Digital Manufacturing Solutions for SMEs

-- An example

digital manufacturing
on a shoestring

Digital Manufacturing on a Shoestring: Low-Cost Digital Solutions for SMEs

UNIVERSITY OF CAMBRIDGE
Department of Engineering

IfM MANAGEMENT TECHNOLOGY POLICY

UKRI Engineering and Physical Sciences Research Council

University of Nottingham
Institute for Advanced Manufacturing

The journey of digital manufacturing

- **1960s** — *Numerically controlled machine tools*
- **1970s** — *PLCs* as the electronic replacement for hard-wired relay systems
- **1980s** — *Computer-aided design and digital product information*
- **1990s** — *Digital solutions for the enhancement of manufacturing processes*
- **2000s** — *Smart Factory empowered by IT, OT and AI*
- **2010-** — *Industry 4.0, Smart Factory, Product life cycle, Value chain management*

Remove the barriers for SMEs

Barriers for SMEs	How
Cost	Low-cost approach
Risk	Non-core systems approach
Complexity	Requirements co-development approach 'Dip a toe in the water' Adopt one digital solution at a time

Potential benefits for such an approach

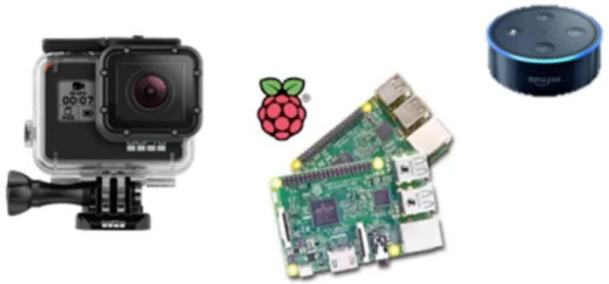
- Enable growth and productivity in businesses
- Support business resilience, exports, and development opportunities
- Increase confidence in company's digital endeavour
- Create and capture future economic opportunities
- Inform capital investment/inward investment that aligns with opportunities

Low-cost solution design approach

- **Simple and structured**
  - The design process is easily understood by inexperienced designers
  - It follows a logical process and ensures the designer always has a clear next step.
- **Streamlined**
  - The design approach should accelerate the development process by facilitating quick design decisions that are transparent and well-informed.
- **Versatile and expandable**
  - The design approach should be able to incorporate a large variety of available components, easily interchangeable similar/equivalent components, and incorporate new components that are developed or available on the market.

Hawkridge, G., McFarlane, D., Kaiser, J., de Silva, L., Terrazas, G. Designing Shoestring Solutions: An Approach for Designing Low-Cost Digital Solutions for Manufacturing(2022) Studies in Computational Intelligence, 1034, pp. 249-262.

Low-cost solution design



With suppliers

In the office

On the shop floor

Shoestring Vision:
Increase digital capabilities throughout the company using low-cost, easily accessible "off-the-shelf" components.

Shoestring staged approach

1. Digital requirement assessment
What are the digital solution needs of a construction SME?

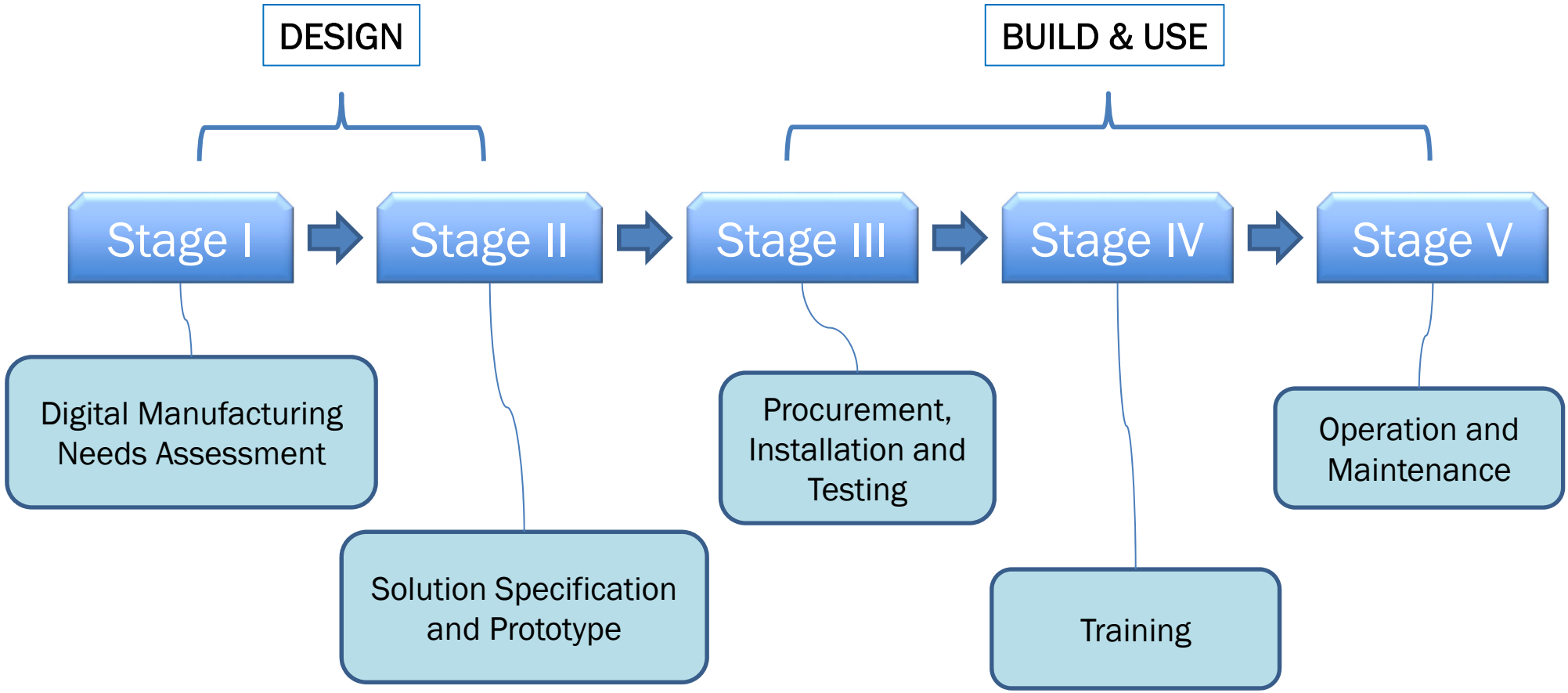
2. Solutions development
How can available technologies, algorithms and software be combined into accessible solutions?

3. Prototyping / Pilot testing
…of the developed technologies and methods in partner SMEs

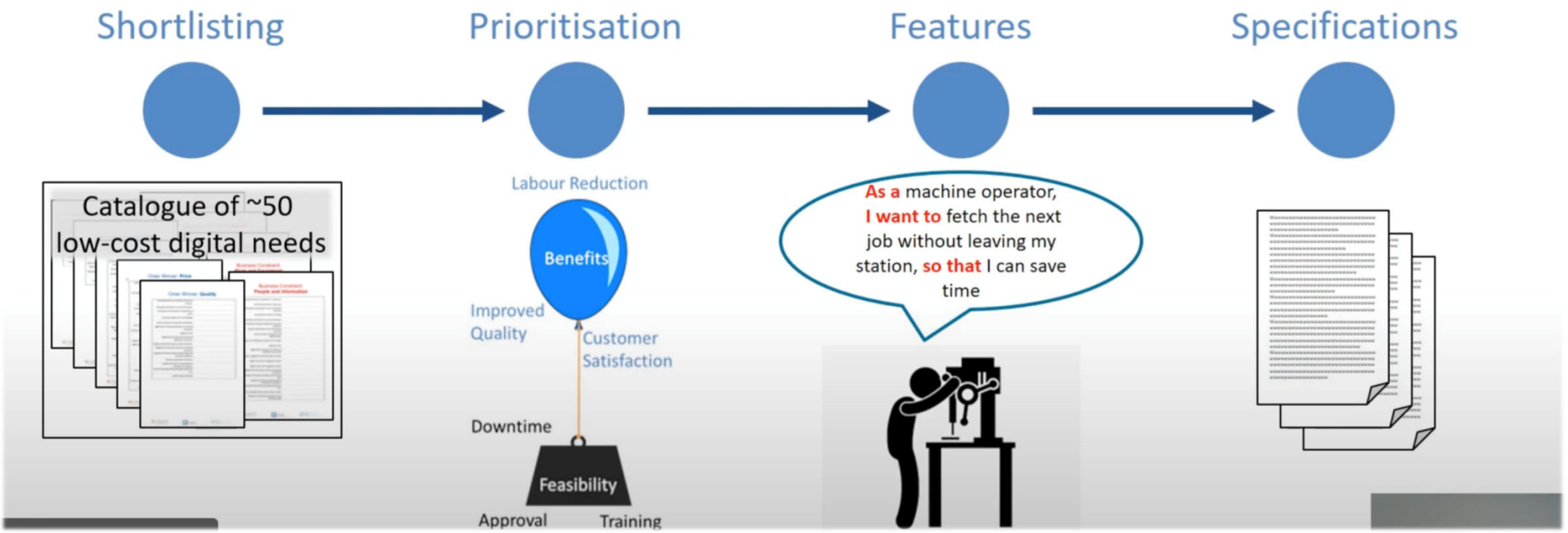
4. Incremental integration
Implementing and integrating solutions in an incremental manner

