="list-style-type: none"> Assess a system's current and future capabilities during its lifecycle Discover system performance deficiencies by simulating results before developing physical processes and product Optimise the product's operations and improve future manufacturing processes Continuously refine designs and models through data captured 	<ul style="list-style-type: none"> Improve product quality by avoiding mistakes in manual translations of engineering specifications along the product value chain Improve the velocity of new product introductions and the communication of engineering changes along the product value chain Increase the efficiency of digitally capturing and analyzing data related to product manufacturing Allow manufacturers to deliver new services to customers along with physical product leveraging the digital data now available on the product

<http://www.manufacturing-operations-management.com/manufacturing/2016/04/what-is-the-digital-thread-and-digital-twin-definition.html>

2 Connectivity

All Testlab objects and resources (machines, products, humans, etc) are connected through sensors, actuators, and interfaces to a connectivity layer for control and optimisation purposes, such as through the Manufacturing Execution System (MES).

3 Intelligent modules in production

Testlabs use flexible, modular production assets like robots, storage vehicles, and fixtures that are flexibly integrated into the production flow as required by the current production process.

4 Flexible production methods

Testlabs incorporate flexible production processes such as 3D printing to support a high variant diversity, significantly increasing flexibility.

5 Process visualisation

Testlabs will develop visualisation technologies as decision support systems. Processes are visualised through mobile apps that combine VR and AR solutions on tablets/digital glasses/LCD monitors.

6 Manufacturing Execution System (MES)

Testlabs have integrated planning and scheduling systems from machine level up over an MES, allowing for immediate reaction to changes in resource availability, and supporting “just-in-sequence” delivery of components.

7 Big data/analytics

Testlabs employ sophisticated analytics to identify patterns in the massive volume of data to get value out of the data to optimise production processes and product quality.

8 Predictive maintenance

Remote monitoring of machines in dynamic Industry 4.0 Testlab environments use sensor data and analytics to predict maintenance and repairs.

9 Data-enabled resource optimisation

Data analytics on production processes help optimise resource and energy consumption in Testlabs.

10 Autonomous intraplant logistics

Testlabs will develop systems capable of operating and performing logistics without human intervention.

11 Networked production

Testlabs may be networked across Australia to simulate transfer of production parameters to other demonstration sites.



Flinders at Tonsley

Glossary of particular technologies accelerating Industry 4.0 development

AI

Artificial intelligence, combined with advanced robotics and sensor technology will lead to increased autonomy and enhanced individualisation and flexibility.

Augmented reality

A visualisation technology that overlays information and instructions onto real images, with applications ranging from installation, assembly and operation of machinery through to training.

Big data analytics

Powerful technology able to examine large and varied data sets produced by sophisticated sensors to reveal patterns and correlations, providing information on performance, maintenance and repair needs.

Cobots

Collaborative robots – designed for direct and safe human-robot collaboration in industrial work environments. Being integrated into human workspaces increases economies and productivity without the need for any safety enclosure. Cobots can learn from human colleagues and can independently check, optimise, and document its own work while connected to the cloud.

Flying maintenance robots and autonomous trains

Drones will deliver spare parts, component sequencing, and enhance flexibility of manufacturing logistics.

Nanomaterials and nanosensors

Used in production control functions, will lead to next generation cobots (collaborative robots), working alongside humans.

Robotic vision

Expands the capabilities of robots, allowing them to see and understand the environment in which they are working.

3D printing

Additive manufacturing will greatly increase flexibility, allowing new production solutions (functionality, increased complexity, customisation in-situ). For example 3D printing of implants in surgery or insoles for shoes. 3D printing could also disrupt business models through disintermediation of the supply chain.



1.3 Industry 4.0 Testlab – Qualification Criteria and Accreditation

Standards Australia released in March 2017 a report recommending its approach to standardisation in Industry 4.0. According to Standards Australia, the fundamental purpose of Industry 4.0 standards is to facilitate cooperation and collaboration between technical objects, requiring them to be virtually represented and connected. Plattform Industrie 4.0 proposes a neutral reference architecture model – RAMI 4.0 – that integrates systems across domain borders, hierarchy borders and life cycle phases.

Reference Architecture Model Industrie 4.0 (RAMI 4.0) is a three-dimensional coordinate system that describes all aspects crucial to Industrie 4.0, and will form the standard for Testlab architecture. In this way, complex interrelations can be broken down into smaller and simpler clusters. Within the 3D space formed by the three axes, all important aspects of Industry 4.0 can be mapped, allowing objects such as machines to be classified according to the model.

RAMI 4.0 describes highly flexible Industry 4.0 concepts, allowing for systematic migration from the present into Industry 4.0.

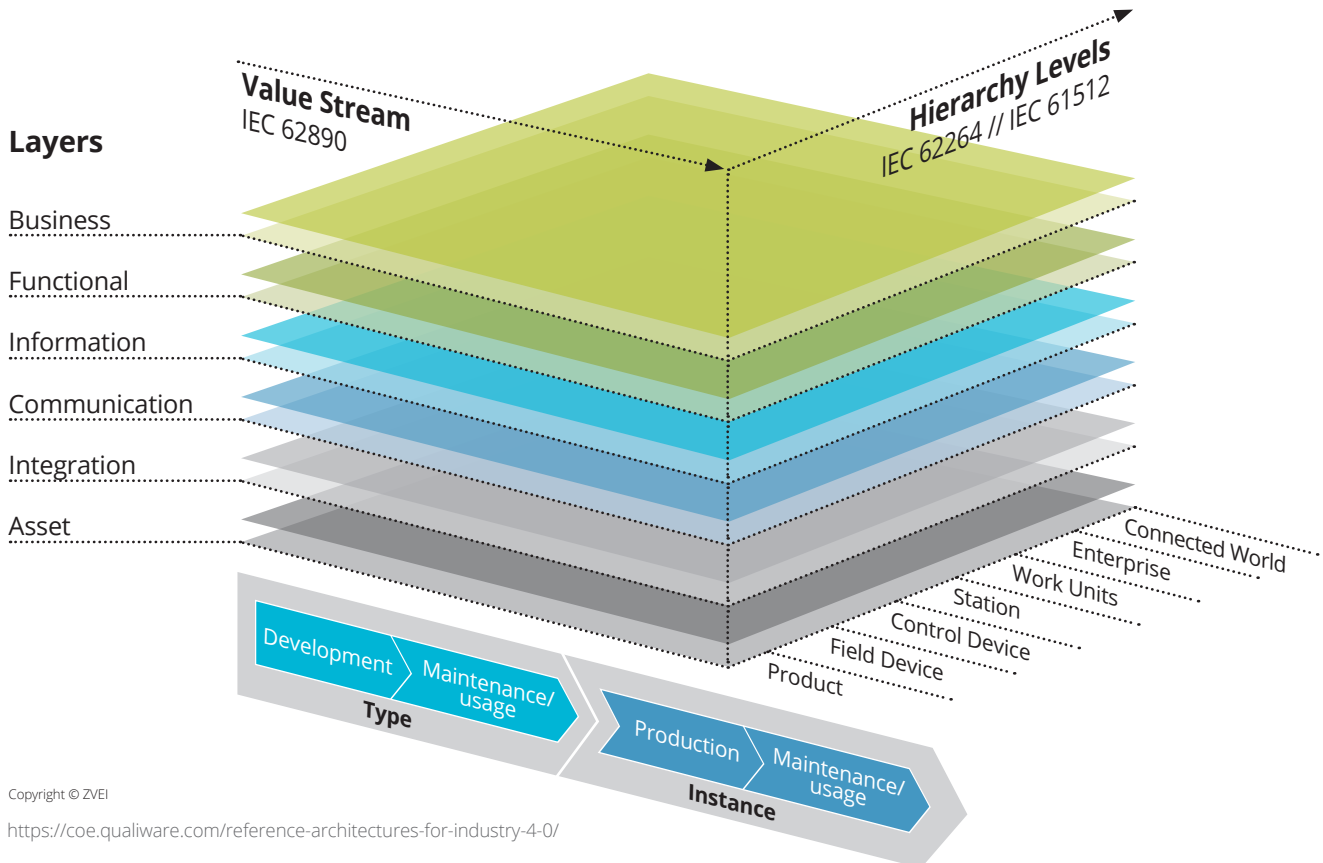
Standards Australia is collaborating with its German counterpart to add Australian use cases to the body of international work on RAMI 4.0. The Prime Minister's Industry 4.0 Taskforce will select use cases in industry to test against RAMI 4.0, measuring the effect on the company.

Testlabs are based on RAMI 4.0 which combines all elements of Industry 4.0 in a 3D layered model.

Section 1

Industry 4.0 Testlab

Reference Architectural Model Industrie 4.0 (RAMI 4.0)



Hierarchy Levels

Hierarchy levels derive from IEC 62264, the international standards series for enterprise IT and control systems integration, and IEC 61512 for batch control and represent the different functionalities within factories or facilities. To represent the Industry 4.0 environment, these functionalities extend from workpieces, "Product", through to connection to the Internet of Things and Services, labelled "Connected World".

Life Cycle and Value Stream

Life cycle of facilities and products is based on IEC 62890 for life-cycle management. Note the distinction between "types" and "instances" such that a "type" becomes an "instance" when design and prototyping have been completed and the actual product is being manufactured.

Layers

The six layers on the vertical axis serve to describe the decomposition of a machine into its properties structured layer by layer, i.e. the virtual mapping of a machine.

Industrial Internet Reference Architecture

The Industrial Internet Reference Architecture (IIRA) is the reference guide in developing, documenting, communicating and deploying IIoT systems. Core to IIRA are the "IIRA viewpoints", which are different enterprise frames of reference. This includes business viewpoint, usage viewpoint, functional viewpoint, and implementation viewpoint.

Plattform Industrie 4.0 and IIC have established a working group to consider the technical alignment of RAMI 4.0 and IIRA architectures. They released a working paper in April 2017 "Exemplification of the Industrie 4.0 Application Scenario Value-Based Service following IIRA Structure".