5. Engagement / Dissemination
Application of the approach in a wide array of companies & labs

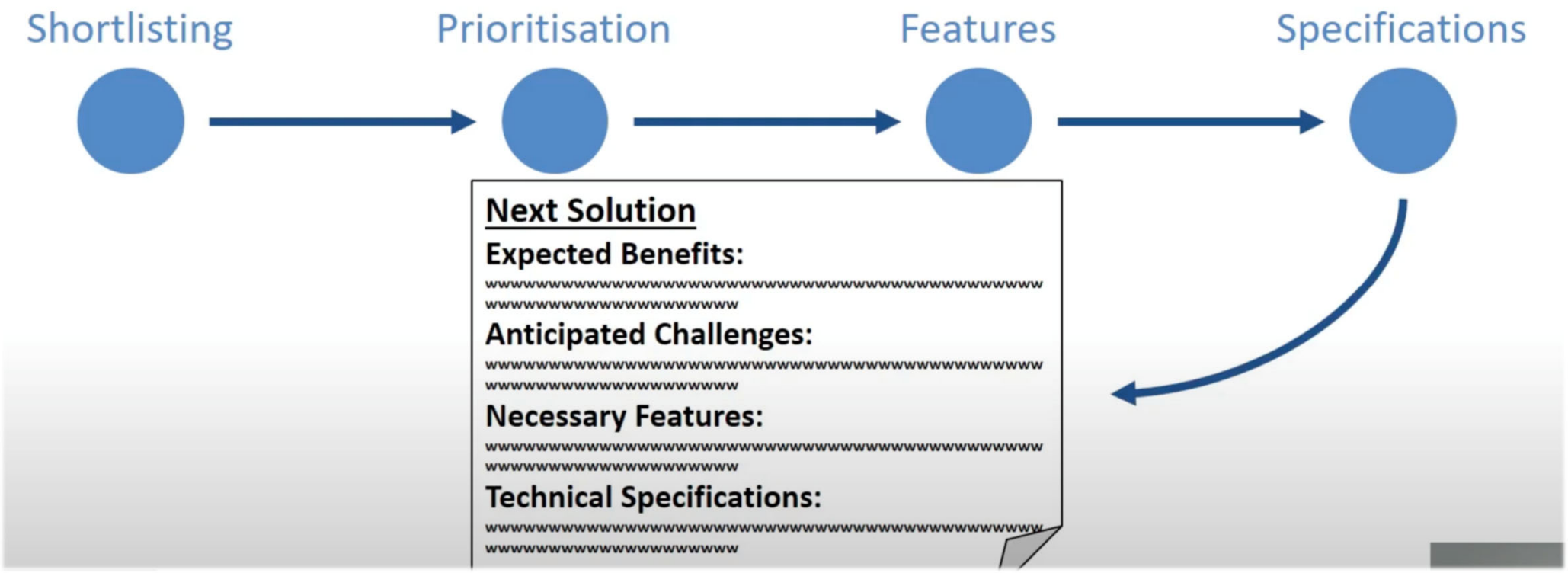
Shoestring design and application approach



Stage I: Digital manufacturing needs assessment



Stage I: Digital manufacturing needs assessment



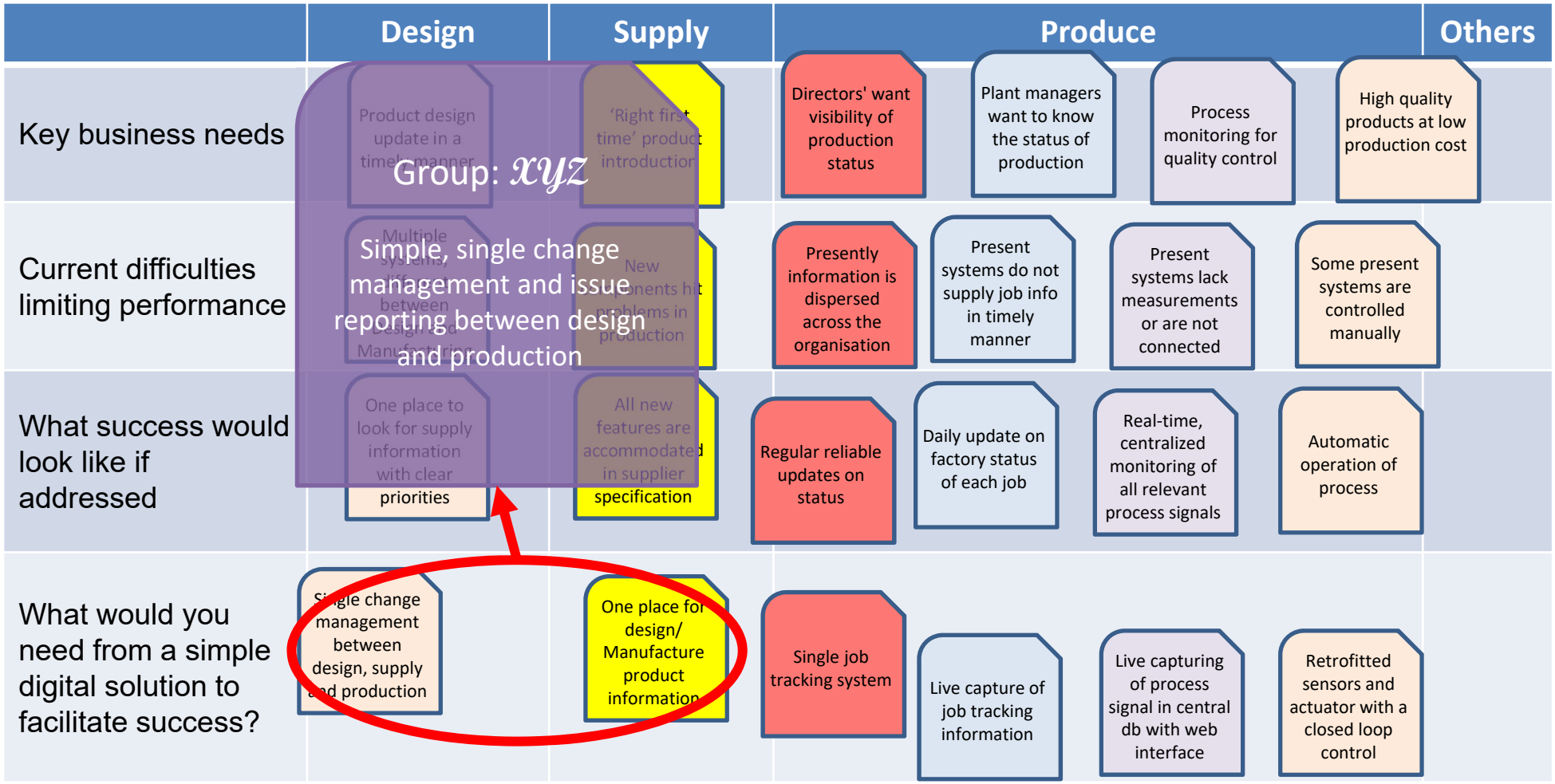
An example

	Design	Supply	Produce	Others
Key business needs				
Current difficulties limiting performance				
What success would look like if addressed				
What would you need from a simple digital solution to facilitate success?				