Industry 4.0 Testlabs Security Guidelines

Security in Industry 4.0 platforms is critical. The holistic and integrated nature of Industry 4.0 demands security solutions that encompass everything from component manufacturing to integration to plant operation. Fundamental to Industry 4.0 is the seamless connections between all the production links within a value chain and network. For suppliers, customers, partners to be horizontally and vertically integrated means boundaries between companies – between competitors – will gradually disappear. At the same time, speed and flexibility in production will drive Industry 4.0 profit models meaning any shutdown in production will cause significant disruption to supply chains.

Implementing security measures is more than risk management and safeguarding IT systems. Rather Industry 4.0 security is a forcing function for companies to oversee manufacturing and production from the perspective of the entire lifecycle. Risk and strategy become two sides of the same coin. The goal of Industry 4.0 Security is to ensure security is “designed in” as an integral aspect right from the beginning of the production development process. Establishing security as a function must ultimately replace the post facto “bolt on” security measures of today’s conventional manufacturing.

These security guidelines, based on Industrie 4.0 Security Guidelines of VDMA Germany, introduce technologies and approaches necessary to enhance the security of complex systems, which Industry 4.0 Testlabs will embed. Testlabs will be a critical resource in developing security measures for SMEs where lack of resources can hamper developing comprehensive security risk management systems within their respective business environments.

Appendix 2 provides more detailed information on security considerations, as outlined by VDMA.

Section 2

Implications for Australia

Industry 4.0 Testlabs will engage with a broad range of organisations to showcase Industry 4.0, be platforms for innovation, and catalyse transformation. Industry 4.0 Testlabs are being located around Australia to demonstrate Industry 4.0 technologies across a range of different manufacturing processes and to show the practical approaches and tangible benefits of digital technology. These sites are intended to be a strategic resource for Australian industry, in particular SMEs. But so too will they be valuable for government, universities and other organisations.

Since the establishment of the Prime Minister's Industry 4.0 Taskforce, there has been a growing and increasingly focused effort across Australia to establish Industry 4.0 initiatives. At various stages of development and implementation, the Testlabs showcased here will each provide a valuable contribution to understanding the true potential and value of Industry 4.0 in an Australian context. In learning by doing each Testlab will be encouraged to continuously improve their Industry 4.0 maturity.



“Given our whole reason for existence is about enhancing the competitiveness of the manufacturing sector, we see that industry 4.0 is a key element of maintaining and increasing that global competitiveness. Adoption is one of the issues that the Task Force and indeed our approach is looking to progress, through greater awareness, initially, greater application, secondly, and greater benefits and competitiveness, at the third level.”

Andrew Stevens, Chairman of AMG



Factory of the Future, Swinburne University of Technology

Each Testlab has a specific application focus. The Swinburne Industry 4.0 Testlab focuses on composite product automation, at UTS it is algae production and LNG production at UWA. Each Testlab is being set up as a complex and interconnected environment of production assets and processes to help companies in a specific industry understand and prepare themselves for Industry 4.0. Industry 4.0 Testlabs provide a platform for companies to test technological feasibility and the implications Industry 4.0 will have on the business.

Based at leading research organisations across Australia, the Industry 4.0 Testlabs will demonstrate complex production and logistics systems under realistic conditions. Testlabs may be networked across Australia to simulate transfer of production parameters to other demonstration sites.

This section provides overviews of leading use cases of Industry 4.0, as well as examples of enabling Industry 4.0 technologies.

Use cases of Industry 4.0 Testlabs and Technology across Australia



INDUSTRY 4.0 TESTLAB COMPOSITE PRODUCT AUTOMATION

Industry 4.0 Testlab for Composite Product Automation

In his book, "The Fourth Industrial Revolution", Klaus Schwab (Founder and Executive Chairman, World Economic Forum) identifies the paradigm shift to engineered materials as being a key innovation of the fourth industrial revolution.

"With attributes that seemed unimaginable a few years ago, new materials are coming to market. Overall, they are lighter, stronger, recyclable and adaptive. When graphene becomes price competitive, it could significantly disrupt the manufacturing and infrastructure industries."

Located in Swinburne's Factory of the Future at the Hawthorn Campus, the Industry 4.0 Testlab for Composite Product Automation will specialise in composite product design and manufacturing. Our initial focus will be on carbon-fibre reinforced composites before moving to nanocomposite materials such as graphene-coated textiles.

According to Acmite Market Intelligence, the global market for carbon fibre composites is expected to grow exponentially to \$38 billion by 2024 with key applications in aerospace, automotive, defence, wind energy and civil engineering. With advanced automation in conjunction with rapid processing being utilised to manufacture complex high-volume parts at a rate of under 3 minutes, the U.S. Department of Energy Office of Nuclear Energy expects current costs per part can be reduced from \$50/lb down to \$5/lb.

Swinburne's Industry 4.0 Testlab will bring a world first, digital approach to carbon-fibre deposition to Australia. This newly developed process will provide the ability to rapidly create near net shape preforms that will minimise waste, reduce cost and be applicable to high volumes not previously possible. Through our partnership with two OEMs and one Tier 1 supplier, we will be manufacturing and assessing actual industrial parts.

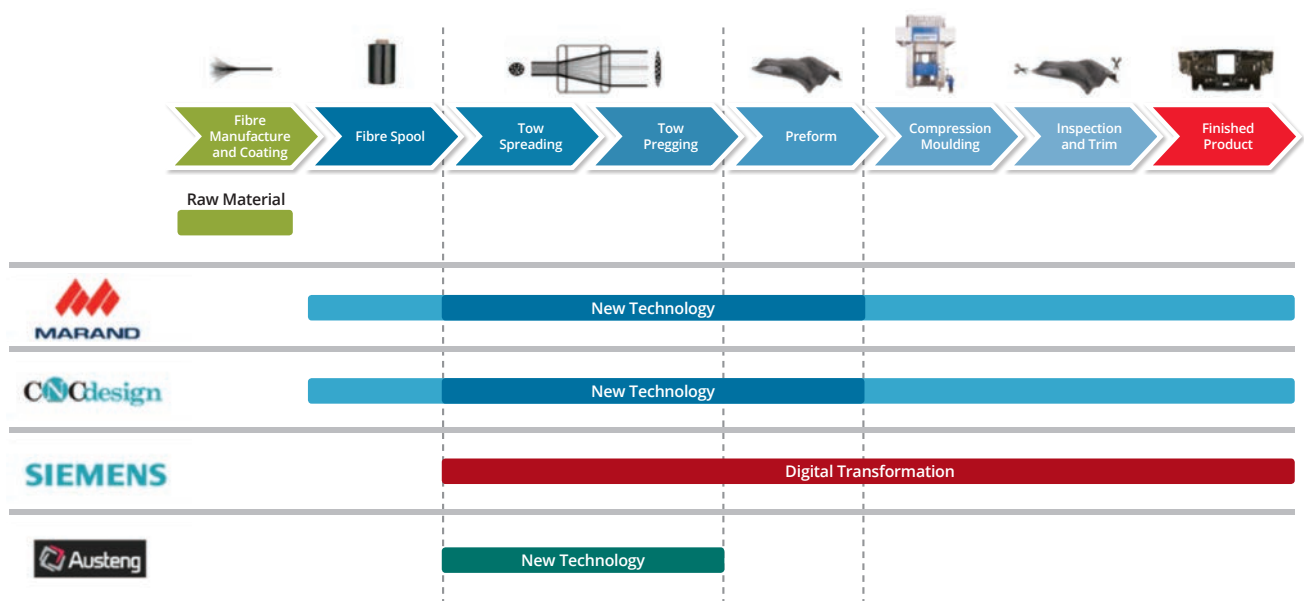


As illustrated in Figure 1, the new technology will be integrated into a versatile, reconfigurable and upgradable production line including resin dispensing and curing.

This world-class production line will be developed with our industry partners, including Marand, CNC Design, AustEng and Bosch.

The Testlab will connect Swinburne and the CSIRO's world-leading knowledge in carbon-fibre composites product design and manufacturing, robotic systems, sensors and Internet of Things platforms to provide a comprehensive, future ready facility.

Figure 1: An overview of the novel manufacturing process illustrating the introduction of novel technology

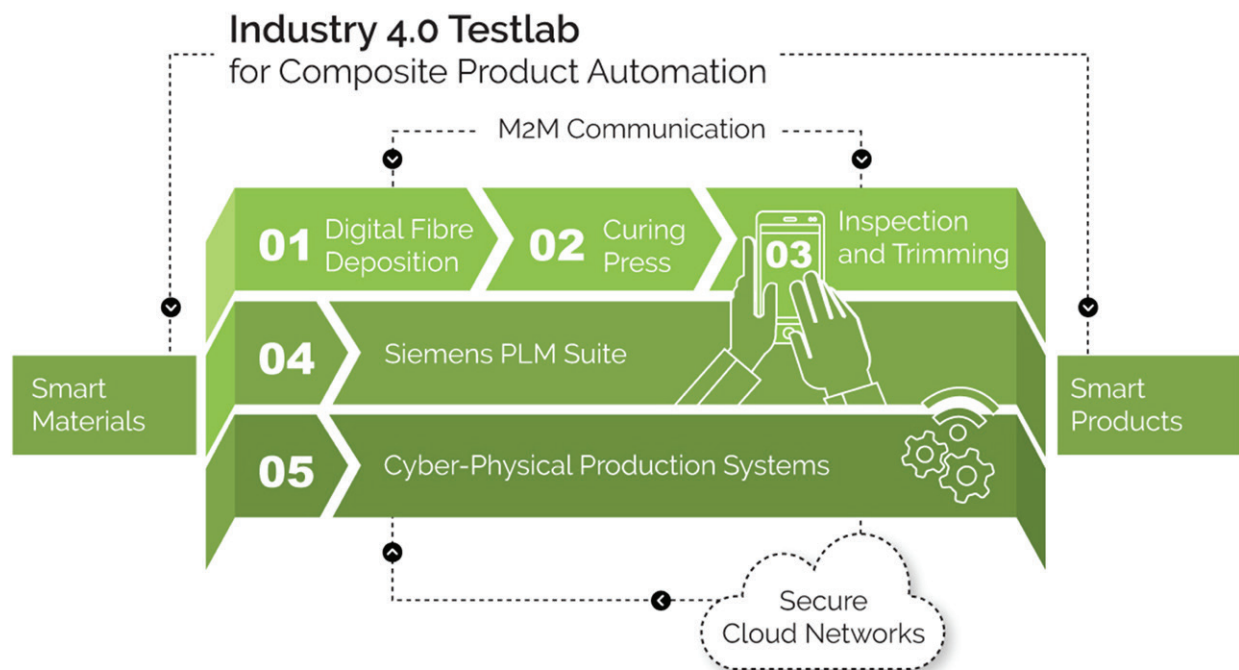


Section 2

Implications for Australia

As illustrated in Figure 2, the manufacturing line will be controlled using Siemens's Product Lifecycle Management (PLM) platform. The PLM suite will allow us to create a digital twin of the process, enabling accelerated development of new products and processes and the exploration of new frontiers in virtual commissioning.

Figure 2 : The role of cyber-physical systems and Siemens PLM suite



The Industry 4.0 Testlab will be developed in close partnership with world leading experts in the field from the University of Stuttgart and the University of Weingarten. Swinburne University of Technology recently formalised a research partnership with the University of Stuttgart and its industry campus, ARENA2036, to collaborate on joint research projects in advanced manufacturing, Industry 4.0, innovation in manufacturing and design, and carbon-fibre composites. The University of Stuttgart recently completed a related project (LOWFLIP) and will contribute to the next extension of this technology.

The outcome will be a showcase for the digital transformation of a pilot manufacturing process while facilitating R&D with a world first technology. It will allow Victoria to pilot Australia's Industry 4.0 vision, and will enable interface and collaboration with international pioneers Industrie 4.0 in Germany and the U.S. Industrial Internet Consortium.

The Testlab will support any company beginning their Industry 4.0 journey. The Victorian government investment will ensure the Testlab has the workforce development technology capabilities and programs required for transitioning small and medium manufacturers.

This capability will be enhanced through our partnership with the Advanced Manufacturing Growth Centre which will deliver collaborative research & development projects to clusters of SMEs.

Additionally, the Testlab will function as a hub for the indigenous engineered materials ecosystem in Australia. It will help to support and connect companies such as Boeing, Imagine Intelligent Materials, Multimatic, Marand, Thales, Quickstep and Carbon Revolution.

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Flinders
UNIVERSITY

INDUSTRY 4.0 TESTLAB
ASSISTIVE TECHNOLOGY SOLUTIONS

Tonsley i4.0 Testlab for Assistive Technology Solutions

Located in the award winning Tonsley Innovation Precinct in Adelaide's southern suburbs (the former site of Mitsubishi's automotive manufacturing in Australia), the Tonsley i4.0 Testlab for Assistive Technology Solutions will support the design, application and evaluation of assistive technologies to maximise the health and wellbeing of people who are ageing and people with a disability. The market for assistive technologies is growing rapidly in response to population ageing with domestic demand expected to rise significantly over the next

five years as the National Disability Insurance Scheme is rolled out. Higher dependency ratios in other OECD nations will drive rising global demand, particularly for customised assistive technology solutions.

The Tonsley Innovation precinct is an exemplar of successful industrial transformation in the face of change and an ideal site for an Industry 4.0 Testlab given the growing presence of major global and local companies including Siemens, Zen Energy, MicroX, Advanced Focus, Sage Automation, Azzo Automation, Radical Torque, 3RT, Hydrix, Signostics, Advanced Focus and Simulation Australasia.

Flinders University's New Venture Institute has supported the development of 185 start-up companies in this new environment and will shortly be launching an Advanced Manufacturing Accelerator to match startups and SMEs to support growth of the assistive technology sector.

Tonsley is home to the Flinders at Tonsley facility which includes the Flinders Digital Health Research Institute, the Medical Devices Research Institute and Partnering Program, NanoConnect, the New Venture Institute and the Australian Industrial Transformation Institute (AITI).

Section 2

Implications for Australia

Central to accelerating the growth of the assistive technology industry in Australia is development and application of Industry 4.0 capabilities including robotics and automation in highly networked and flexible production systems that take advantage of cloud computing. Much higher levels of customisation of assistive technologies is made possible by the latest generation of 'smart factories' which make use of sensors and monitoring equipment to tailor solutions and achieve exacting quality standards.

The successful deployment of Industry 4.0 technologies and capabilities in support of the growth of the assistive technology industry is the focus of the Tonsley i4.0 Testlab. The Testlab will support companies to build i4.0 maturity as part of an industry partnering program focused on accelerating the successful commercialisation of assistive technologies for domestic and global markets.

In partnership with the South Australian Government and the Innovative Manufacturing CRC the Testlab will help to build higher levels of i4.0 maturity through peer to peer based capability building and action research partnerships that substantially increase the number of advanced assistive technology solutions provider use cases in Australia.

It will significantly augment these through the installation of one of Australia's first Cyber-physical (CP) Factories provided by Festo Didactic. The CP Factory is robust operating platform for i4.0 training and research, emulating best practice applications of automation, Internet of Things and robotics technologies in real world settings.

The Testlab will also provide participant companies with access to a range of PLM and Simulation software to enable the development of 'digital twins' that support design, visualisation and testing in a virtual environment. Digital twins are the foundation for 'virtual commissioning', a process that greatly mitigates risks prior to physical production. A range of visualisation platforms will be available to support engagement in this process by both technical and non-technical stakeholders.

Co-design processes with assistive technology end-users will be supported by the Ageing Well Living Laboratory Network initiated by the South Australian Government and its Economic Development Board. The Testlab will facilitate interaction between start-ups and established companies through an Advanced Manufacturing Accelerator supported by AusIndustry.

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**Queensland University
of Technology**

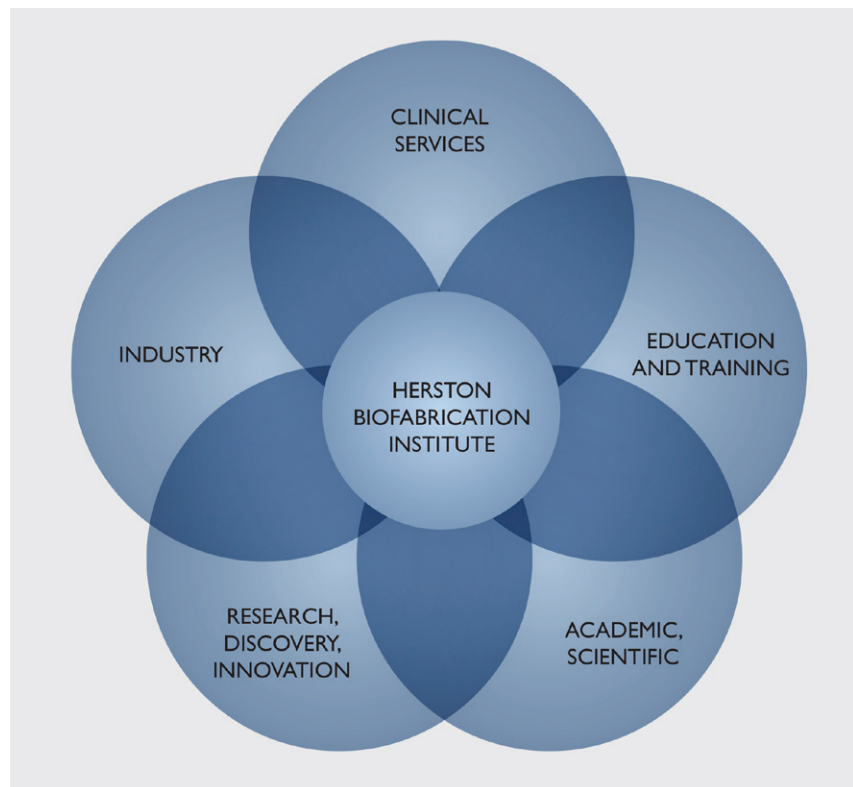
INDUSTRY 4.0 TESTLAB
BIOFABRICATION

The Herston Biofabrication Institute Testlab

The Herston Biofabrication Institute will bring together clinicians, scientists, researchers and engineers on one of the largest integrated health, teaching and research precincts in Australia (the Royal Brisbane and Women's Hospital/Herston Precinct) to focus on developing next generation fabrication technologies combined with biological systems in three key areas:

- Medical data acquisition and 3D clinical imaging,
- Computational medicine, 3D modelling and visualisation, and
- 3D cell culture and advanced manufacturing to create engineered tissue platforms/constructs.

The Herston Biofabrication Institute has the ambition to be the Australian Testlab showcasing research-informed, health-specific outcomes grounded in Industry 4.0 technologies and with high impact on the competitiveness and growth potential of relevant industries in Australia.



Five pillars of the Herston Biofabrication Institute

Section 2

Implications for Australia

A Platform for Industry Transformation

The Herston Biofabrication Institute will form foundational relationships with industry partners from the health, technology and engineering sector to develop and realise its discoveries, deliver the broadest social and economic benefit, and capture the commercial value of its intellectual property. It will represent a new era for Australia, supporting the transition of the economy towards the jobs of the future, which is critical with the domestic contraction of advanced manufacturing disciplines.

A central component of the Institute is a discovery, innovation and industry hub, which will provide a flexible, and transformable zone which encourages collaboration between clinical teams, researchers, scientists, industry (including entrepreneurs), and other partners around clinical issues, to seed the next innovative research idea and clinical application, and create the pathway for its translation into the clinical environment.

An Industry Showcase

Biofabrication sits at the convergence of biology and engineering, applying 3D technologies to medicine.

It involves strong collaboration across the fundamental sciences of chemistry, biology, physics, advanced manufacturing, technology disciplines, engineering and applied clinical practices, to develop new biomaterials, novel ways to interface these with natural tissue, and techniques to understand and create new ways to grow 3D tissue structures. Biofabrication leverages a wide array of technologies including advanced imaging, cell and tissue analysis, microscopy, micro-computed tomography, magnetic resonance imaging, and pre-clinical models and scaffold/tissue histological analyses.