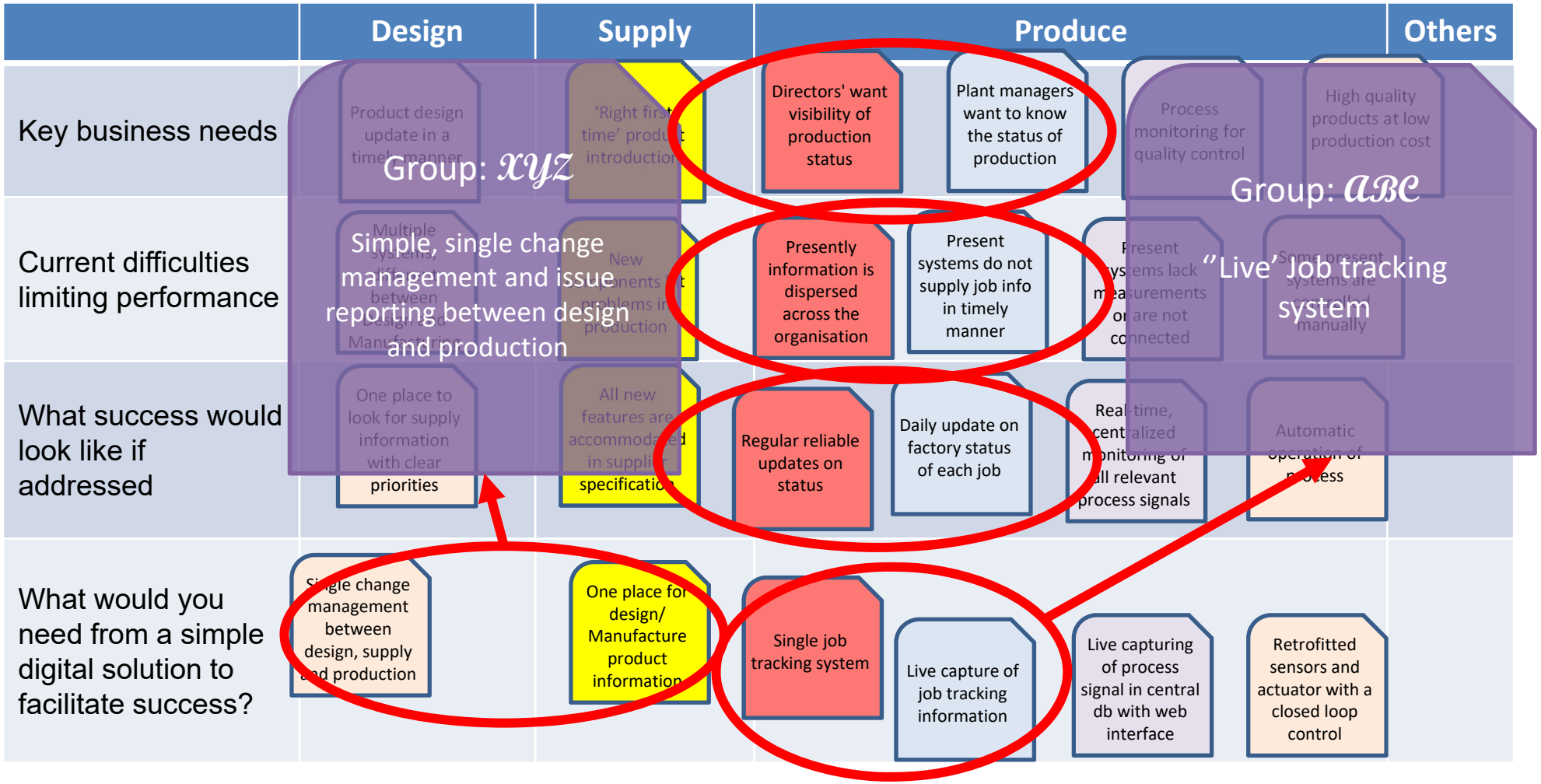
An example

	Design	Supply	Produce				Others
Key business needs	Product design update in a timely manner	'Right first time' product introduction	Directors' want visibility of production status	Plant managers want to know the status of production	Process monitoring for quality control	High quality products at low production cost	
Current difficulties limiting performance	Multiple systems, different between Design and Manufacturing	New components hit problems in production	Presently information is dispersed across the organisation	Present systems do not supply job info in timely manner	Present systems lack measurements or are not connected	Some present systems are controlled manually	
What success would look like if addressed	One place to look for supply information with clear priorities	All new features are accommodated in supplier specification	Regular reliable updates on status	Daily update on factory status of each job	Real-time, centralized monitoring of all relevant process signals	Automatic operation of process	
What would you need from a simple digital solution to facilitate success?	Single change management between design, supply and production	One place for design/ Manufacture product information	Single job tracking system	Live capture of job tracking information	Live capturing of process signal in central db with web interface	Retrofitted sensors and actuator with a closed loop control	

An example


Design
Supply
Produce
Others
Key business needs
Current difficulties limiting performance
What success would look like if addressed
What would you need from a simple digital solution to facilitate success?
Product design update in a timely manner
'Right first time' product introduction
Directors' want visibility of production status
Plant managers want to know the status of production
Process monitoring for quality control
High quality products at low production cost
Multiple systems, different between Design & Manufacturing
New components hit problems in production
Presently information is dispersed across the organisation
Present systems do not supply job info in timely manner
Present systems lack measurements or are not connected
Some present systems are controlled manually
One place to look for supply information with clear priorities
All new features are accommodated in supplier specification
Regular reliable updates on status
Daily update on factory status of each job
Real-time, centralized monitoring of all relevant process signals
Automatic operation of process
Single change management between design, supply and production
One place for design/ Manufacture product information
Single job tracking system
Live capture of job tracking information
Live capturing of process signal in central db with web interface
Retrofitted sensors and actuator with a closed loop control
Group: xyz
Simple, single change management and issue reporting between design and production

An example


Design
Supply
Produce
Others
Key business needs
Current difficulties limiting performance
What success would look like if addressed
What would you need from a simple digital solution to facilitate success?
Group: xyz
Simple, single change management and issue reporting between design and production
Group: abc
"Live' Job tracking system
Directors' want visibility of production status
Plant managers want to know the status of production
Process monitoring for quality control
High quality products at low production cost
Presently information is dispersed across the organisation
Present systems do not supply job info in timely manner
Regular reliable updates on status
Daily update on factory status of each job
Single change management between design, supply and production
One place for design/ Manufacture product information
Single job tracking system
Live capture of job tracking information
Live capturing of process signal in central db with web interface
Retrofitted sensors and actuator with a closed loop control

Stage II: Solution Specification & Prototype

Solution
Collection of services

Service modules
common collections of building blocks

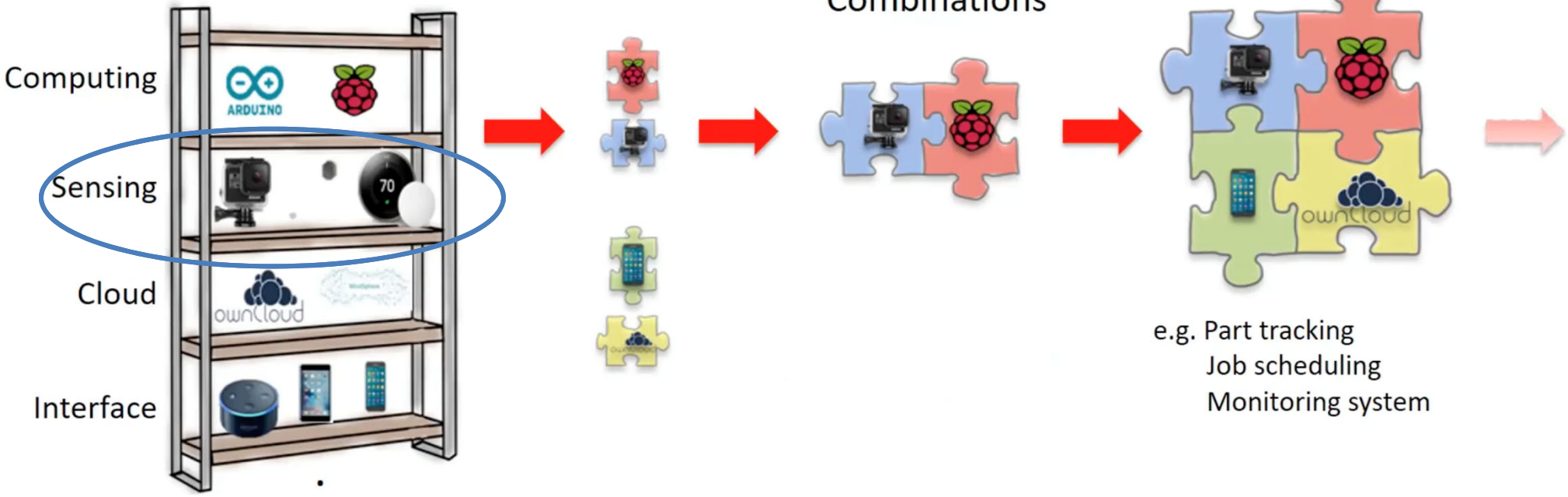
(Standard interfaces)

Off The Shelf Technologies

Building Blocks

Standard Building Block Combinations

Modular, Low Cost Solution



e.g. Part tracking
Job scheduling
Monitoring system

Examples of common low-cost sensing technologies for monitoring

Sensed parameter	Sensor	Type	Output	Range	Accuracy H(L)	Resolution (R)/ Sensitivity(S)	Price range (USD)
Temperature	LM335	Transistor	A	-40 °C ~ 100 °C	±3 °C (±5 °C)	R=10 mV/ °C	1.4
	LMT01LPG	Transistor	D	-50 °C ~ 150 °C	±0.5 °C (±0.6875 °C)	R=0.0625 °C	2.8
	MLX90614	IR	D	-70 °C ~ 380 °C	±0.5 °C (±4 °C)	R=16 bit	32
	NB-PTCO	RTD	A	-50 °C ~ 600 °C	±0.3 °C	R=3850 ppm/ °C	1.8
	NTCLE100E3103JB0	NTC Thermistor	A	-40 °C ~ 125 °C	NA	NA	0.69
	TP29	K-type Thermocouple	A	-50 ~ 200 °C	NA	NA	9.6
Vibration	PC420A	Piezoelectric	A	10 Hz - 1.0 kHz	NA	S=5%	330
	KX122	MEMS	D	6.25 Hz ~ 12.8kHz	NA	S= ±2 g ~ ±8 g	1.83
Acoustic	CMA-4544PF	Electret	A	20 Hz ~ 20.0 kHz	SNR = 60dB	S=-44 dB ±2dB	0.77
	SPU0410LR5H	MEMS	A	100 Hz ~ 80.0 kHz	SNR=63dB	S= -38 dB ±3 dB @ 94 dB SPL	0.67
	PMO-4015PN	Magnetic	A	50 Hz ~ 12.0 kHz	SNR= 58dB	S= -42 dB ±2 dB @ 94 dB SPL	1.58
Pressure	SDP31–500PA	Differential	D	-0.5 kPa ~ 0.5kPa	±3%	R= 16 bit	30.69
	DP-101-N	Vented gauge	D	±100kPa	NA	NA	92
	24PCEFA6G	Compound	A	±3.45kPa	±1%	NA	27.27

*IR: Infrared, RTD: resistance Temperature Detector, NTC: Negative temperature Coefficient, MEMS: Micro Electro-Mechanical Systems, A: analogue, D: Digital, SPL: Sound Pressure Level, PPM: Parts per Million, Hz: Hertz, Pa: Pascal, C: Celsius.

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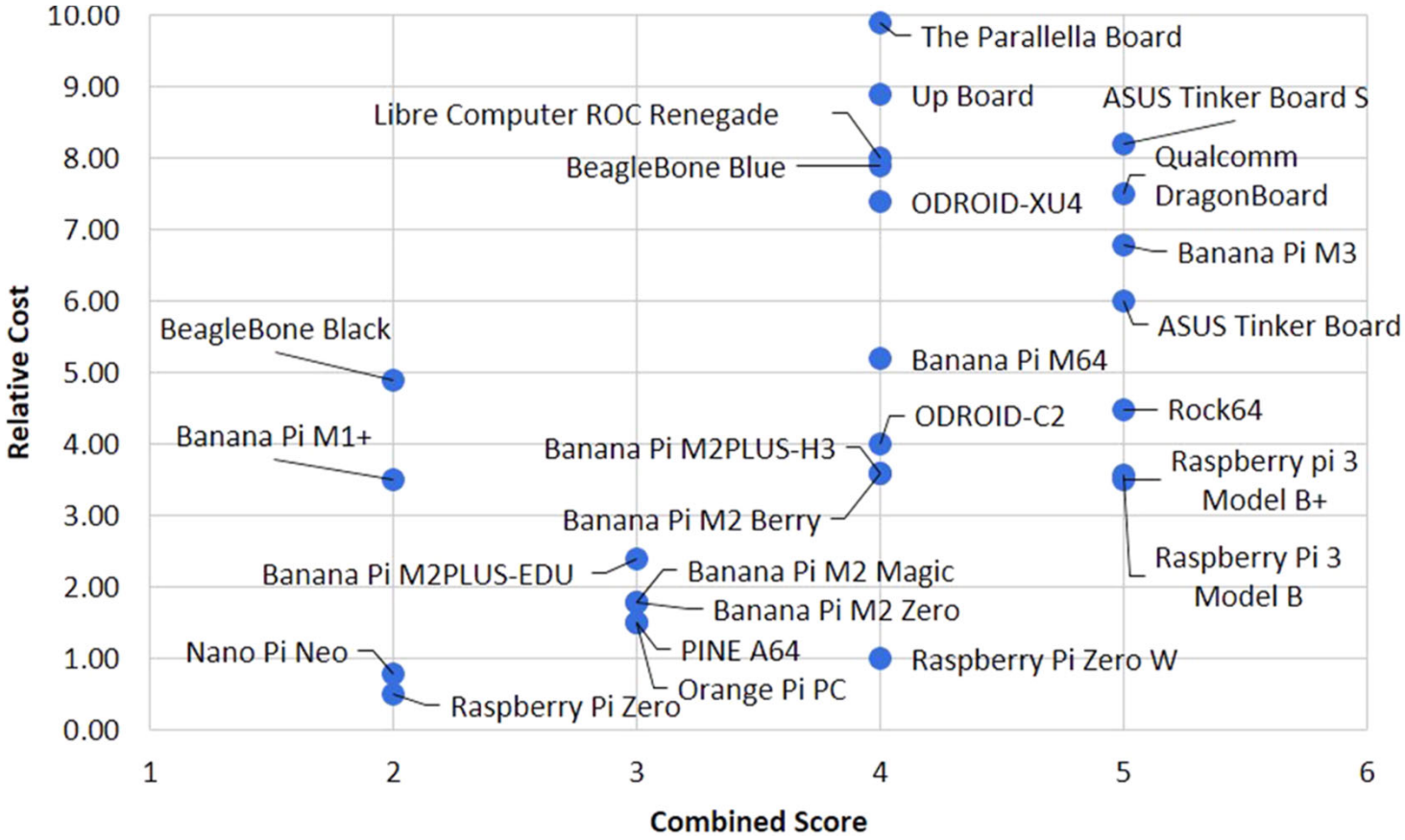
Review of low-cost wireless communication technologies – considering cost, computing performance and connectivity