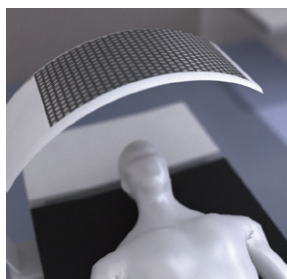
Advances in biofabrication technologies are driven by fundamental research investigating the nature of tissue and cell behaviour, biomaterials, and the interaction between natural and engineered structures.

By applying advanced manufacturing and engineering principles to regenerative medicine, we can find new and innovative ways to solve complex medical problems through the novel use of platform technologies, and understanding of cell and tissue function and behaviour.

These advances will enable us to generate new tissue constructs and implants which are anatomically, biologically, and mechanically precise, which will lead to lower health costs, improved access to the better treatments, health outcomes and quality of life for individuals and society, and commercialisation opportunities in partnership with industry.

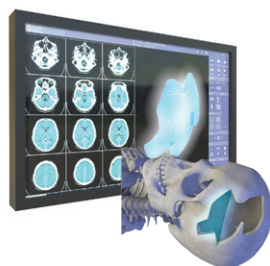
The Institute will be inclusive by design and will be open for relevant stakeholders including corporations, start-up, policy makers, students and the broader public to ensure highest levels of awareness and the integration within a broader, federated innovation ecosystem.

Hospital of the Future



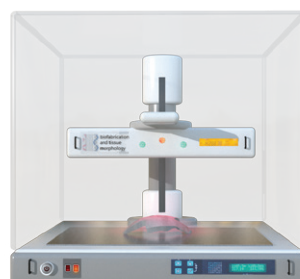
1

3D scan of damaged tissue



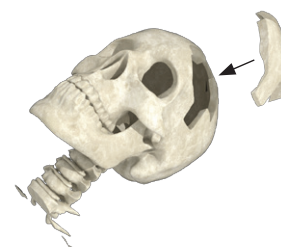
2

Computer model of replacement tissue



3

3D biofabrication of replacement tissue made from biodegradable polymers and patient cells



4

Personalised tissue construct implanted

An Industry 4.0 Platform and Transformation Catalyst

The Herston Biofabrication Institute will pursue an accelerated innovation model for translating novel clinical ideas into new bio-engineered therapies, devices and applications and broader future hospital scenarios and processes.

The Institute as a platform will:

- draw on the expertise of multi-disciplinary teams, collaborating with patients, clinicians, academic, research, and industry partners to pursue innovative approaches to complex clinical problems which disrupt traditional business models and approaches to healthcare,
- undertake research, pre-clinical, and clinical trials on bio-fabricated materials and applications,
- grow Australia's scientific footprint, and provide a catalyst for renewed industry engagement,
- deploy relevant Industry 4.0 technologies and develop a new era for advanced manufacturing in Australia, combining biology, medicine, chemistry, engineering, bionics, robotics and digital technologies such as mixed/augmented reality,
- provide a catalyst for economic growth in Australia, attracting pre-industry and industry partners to Australia,
- investigate the regulatory environment in Australia and how it can be best structured to support the rapid advancements in the field of biofabrication, and
- transform how we educate and train people, offering new inter-disciplinary training pathways for our future clinicians, scientists, engineers, mathematicians, and entrepreneurs which are not currently available in Australia.

Features of the Herston Biofabrication Institute Testlab

Features of the Herston Biofabrication Institute Testlab include:

- Pursuing relevant Industry 4.0 technologies in the health care sector,
- Promoting overt collaboration between professions, industries, and sectors covering significant global corporations as well as regional entrepreneurial ecosystems,
- Fostering state, national and international partnerships,
- Bringing industry into the heart of the model,
- Focusing on outcomes and impacts of global relevance and significance,
- Providing flexible and transformable space to encourage collaboration and foster change,
- Having a physical and virtual environment, enabling people to connect from across the world, and
- Having a profound positive impact on the community and the economy.

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Section 2

Implications for Australia



INDUSTRY 4.0 TESTLAB INDUSTRIAL ALGAE PRODUCTION

Industry 4.0 Testlab for Industrial Algae Production

Researchers in UTS Climate Change Cluster are using their knowledge of photosynthetic processes in aquatic plants to help industry commercialise the production of novel bio-products from renewable sources, such as microalgae: clean green raw materials that have the potential to be used by dozens of industries.

There are more than 70,000 species of algae and they have use in both natural products – such as human food supplements, nutraceuticals, aquaculture and agriculture – and engineered products – including pharmaceuticals, industrial enzymes, biopolymers and fuel. By engaging in algae biotechnology ahead of the wave, UTS would deliver substantial benefits to Australia for example in terms of potential spin-off companies, industry investment, policy development and innovation; all leading to impact.

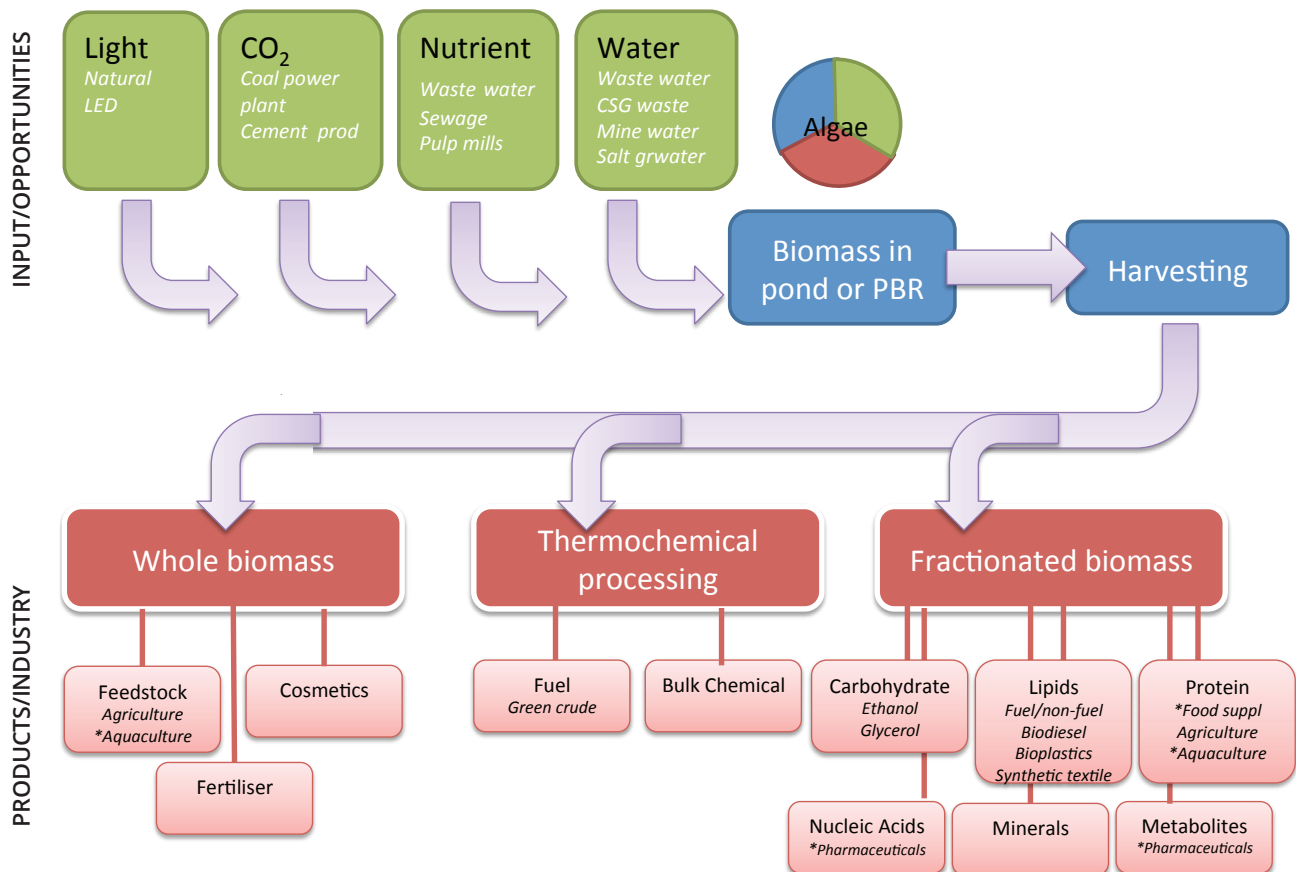
With world-leading research centres, facilities and academic expertise in core specialisations of ICT available within the Faculty of Engineering and IT (FEIT), the University of Technology Sydney ('UTS') is uniquely positioned to apply leading ICT technologies for the creation of an Industry 4.0 Testlab for Industrial Algae Production. Indeed, Industry 4.0's overarching goal is to leverage Information Communication Technologies (ICT) for the benefit and transformation of manufacturing. By applying an Industry 4.0 approach, UTS can set Australia as a leader in the industrialisation of Algae Production.

The potential impact of algae based research associated with the allied manufacturing industry on employment in small and medium sized enterprises (SME) has already been shown in a recent study conducted by the San Diego Association of Governments (SANDAG). This study found that the direct, indirect and induced economic impact of an algae-based industry hub generates approximately, 202 total jobs, USD\$80 million in wages and more than USD\$175 million of economic output to the San Diego region with a population of 1.3 million.

The current production and distribution techniques are highly inefficient, for example, most steps are performed in isolation of each other. The adoption of advanced ICT (Industry 4.0) can revolutionise this industry. The Testlab will explore the research and development of:

- **A secure Industry 4.0 Control Centre** for the entire Industrial Algae Production process. Particular to this context is the management of multiple production sites subject to external environment as well as the organic nature of the product being produced and processed. UTS leading position in autonomous systems will be leveraged for the operation of the Control Centre.
- **An Industry 4.0 Smart Raceway** for the production of Algae, which will have full communication and connectivity with the Industry 4.0 Control Centre through advanced sensors and actuators. The produced data will be utilised through data science technology.