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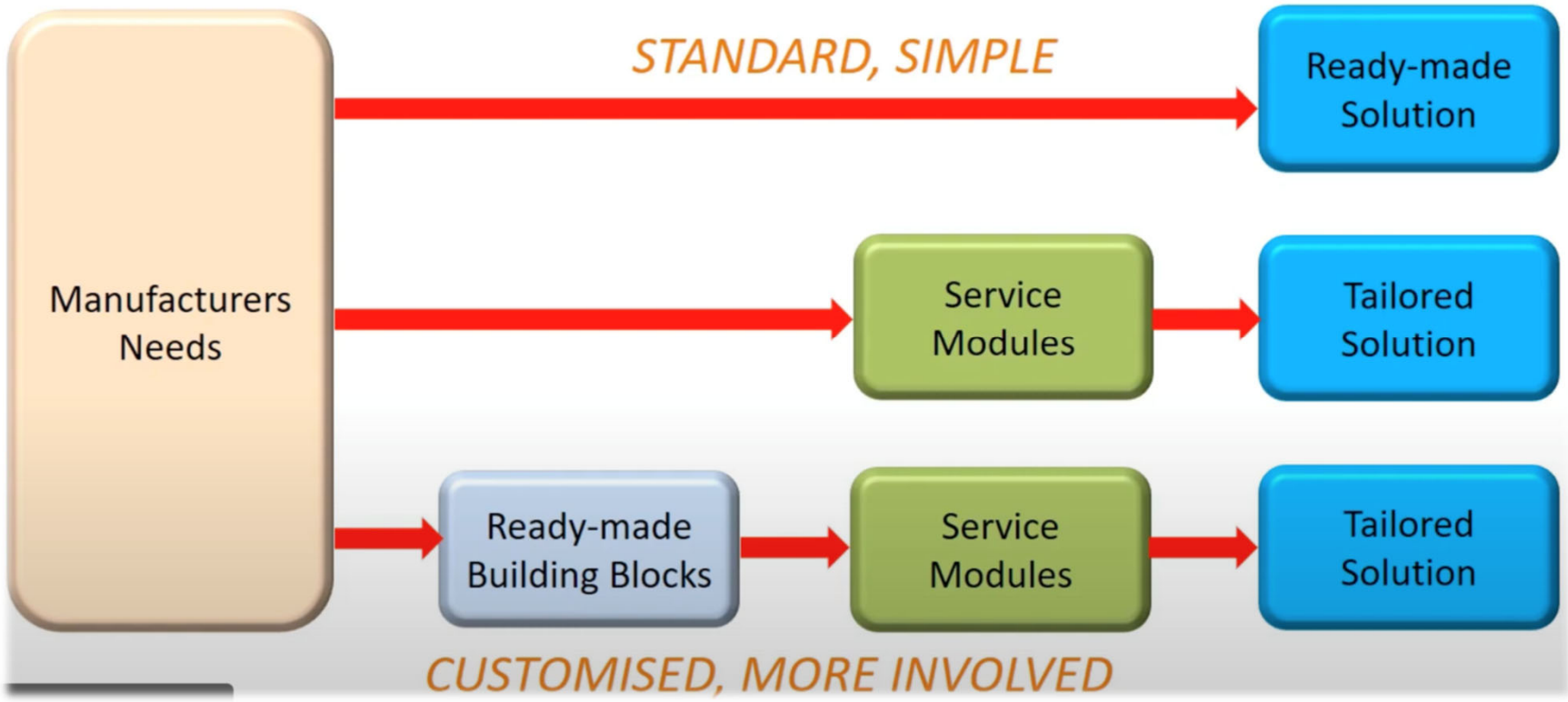
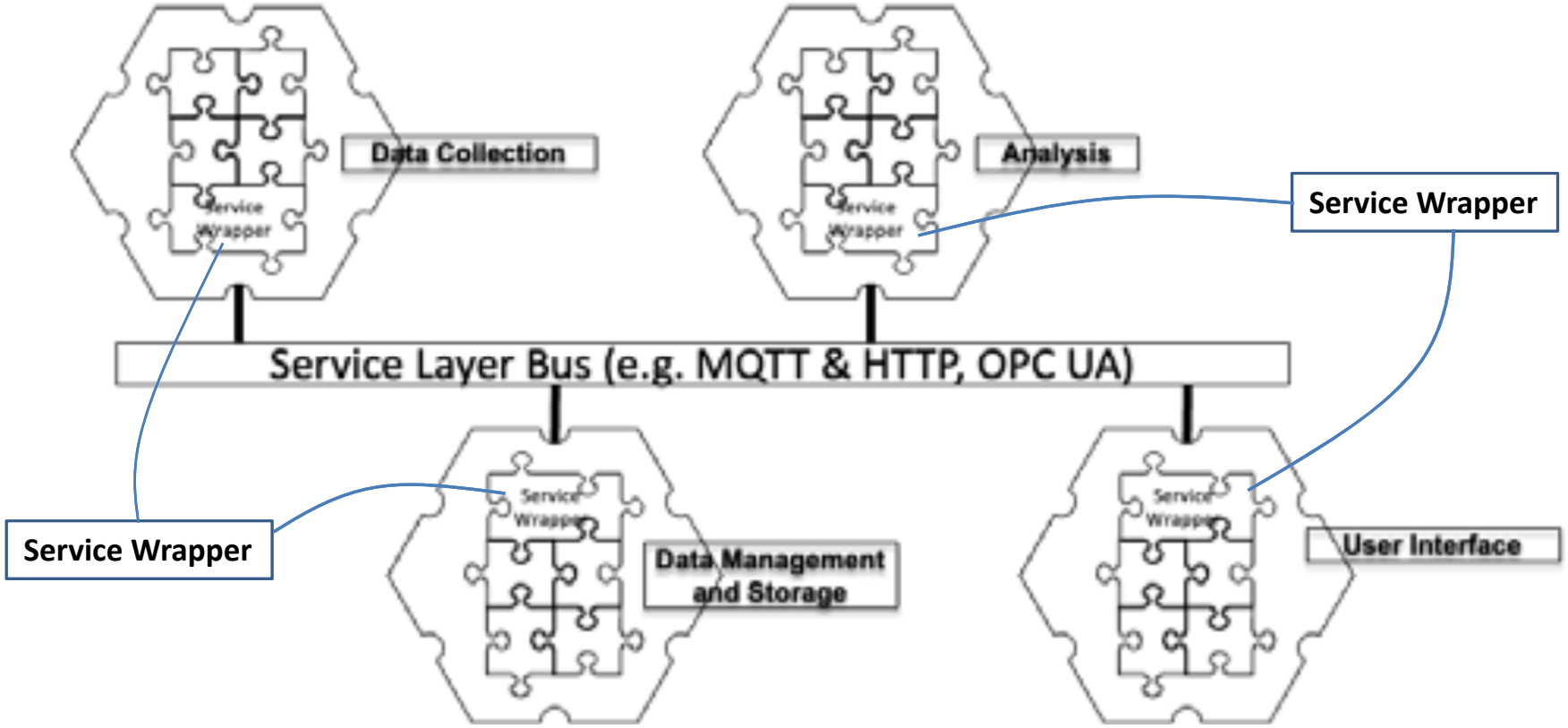
Shoestring solution pathways for SMEs

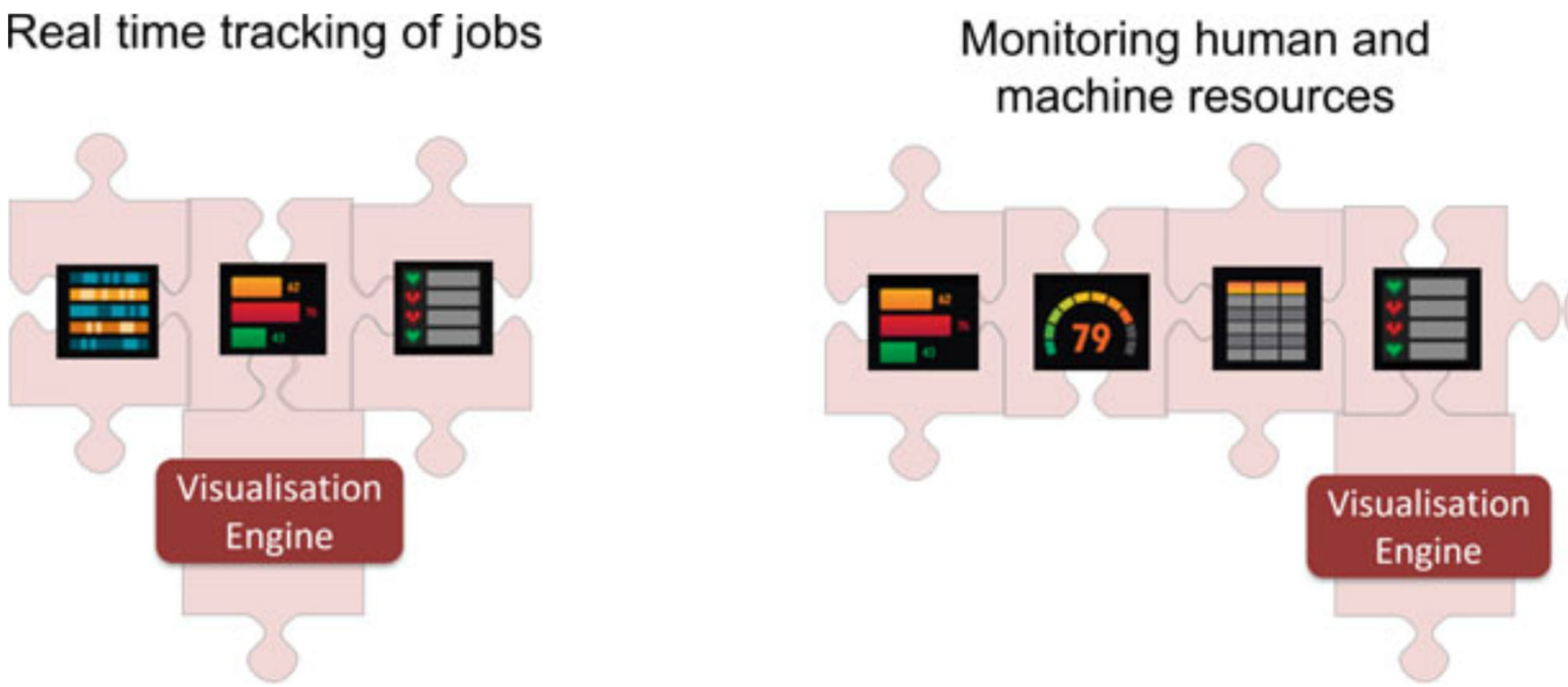


Digital solution as a combination of service modules



McFarlane, D., Ratchev, S., De Silva, L., Hawkridge, G., Schönfuß, B., Angulo, G.T. Digitalisation for SME Manufacturers: A Framework and a Low-Cost Approach(2022) IFAC-PapersOnLine, 55 (2), pp. 414-419.