An overview of the Industrial Algae Production process



The Industry 4.0 Testlab for Industrial Algae Production will serve the needs in the Asia Pacific region and will consist of academic researchers and advanced engineers across multiple faculties that will connect with industry and government agencies to grow the local emerging algae bio-manufacturing sector.

Enriched with interdisciplinary expertise and state-of-the-art technologies, the Industry 4.0 Testlab for Industrial Algae Production will be an excellent world-class training ground for our next generation workforce, particularly for the rapidly evolving bio-manufacturing market.

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Section 2

Implications for Australia



THE UNIVERSITY OF
**WESTERN
AUSTRALIA**

INDUSTRY 4.0 TESTLAB
LIQUEFIED NATURAL GAS

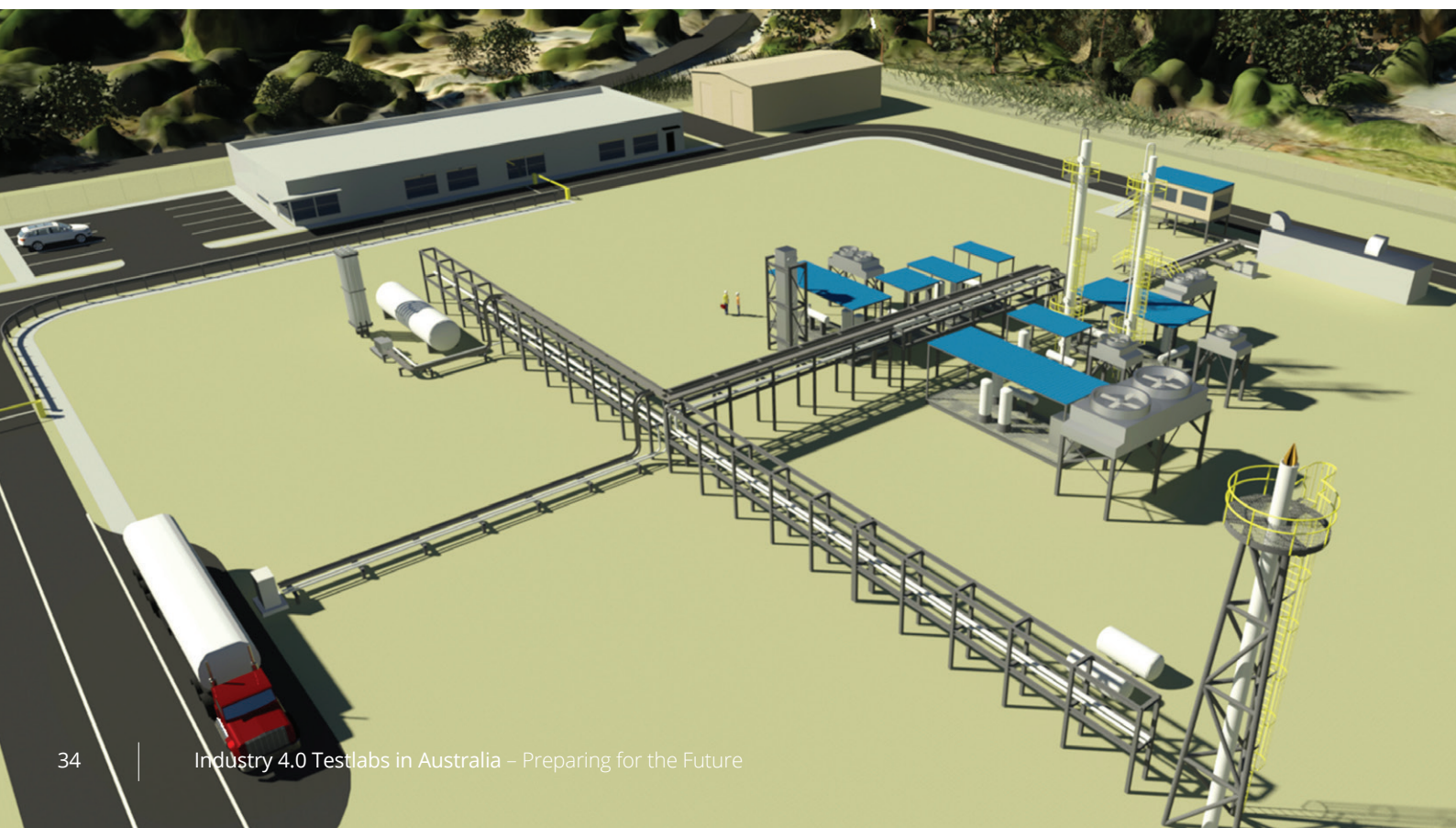
LNG Futures Facility

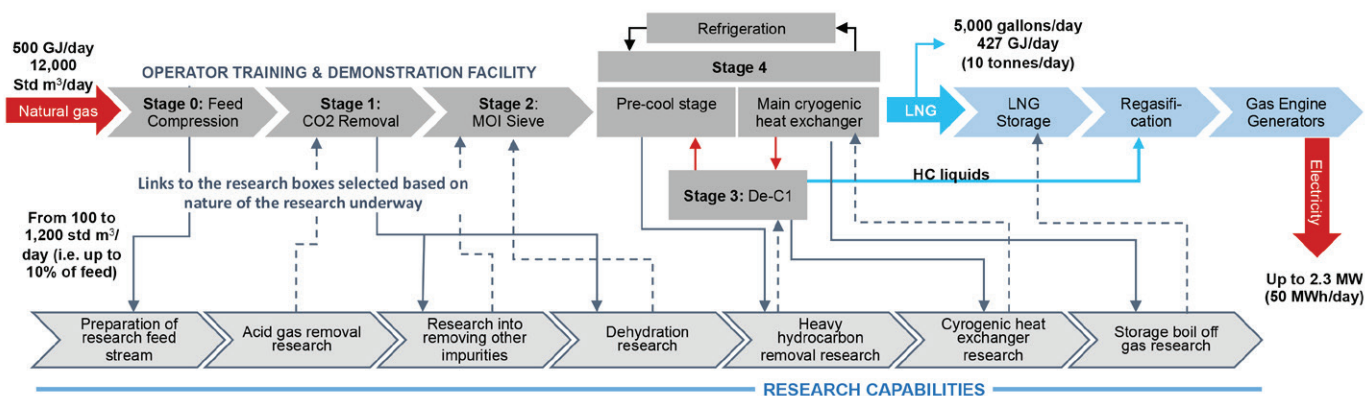
Liquefied Natural Gas (LNG) is central to the worldwide shift now underway towards secure, cleaner sources of energy. Australia's LNG industry is also transitioning from an intensive construction to a steady operating phase, and needs to capitalise further on its natural endowment of resources. To do this, Australia must seize the opportunity to become a leader in the development of LNG technology. However, a significant gap exists between the development of new LNG technologies in laboratory

environments and deploying them on an industrial scale where the risk of failure is the primary barrier to adopting innovation. An Industry 4.0 Testlab for new LNG technology demonstration would play a critical role in bringing Australia to the forefront of the global transitions in industry and energy now underway.

The LNG Futures Facility is the flagship project for the ARC Australian Centre for LNG Futures. It will consist primarily of a microscale LNG plant capable of producing up to 10 tonnes of LNG per day. It will be highly instrumented,

enabling rich and unique data sets from a fully functioning plant to be produced and disseminated. A second 'research train' connected via multiple ports to the primary train will allow on-line testing and validation of new process technologies. As a national, open-access resource providing direct benefits to Australian industry, the LNG Futures Facility will provide a globally unique platform to demonstrate new technologies in a live plant environment, and enable rapid deployment and adoption of innovative solutions by Australian LNG producers, suppliers and consumers.





The LNG Futures Facility concept showing the primary train (top) connected via multiple slipstreams to a second research train (bottom)

By working closely with industry partners ranging from major operating companies like Chevron and Woodside, engineering procurement companies like GE, Clough, and Hyundai Heavy Industries, to Australian small-medium-enterprises working across the sector, the proposed LNG Futures Facility will enable a significant value-creation. The ability to test and showcase innovative technologies without impacting on any energy or LNG supply contracts will make the Facility a key strategic asset both to the companies using it and beyond to the sector they service. The Facility will provide a unique platform for investigating very large operational data sets and the efficacy of emerging analysis platforms that will become increasingly crucial to the industry's

future. The Facility will serve as a test-bed for modular unit operations (e.g. new acid gas rejection technologies) and integrated systems spanning several stages of the production process (e.g. refrigerant and LPG recovery systems). It will provide an accessible pathway for technologies developed by small engineering service companies who are aware of deficiencies with existing solutions but do not have the resources or access needed to progress deployment.

The LNG Futures Facility will also provide a completely new training and education capability in Australia: all existing training facilities currently utilise inert fluids. Australia has a significant need for qualified operations, maintenance and

engineering personnel over the next fifty years across its energy and resources sector. The Facility's state-of-the-art instrumentation and sensing will produce unprecedented, real-time wide ranging datasets which will be available through online networks, providing extended educational access beyond the site to classrooms across Australia and the globe.

Further detail, including a fly-through video of a potential version of the LNG Futures Facility Testlab, is available at Ingfutures.edu.au

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Demonstration	Research	Training
<ul style="list-style-type: none"> Field testing Plant-scale demonstration Laydown space for demonstration modules New and enhanced processes & unit operations New instrumentation & sensors Robotics testing Control strategies, automation Big data analytics Accelerated life cycling 	<ul style="list-style-type: none"> Live fluid slip streams Dynamic testing Highly-instrumented, comprehensive plant datasets for testing analysis platforms Validation of bench scale results Big data analytics 	<ul style="list-style-type: none"> Training for Operators, Engineers & Contractors Live fluids On-site hand on training Remote control-room style training Holistic 'End to End' experience Live Plant Data Process Safety Occupational Safety & Health Maintenance training

Section 2

Implications for Australia



INDUSTRY 4.0 TECHNOLOGY ADDITIVE MANUFACTURING

Industry 4.0 Technology – Additive Manufacturing

Globalisation is changing the nature and economics of manufacturing in “high-wage” countries. On one hand globalisation has led to new markets and on the other to new competitors in particular from “low-wage” countries. In addition, globalisation has also led to increased product individualisation and product segmentation with the associated cost pressures and production scaling effects. Therefore, handling the challenge of product cost pressures, diversity and dynamics becomes the central

focus for manufacturing companies in “high-wage” countries such as the US, Germany, UK, France, Japan and Australia. Advanced technology and research are seen as critical elements in addressing some of these challenges to deliver cost competitive approaches to manufacturing for the companies in “high-wage” countries to remain profitable and in business.