Visualisation building blocks re-used to build different solutions



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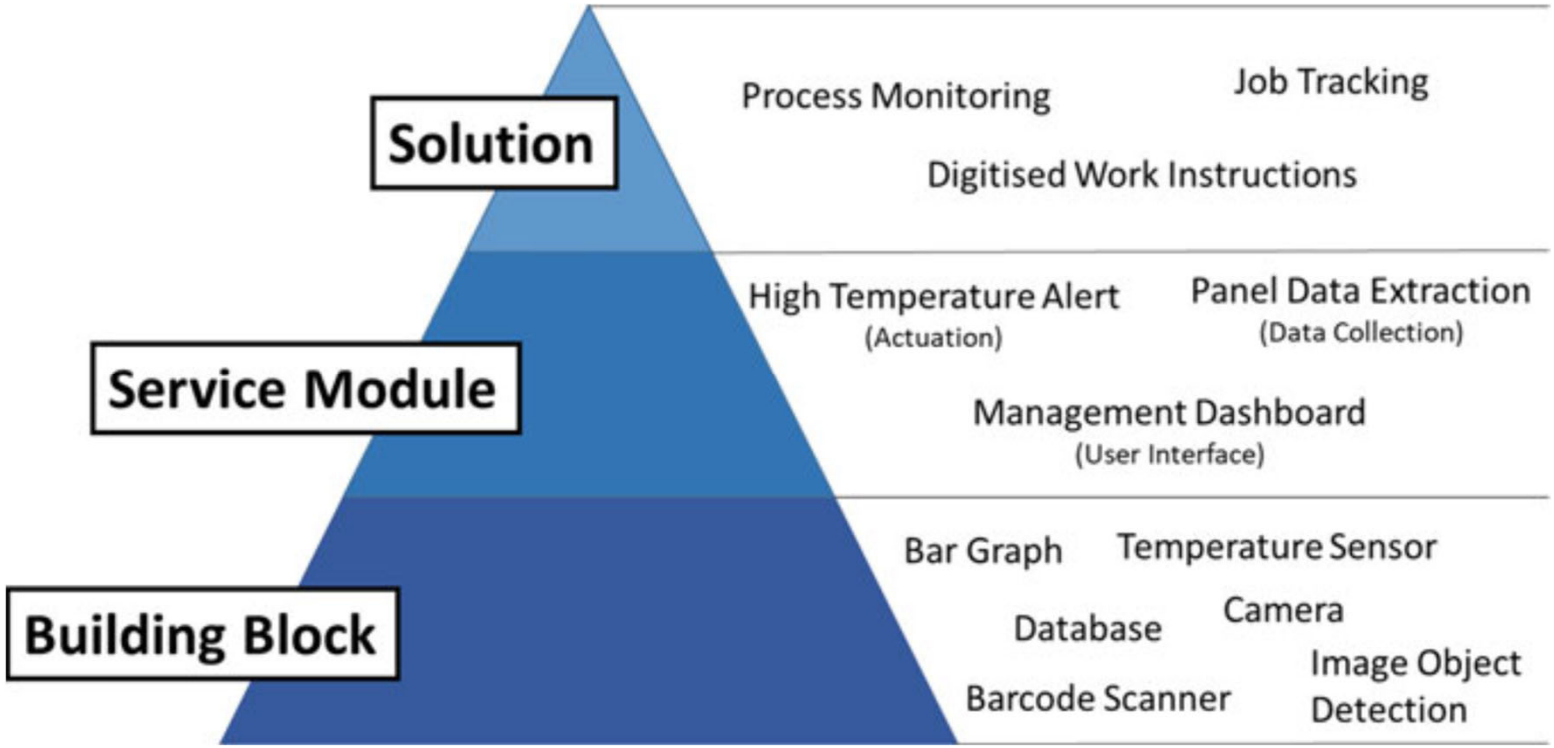
Solution composition hierarchy



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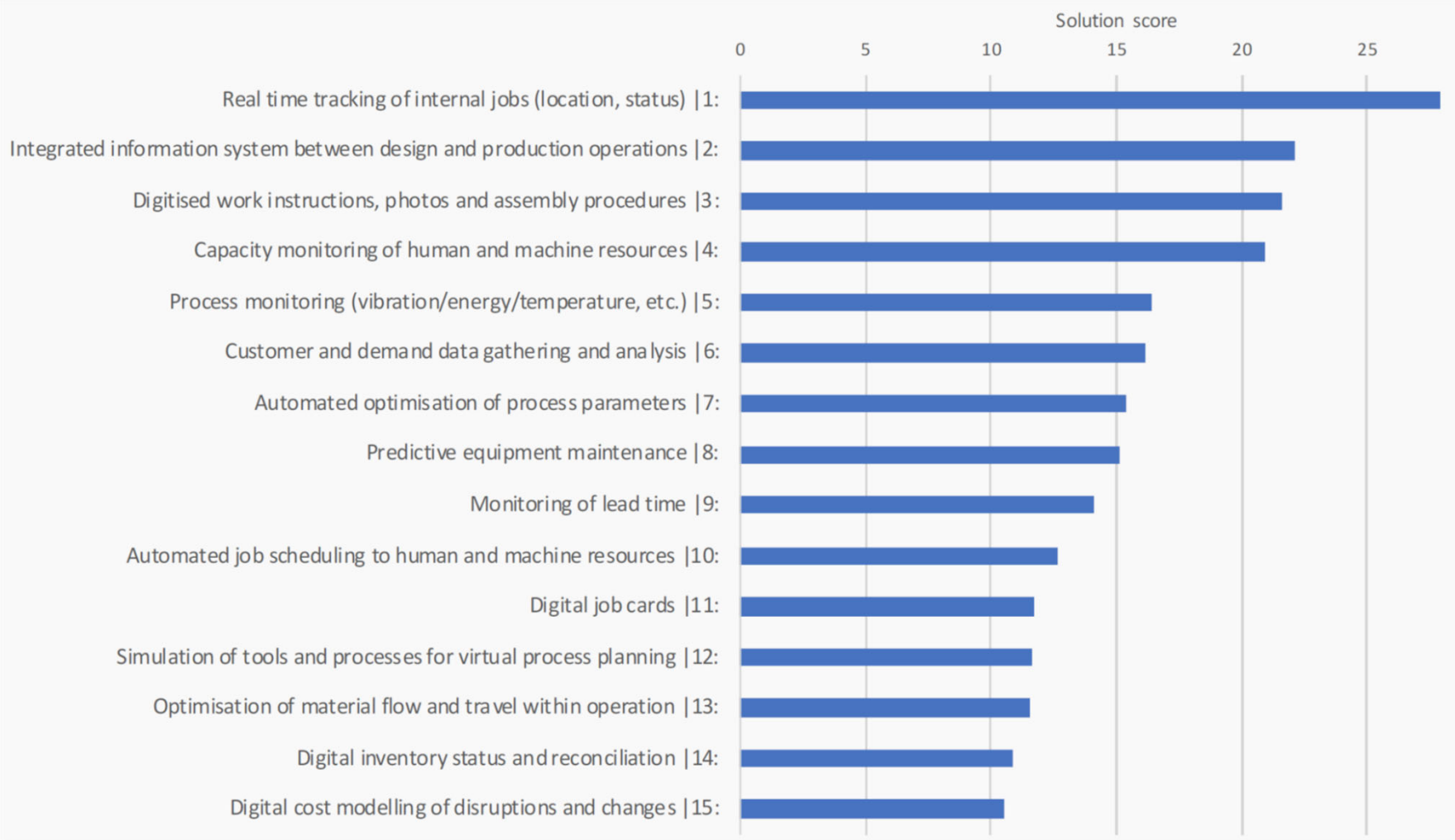
Top 15 demanded digital manufacturing solutions of SMEs in the UK