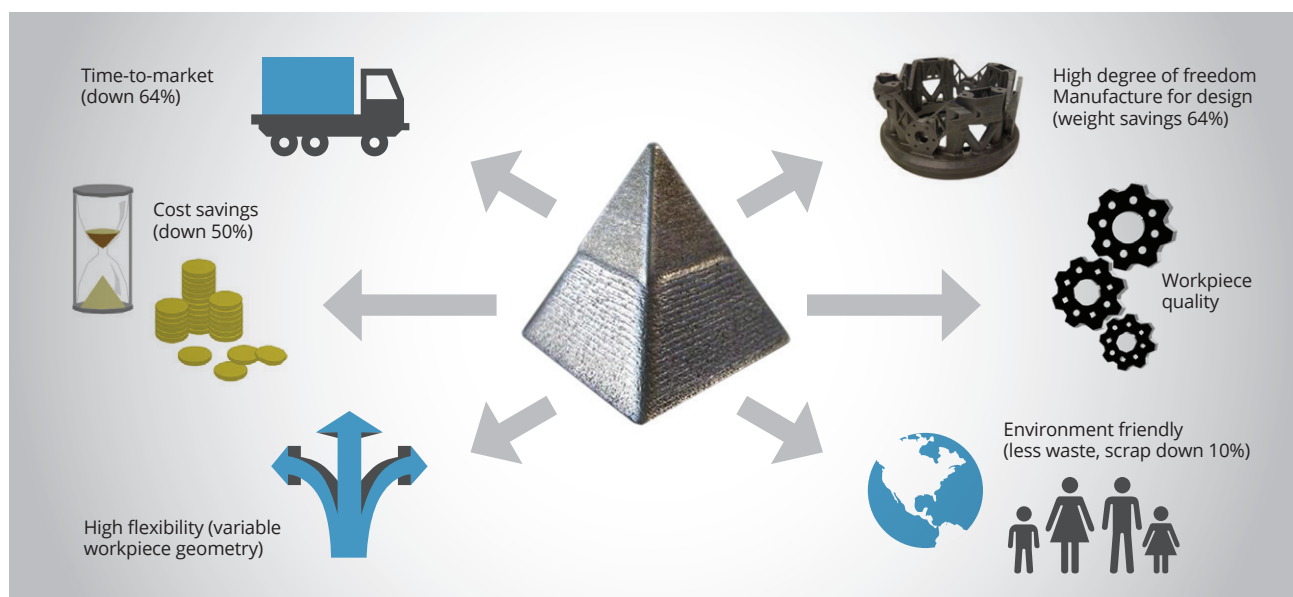
The move to direct digital manufacturing or Additive Manufacturing (AM) is seen as a solution to boost in-country manufacturing because of the many benefits it offers compared to traditional subtractive manufacturing.

RMIT University through its Advanced Manufacturing Precinct is driving the research and development in AM in conjunction with many industry partners both local and overseas in the areas shown in the figure below where AM has significant advantage over conventional technologies, including:

1. New designs not possible using conventional subtractive technology,
2. Dramatic savings in time, materials, wastage, energy and other costs in producing new components,
3. Significant reductions in environmental impact, and
4. Faster time to market for products.

Benefits of additive manufacturing

Figure in brackets refers to savings in aerospace and defence sectors.*



* M. Brandt, Editor *Laser Additive Manufacturing: Materials, Processes, Design and Applications*, Woodhead Publishing, Cambridge, United Kingdom, ISBN: 9780081004333, 2016.



RMIT Advanced Manufacturing Precinct

AM is seen as an integral part of Industry 4.0 because of a strong industry demand and increased requirement for part and process data capture, analysis, adjustment and control. RMIT is investigating IT system implementation across its additive platforms, in which an individual production machine is digitally connected with its environment and manufactured products have a 'digital signature' bound to the product, which would enable optimised production process parameters and product life cycle functionality.

The digital signature allows for horizontal connectivity between upstream and downstream processing such as feedstock type, its characteristics and measurement of resultant properties of the component such as level of porosity and surface roughness, respectively.

AM is a rapidly developing area in which significant commercial gains can be made from the relevant industry sectors.

Development of machine-to-machine communication for AM is of critical importance to be able to effectively harness the capabilities of AM. Implementation of more effective closed loop control, process data analytics and secure file transfer – as well as robust upstream and downstream process integration – will achieve this.

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Section 3

Engaging with Industry

3.1 Jobs of the future

In 1987 noted American economist Robert Solow observed, “You can see the computer age everywhere but in the productivity statistics”. Similar disconnects between a new technology being introduced and productivity dividends were observed with the uptake of the steam engine and electricity.

In each case the productivity benefits of disruptive technology were realised gradually owing to the slow rate of technology diffusion into common use and the time required reorganising work around and mastering efficient use of the new technology. The digital forces of acceleration and convergence mean the technologies supporting Industry 4.0 will likely have both a more immediate impact and wider application than what occurred in previous industrial revolutions.

For instance, one report suggests current technological trends are changing the core curriculum content of many academic fields at break-neck speed. According to McLeod, Scott and Karl Fisch, nearly 50% of subject knowledge acquired by students during the first year of a four-year technical degree is outdated by graduation. The World Economic Forum reports that by 2020, “more than a third of the desired core skill sets of most occupations will be comprised of skills that are not yet

considered crucial to the job today”. Another popular estimate predicts 65% of children starting primary school today will work in job types that do not yet exist.

The Boston Consulting Group predicts that Industry 4.0 technologies will make a significant impact on businesses and the broader economy over the next 10 to 15 years, especially in how the workforce will transform. They identify ten areas that will define this transformation.

Ten use cases show the effects of Industry 4.0 on the workforce

	Big-data-driven quality control Algorithms based on historical data identify quality issues and reduce product failures		Predictive maintenance Remote monitoring of equipment permits repair prior to breakdown
	Robot-assisted production Flexible, humanoid robots perform other operations such as assembly and packaging		Machines as a service Manufacturers sell a service, including maintenance, rather than a machine
	Self-driving logistics vehicles Fully automated transportation systems navigate intelligently within the factory		Self-organizing production Automatically coordinated machines optimize their utilisation and output
	Production line simulation Novel software enables assembly line simulation and optimisation		Additive manufacturing of complex parts 3-D printers create complex parts in one step, making assembly redundant
	Smart supply network Monitoring of an entire supply network allows for better supply decisions		Augmented work, maintenance, and service Fourth dimension facilitates operating guidance, remote assistance, and documentation

Sources: Expert Interviews; BCG analysis.

The composition of the workforce will need to change to match the digital skills required to support Industry 4.0. Entire industries will need to adjust, meaning most occupations will undergo a fundamental transformation. Some jobs will become redundant; demand for other jobs will grow rapidly. Many of the jobs of today will go through a change in the skill sets required to do them.

Compounded by the effects of globalisation, workforce transformation will create many new opportunities in some regions yet there will be a significant dislocation of jobs elsewhere. This will not occur in an even fashion, as transformation will be specific to the industry, region and occupation in question, not to mention the varying ability of employers to manage such significant change.

Ongoing business model innovation and industry transformation will become the new normal such that the skills employers need will constantly change. New technologies will begin replacing specific tasks of existing jobs allowing these workers to focus on higher-level and more complex tasks. Some lower level, repetitive jobs will be completely displaced.

According to the 2016 Future of Jobs Survey of the World Economic Forum there is “a modestly positive outlook for employment across most industries, with jobs growth expected in several sectors ... accompanied by high skills instability across all job categories”. The combination of net job growth and skills instability will result in most businesses facing major recruitment challenges and talent shortages.

The World Economic Forum reported the job families that will experience the most growth owing to these drivers of change. In descending order of demand, they are computing and mathematical (e.g. data scientists, analysts, programmers), architecture and engineering, management, and sales roles. On the other hand, installation and maintenance, construction and extraction, and manufacturing and production are predicted to experience negative growth.

“Festo Didactic as the educational arm of the Festo Group has developed its latest training and teaching factory solution within the framework of Industry 4.0, the so-called CP Factory. CP Factory stands for cyber physical factory, and comprises of the latest technologies and manufacturing execution and control concepts in order to train existing and future employees. We are pleased to be an integral part of the Industry 4.0 Taskforce to support the development of further Testlabs and training facilities that will have a major impact on the competitiveness of the Australian manufacturing sector.”

Volker Schmid, Head of Asia-Pacific Festo Didactic SE

Section 3

Engaging with Industry

Industry 4.0 skills

According to respective reports by PwC Germany (2017), and the World Economic Forum (2016), a majority of the industrial companies they surveyed reported the Industry 4.0 workforce requires competency across digital, project coordination, and soft skills. The following table illustrates some key competencies.

Digital skills	Project coordination skills	Soft skills
<ul style="list-style-type: none"> • Industry 4.0 programming and software engineering • Data science • Data/big data analytics • Visualisation • IoT • IT architecture • Security 	<ul style="list-style-type: none"> • Product management • Multi-project management • Supply chain and support services • Logistics 	<ul style="list-style-type: none"> • Creativity • Design • Innovation • Leadership

A significant challenge in creating an Industry 4.0 workforce is the heterogeneous starting position of companies, from production facilities that are already highly automated and with products rich in variation through to conventional tightly-scheduled assembly operations involving a high proportion of manual labour. There are likewise significant differences in the degree of digitisation and networking. Digital transformation influences not only the manufacturing and production companies but also all organisations in the supply chain, and support services. The theory component of any Industry 4.0 education must be balanced by application of this knowledge in each workplace.