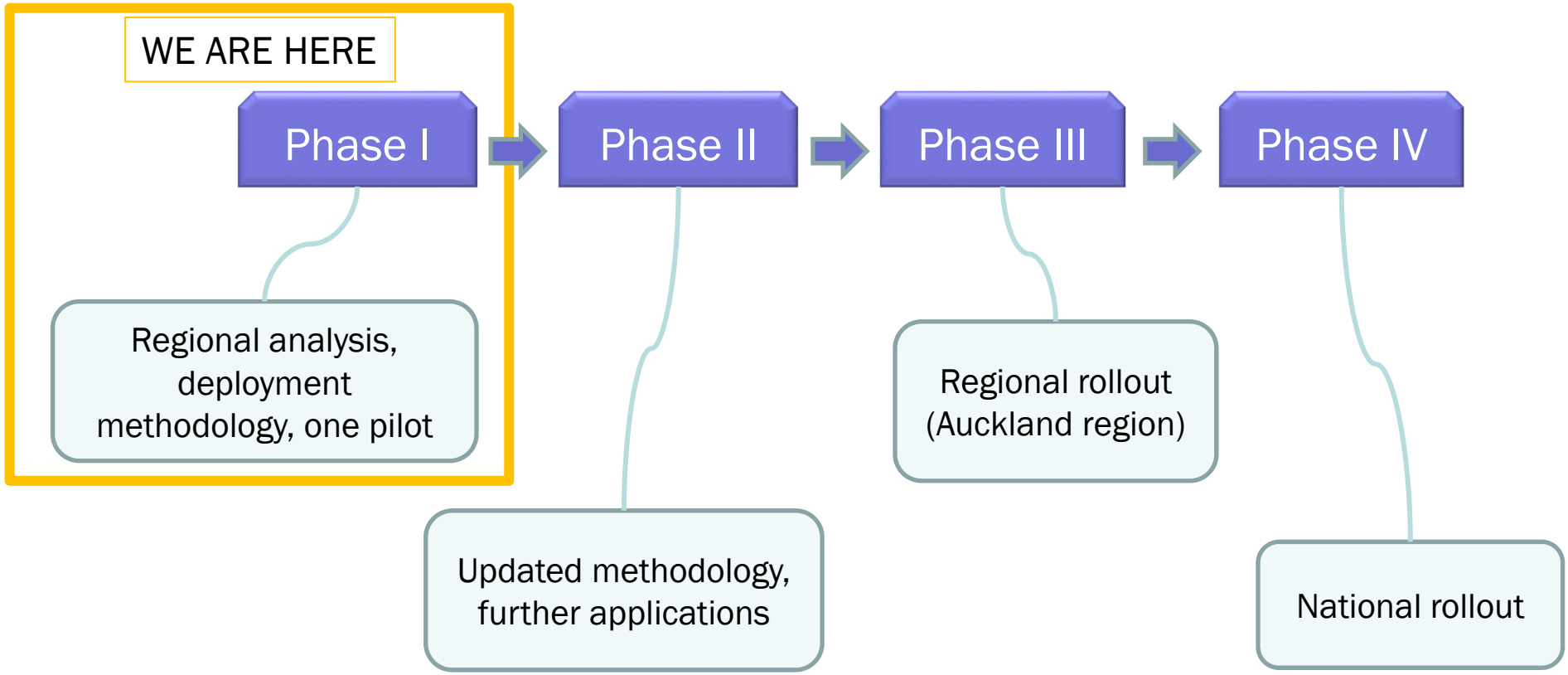
Duncan McFarlane, Svetan Ratchev, Lavindra de Silva, Gregory Hawkridge, Benjamin Schönfuß, German Terrazas Angulo. 2022. “Digitalisation for SME Manufacturers: A Framework and a Low-Cost Approach .” *IFAC PapersOnLine 55-2* . ELSEVIER. 414–419.

Digital Manufacturing Light Auckland Pilot (2022)

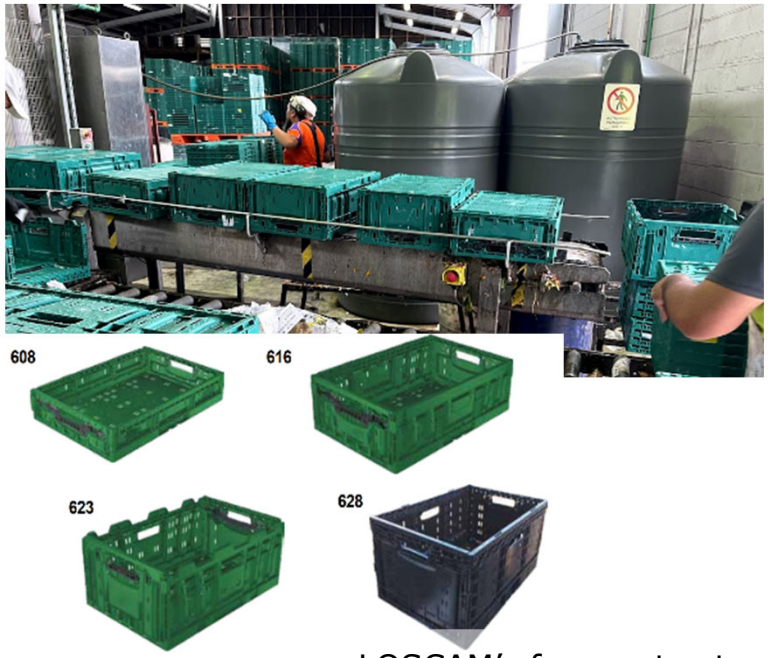
Inspired by the ‘Digital Manufacturing on a Shoestring’ research and application (UK)

aucklandunlimited.com

"Digital Manufacturing Light" Auckland Pilot Framework



An NZ Example for Digital Manufacturing Light – Process Monitoring at LOSCAM

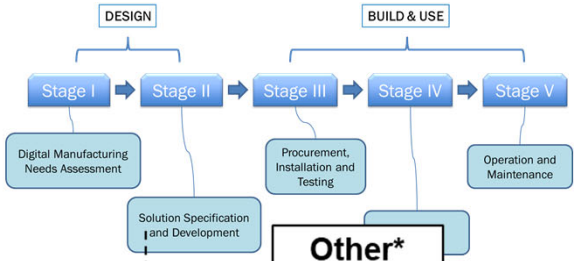


LOSCAM's four crates types *

- Pooling and returnable packaging solutions.
- Suspects of inefficiencies in current processes.
- Needs to determine washing rates, type of crates washed, and length of stoppages.

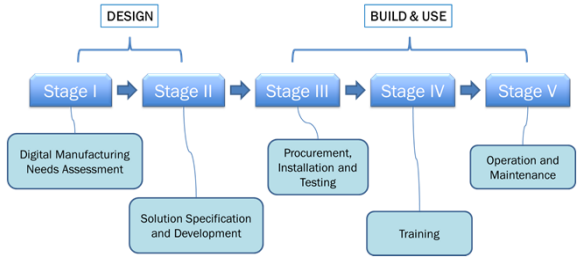
* https://www.loscam.com/ufiles/1595413570.pdf

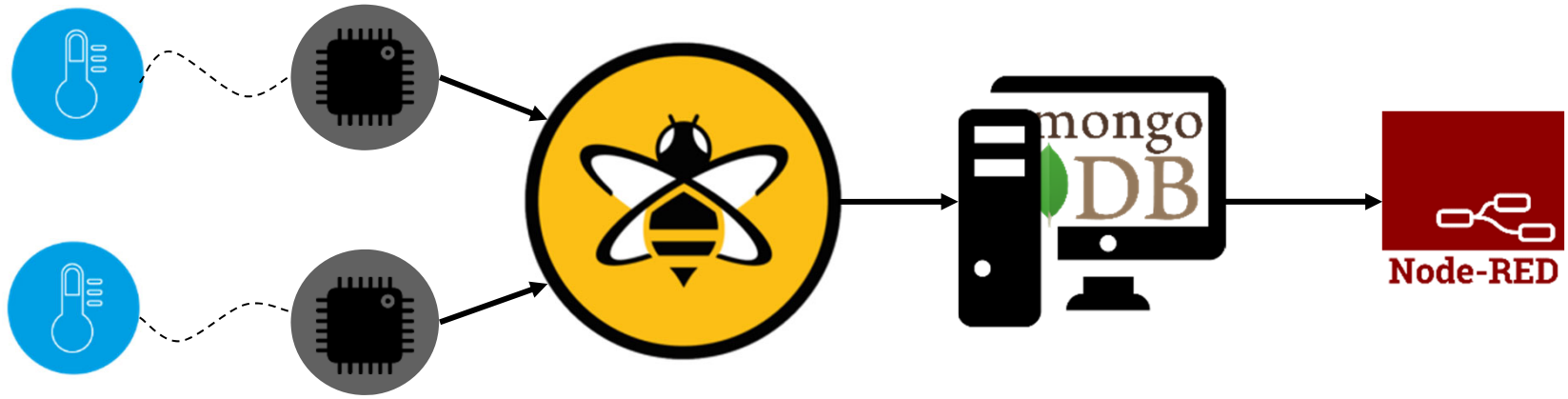
Digital Manufacturing Needs Assessment



	Design	Supply	Produce	Other*
Key business needs			Plant managers want to know the performance of production	
Current difficulties limiting performance against key business need			Present system does not supply performance info in timely manner	
What success would look like if addressed			Real-time visualization of the plant performance	
What would you need from a simple digital solution to facilitate that success?			Live capture and visualization of all cradles washed	Note(*) e.g.: Customers, Partners, Channels