The role of Testlabs in developing Industry 4.0 expertise is two-fold. Firstly, Testlabs will help develop education and training programs related to general Industry 4.0 theory combined with a focus on Industry 4.0 skills needed for the particular manufacturing application of the Testlab. Secondly, Testlabs will assist organisations, especially SMEs, learn from one another to amplify their respective understanding of Industry 4.0. Working together in clusters at Testlabs will help SMEs normalise their respective variations in digital transformation.

Working Group 5 of VDMA ("labour, vocational education and training") in Germany recommends the structure of Industry 4.0 education and training must align closely with how technology is being applied in organisations. Testlabs are at this fulcrum helping ensure training and education programs contain relevant skills and knowledge and are meaningful for real world circumstances of companies by providing a platform where theory meets practice.

Industry 4.0 course exemplar

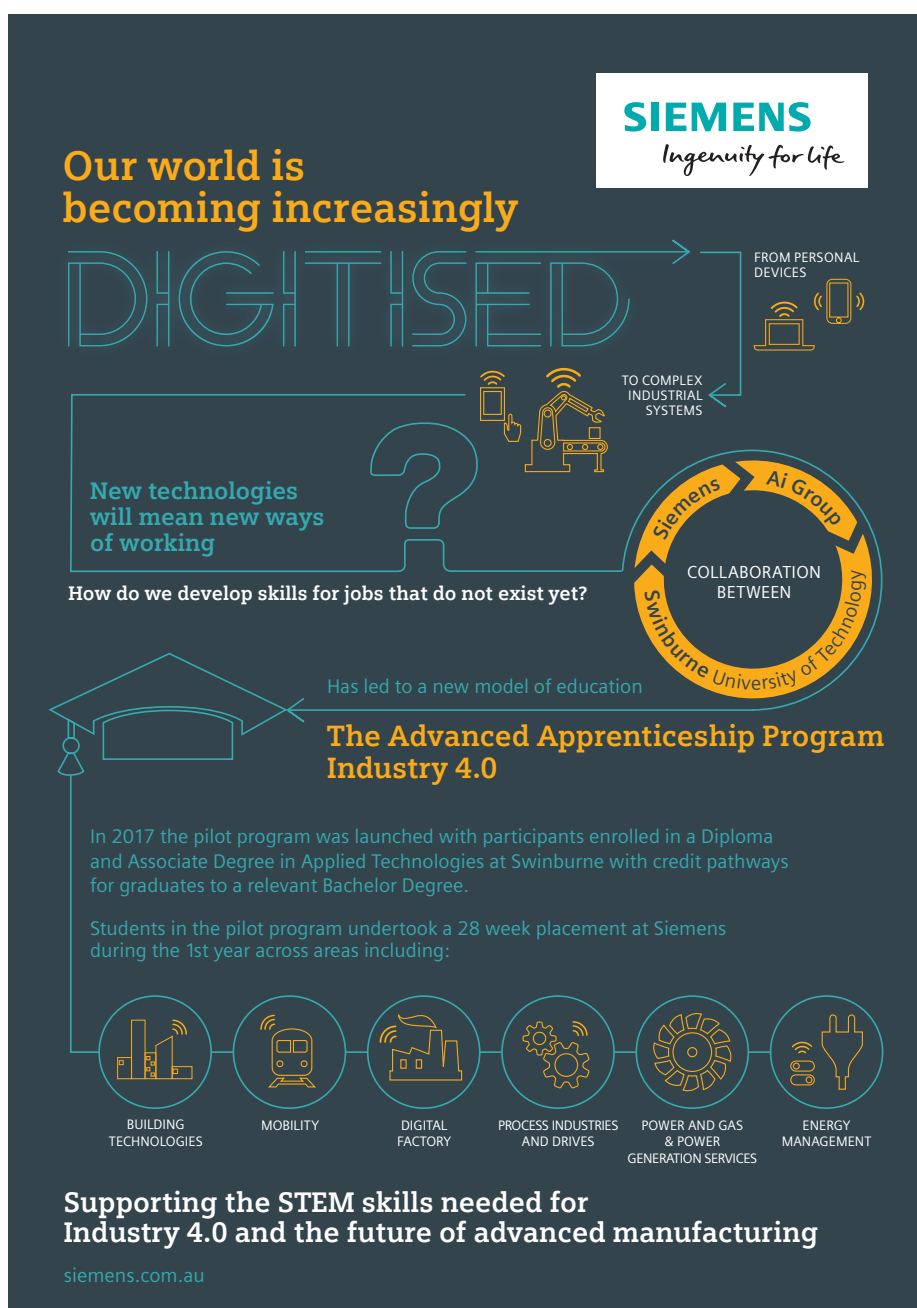
A pilot education program has been developed following the Prime Minister's Industry 4.0 Taskforce recommendation, involving Siemens, Ai Group, and Swinburne University of Technology. The pilot program aims to establish and trial a new model of public-private sector partnerships focused on workforce transformation.

Diploma of Applied Technologies

Swinburne's Diploma of Applied Technologies provides vocational education students with technical engineering and information technology skills, equipping them to work effectively in Industry 4.0. Students learn about the Internet of Things, cloud computing, advanced algorithms, advanced manufacturing practices, automation and robotics, and smart sensor and cyber physical systems. Students will study on campus at Swinburne while also spending time in paid employment at Siemens.

Students who successfully complete this course are able to:

1. Analyse, design, implement and evaluate a range of engineering solutions within an Industry 4.0 environment
2. Apply theoretical concepts and technical skills to troubleshoot and provide integrated solutions for a range of engineering environments and contexts
3. Utilise a range of emerging digital technology skills to troubleshoot and support engineering applications
4. Perform project management tasks to support the completion of advanced engineering projects
5. Apply design concepts to a range of engineering solutions
6. Develop and utilise a range of communication and collective problem solving strategies for innovation in Industry 4.0 environment



3.2 Partnering with an Industry 4.0 Testlab

Labs Network Industrie 4.0 (LNI4.0) in Germany is a resource for companies and associations to make widely available tried and tested recommendations and examples, to provide transparency about technical infrastructure and competencies, and provide advice for SMEs on how to progressively uptake Industry 4.0 technologies, processes, systems and strategies.

Industry 4.0 Testlabs are designed to be an easy entry point for Australian industry, government, universities, and unions to access, understand and familiarise themselves with the field of Industry 4.0. Industry 4.0 Testlabs draw directly from the LNI4.0 German approach by focusing on real scenarios for SMEs and Australian industry. In doing so they offer all stakeholders:

- A platform for dialogue, competence, and experimentation,
- A low-risk environment to identify issues, find potential solutions, and build up expertise, and
- A pre-competitive environment that supports transparency of results.

Industry 4.0 Testlabs provide a range of benefits for partner organisations.

1 Test

Industry 4.0 Testlabs provide SMEs and other stakeholder organisations the opportunity to work alongside and learn from experts to help define, refine and realise Industry 4.0 aspirations. More than just a technology showcase, each Testlab assists companies run through various Industry 4.0 scenarios. A whole-of-lifecycle experimental approach means Testlabs can test scenarios from concept through to feasibility.

2 Network cluster

Each Testlab will cluster a group of SMEs related to a specific application of Industry 4.0 manufacturing. Testlabs play a central role in building connections and creating synergies within and across each cluster.

3 Feasibility

The product and production data arising from testing scenarios will help inform value creation leading to new business models across each cluster in the pre-competitive environment of a Testlab.

4 Design standards

Testlabs will lead the way in defining Industry 4.0 standards. Knowhow derived from individual projects will inform policy development through each Testlabs industry advisory body, working in collaboration with industry bodies such as AMGC and AiGroup.

5 Workforce development

Testlabs provide an early evaluation of the impact of Industry 4.0 on manufacturing processes, business models and workforce requirements. Transparency of outcomes at Testlabs will allow employers and unions to better understand the jobs of the future and the skills required to do them. Technological and methodical competence will be built up in working alongside companies and industry in real-world applications of Industry 4.0. In turn Testlabs' associations with universities and registered training organisations will inform training and education programs for Industry 4.0 skills.

6 Global value chain

To provide SMEs world's best practice opportunities in Industry 4.0, Testlabs will partner with leading multinational companies that provide state-of-the-art equipment, software and knowhow. As both a showcase and innovation platform of these technologies, Testlabs provide a direct connection between SMEs and global leaders in Industry 4.0 manufacturing and production.

3.3 Practical guide for Australian SMEs

Testlabs will assist SMEs align to Industry 4.0 following the guidelines set out by VDMA and summarised here. Industry 4.0 is as equally described from the perspective of the products as it is of production. VDMA's Toolbox Industrie 4.0 breaks down "Products" and "Production" into various dimensions ("fields of expertise"), demonstrating how to think about a pathway to Industry 4.0 by highlighting different development stages within each dimension.

Toolbox Industrie 4.0



Industrie 4.0

Products					
Integration of sensors / actuators					
	No use of sensors / actuators	Sensors / actuators are integrated	Sensor readings are processed by the product	Data is evaluated for analyses by the product	The product independently responds based on the gained data
Communication / Connectivity					
	The product has no interfaces	The product sends or receives I/O signals	The product has field bus interfaces	The product has Industrial Ethernet interfaces	The product has access to the internet
Functionalities for data storage and information exchange					
	No functionalities	Possibility of individual identification	Product has a passive data store	Product with data storage for autonomous information exchange	Data and information exchange as integral part
Monitoring					
	No monitoring by the product	Detection of failures	Recording of operating condition for diagnostic purposes	Prognosis of its own functional condition	Independently adopted control measures
Product-related IT services					
	No services	Services via online portals	Service execution directly via the product	Independently performed services	Complete integration into an infrastructure of IT services
Business models around the product					
	Gaining profits from selling standardized products	Sales and consulting regarding the product	Sales, consulting and adaption of the product to meet customer specifications	Additional sale of product-related services	Sale of product functions

Toolbox Industrie 4.0



Industrie 4.0

Production

Data processing in the production					
	No processing of data	Storage of data for documentation	Analyzing data for process monitoring	Evaluation for process planning / control	Automatic process planning / control
Machine-to-machine Communication (M2M)					
	No communication	Field bus interfaces	Industrial ethernet interfaces	Machines have access to internet	Web services (M2M software)
Company-wide networking with the production					
	No networking of production with other business units	Information exchange via mail / telecommunication	Uniform data formats and rules for data exchange	Uniform Data formats and inter-divisionally linked data servers	Inter-divisional, fully networked IT solutions
ICT infrastructure in production					
	Information exchange via mail / telecommunication	Central data servers in production	Internet-based portals with data sharing	Automated information exchange (e.g. order tracking)	Suppliers / customers are fully integrated into the process design
Man-machine interfaces					
	No information exchange between user and machine	Use of local user interfaces	Centralized / decentralized production monitoring / control	Use of mobile user interfaces	Augmented and assisted reality
Efficiency with small batches					
	Rigid production systems and a small proportion of identical parts	Use of flexible production systems and identical parts	Flexible production systems and modular designs for the products	Component-driven, flexible production of modular products within the company	Component-driven, modular production in value-adding networks

Section 3

Engaging with Industry

Products

The Products section supports the generation of ideas during the development of innovative Industry 4.0 products and can be as equally applied to entire products as to single components of products. VDMA poses the key question: To what extent can new products be developed or existing ones be further developed with the help of Industry 4.0? How can this create an added value for prospective customers? The application levels of Products are:

- Integration of sensors and actuators
- Communication and connectivity
- Functionalities for data storage and information exchange
- Monitoring
- Product-related IT services
- Business models around the product

Production

This section focuses on approaches related to production. VDMA suggests the starting consideration is: how can production processes be optimised and how can production costs be reduced with the help of Industry 4.0? The application levels of Production are:

- Data processing in production
- Machine-to-machine communication
- Company-wide networking with the production
- Infrastructure of information and telecommunication technologies in production
- Human-machine interfaces
- Efficiency for small batches

The VDMA Toolbox serves as the starting point for classifying the various fields of expertise at the company, and serve as a starting point for new ideas in the uptake of Industry 4.0.

Modifying the VDMA workshop approach, there are five phases leading to implementation of an Industry 4.0 project. Testlabs will work alongside a company's project team in phases 2–4.

1 Preparation phase

An in-depth knowledge of the relevant market or of one's own production is the starting point for elaborating product ideas and improving production. A solid knowledge base of all workshop participants in matters related to Industry 4.0 will support the later development of ideas. Testlabs will work with the project team to create a common understanding of Industry 4.0 within the company.

2 Analysis phase

The analysis phase helps identify the expertise available in the company concerning Industry 4.0 technologies. The analysis of the competencies, or fields of expertise, is carried out for the products as well as for the production, referring to the Industry 4.0 toolbox. This is a starting basis for idea generation.

3 Creativity phase

New ideas that lead to concepts for business models is the aim of the creativity phase. The workshop participants identify and collect initial ideas then analyse their respective merits. The best concepts will be developed into business models.

4 Evaluation phase

Business models are assessed according to either their market potential or their potential for production. Resources required for implementation are considered. The aim is to identify business models with a high potential and a low resource input while aligning to the company's strengths.

5 Implementation phase

The company's project team works up select business models as proposals for further examination and presentation to the company's executives, helping ensure workshop results translate to suitable projects for practical implementation.

Appendix 1

Strategic considerations of Industry 4.0

Regionalisation and customer centricity

With changing consumer mindsets for individualised products and services, cheap mass-manufactured products in a developing country no longer satisfy consumers' expectations. The fast, flexible and efficient characteristics of Industry 4.0 will lead to a regional focus on production driven by ever-increasing pressure to respond quickly to changing consumer demands. The network of Industry 4.0 Testlabs can demonstrate the potential of regional value chains and networks, and help identify opportunities for efficiencies where the goal is to make the local smart factory more efficient than offshore manufacturing.

Innovation

Testlabs are ideal innovation platforms for Industry 4.0: new materials, innovative products, sophisticated advanced manufacturing processes. Testlabs are located at leading Australian technology universities within dedicated facilities of specialist researchers, state-of-the-art equipment and latest automation systems. Unlike other research centres, Industry 4.0 Testlabs exist, first and foremost, to design, develop and demonstrate digital solutions for manufacturing. R&D at Industry 4.0 Testlabs therefore keenly focuses on developing practical approaches that translate easily to industry settings.

Investment cost

A recent survey of manufacturers in Germany (PwC) found that the vast majority (97%) expect the return on investment for digital transformation to be between 2 and 5 years. Adopting Industry 4.0 approaches is therefore a significant investment. By leveraging the capability of Testlabs, companies can de-risk the capital investment costs by resolving proof of concept before they proceed. For instance, production processes can be virtually tested and optimised with digital twins.

Sustainability

Industry 4.0 is a highly efficient, automated manufacturing process. Testlabs can help companies understand how they might achieve their sustainability goals (less energy, less materials) through just-in-sequence logistics, and a goal of "lights-out factory" where electricity is only consumed on demand.

Workforce development and transformation

Industry 4.0 will likely not mean manufacturers employ less people but they will require people with different skillsets. Higher level, interdisciplinary manufacturing jobs, digital engineers, software developers, data analysts and a multitude of IT-related skills will be required. Industry 4.0 Testlabs work with companies on their Industry 4.0 plans to help determine the workforce mix and recommend education and training to help transform the workforce.

Business models

Industry 4.0 will profoundly disrupt manufacturing. By working with an Industry 4.0 Testlab, industry partners can see firsthand the implications of Industry 4.0 on every dimension of the business: product design, manufacturing processes, workforce needs, resource management, and customer service. By experiencing and understanding the far-reaching impact of Industry 4.0 at a Testlab, companies will be better able to determine how they will create value, what their competitive advantage will be, and innovate their business models.

Opportunity cost

The opportunity cost of not adopting/ exploring the potential of Industry 4.0 for a business will continue to increase. There are no turnkey solutions with Industry 4.0 – one size does not fit all. Each approach is unique and extends beyond developing new manufacturing process to a new manufacturing strategy and the need to redefine business models. With significant lead-time for return on investment, the opportunity cost of not beginning to explore Industry 4.0 solutions will only increase.

Appendix 2

VDMA Security Guidelines

These security guidelines, based on Industrie 4.0 Security Guidelines of VDMA Germany, introduce technologies and approaches necessary to enhance the security of complex systems, which Industry 4.0 Testlabs will embed. Testlabs will be a critical resource in developing security measures for SMEs where lack of resources can hamper developing comprehensive security risk management systems within their respective business environments.

Security design

Risk analysis – risk analysis should be integrated from the beginning of the development process, such as machine concept and design.

- Identify which hardware and software components of a machine are valuable and need protecting.
- Determine protection goals for each asset such that the protection goal of a critical rating ensures availability of the data during remote access to the machine.

Network segmentation – dividing a plant into zones allows connected machines and components within that zone to have similar security requirements.

- In zoning it is important to ensure network segments directly connected to the machine only contain services with comparable security measures. The failure of one zone should affect as few other zones as possible.

- Security zones assigned to a machine's hardware and software should be sufficiently isolated so that the failure of one section does not compromise the whole system.
- Technology measures such as firewalls can protect isolated components while VPN solutions allow networks in separate geographic locations to be integrated.

Security considerations and protocols

Access – secure management of user accounts data access.

- All individuals must be able to be identified uniquely – known as “players” – and to be given the requisite security level.
- In general, a player is only authenticated within a specific zone. If the player crosses zone boundaries, authentication must occur at each zone transition and verification of the corresponding rights of the player in the new zone.

Secure protocols – constantly updating security protocols are required to avoid external attack on machines via communication links.

- Use of standardised encryption processes (cryptographic algorithms) is sufficient for such protocols.

Wireless technologies – all wireless technology safeguards by the machine should align to the latest standards.

Remote service – ensure appropriate security, organisational and technical measures protect systems during remote service and maintenance.

- Remote service should be ruled out when a machine is performing a critical task.
- All connections should be encrypted.

Monitoring and recognizing attacks – logging and saving all data is essential to help identify and evaluate attacks using recognition.

- Security-related incidents include incorrect password entry, exhaustion of resources, unauthorised access attempts, virus attacks through malware, and changes to security-related configuration files.

Recovery plan – in case of a malfunction or attack, a recovery plan should reset the plant to a trustworthy state.

- Regular and recoverable backups are essential to restore a machine.

Product lifecycle – secure the product lifecycle of the machine.

- Monitoring and responding to vulnerabilities, requires being able to identify and classify newly-detected attack vectors by their risk potential.
- A patch management plan should be developed and be in place to respond to vulnerabilities.

Appendix 2

VDMA Security Guidelines

Testing, refinement and training

Adapting and testing components – a plant's security functions should be regularly checked.

- Testing should cover standard settings, hardware configuration, internet access and machine software integrity.

Minimising component functions – a machine will have a multitude of functions, many of which will be superfluous to a particular task. Functions not relevant to a machine's field of application should be excluded to minimise vulnerability of attack.

- Remove unnecessary software functionality and deactivate hardware components not in use.

Component hardening – a holistic approach to ensure the security of all functions and avoid compartmentalisation.

- Institute rules requiring components to only execute hardened code.
- Develop a whitelist and blacklist of acceptable applications.
- Reduce system complexity.
- Safeguard all external points of access such as field devices outside the plant and electronic interfaces.

Isolation scenarios – isolate individual software components where possible.

- Protect against malicious code by sandboxing and virtualising.
- Restrict operational and configuration data.

Cryptography – all cryptographic algorithms and parameters must be state-of-the-art.

- Implement standardised algorithms and avoid in-house cryptographic developing.

Managing security of vendors and suppliers – establish minimum security requirements for all supplied components.

Documentation – fully document and update security measures.

- This includes interfaces, processes, risk analysis, machine inventory, document management, and security incidents.

Workforce training – enhance employee expertise on IT security and network security, and ensure planners and developers integrate security functions from the outset.

Reference sites/materials

<http://www.plattform-i40.de/I40/Navigation/EN/Home/home.html>

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