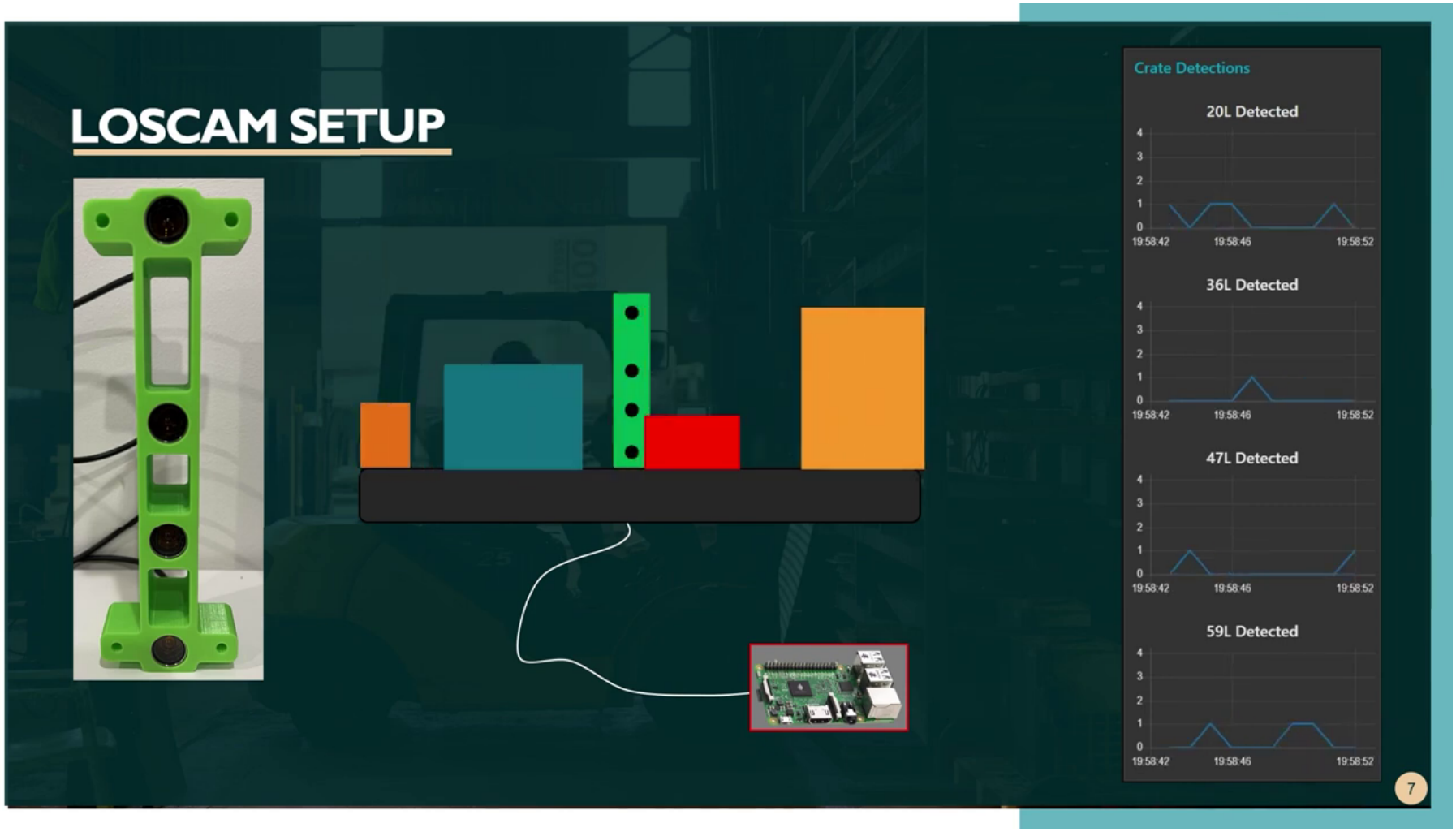
Solution Specification and Development



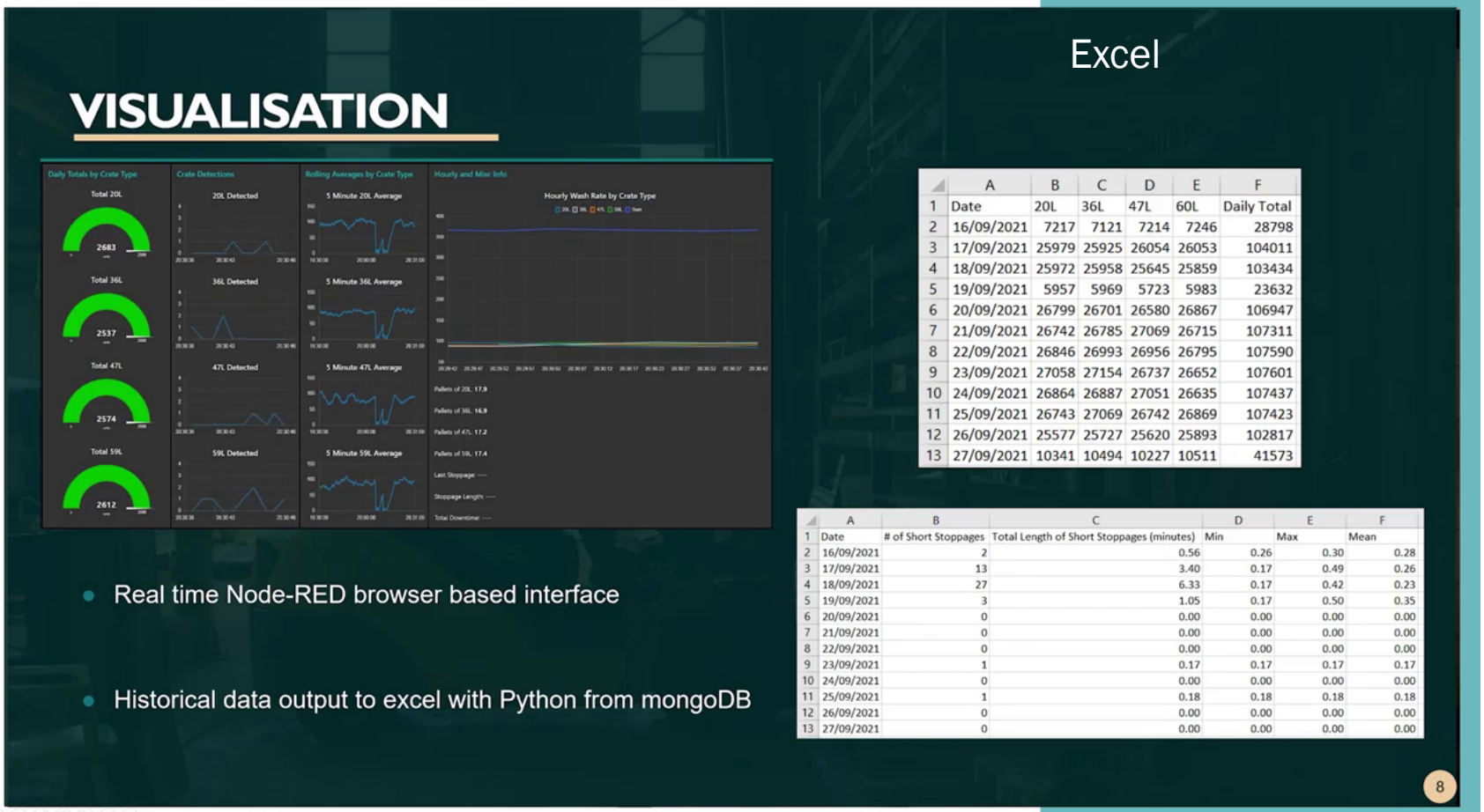


Sensors Microcomputer MQTT Broker NAS/Database Visualisation

Sensor Setup



Visualisation via Web-Browser



	A	B	C	D	E	F
1	Date	20L	36L	47L	60L	Daily Total
2	16/09/2021	7217	7121	7214	7246	28798
3	17/09/2021	25979	25925	26054	26053	104011
4	18/09/2021	25972	25958	25645	25859	103434
5	19/09/2021	5957	5969	5723	5983	23632
6	20/09/2021	26799	26701	26580	26867	106947
7	21/09/2021	26742	26785	27069	26715	107311
8	22/09/2021	26846	26993	26956	26795	107590
9	23/09/2021	27058	27154	26737	26652	107601
10	24/09/2021	26864	26887	27051	26635	107437
11	25/09/2021	26743	27069	26742	26869	107423
12	26/09/2021	25577	25727	25620	25893	102817
13	27/09/2021	10341	10494	10227	10511	41573

	A	B	C	D	E	F
1	Date	# of Short Stoppages	Total Length of Short Stoppages (minutes)	Min	Max	Mean
2	16/09/2021	2	0.56	0.26	0.30	0.28
3	17/09/2021	13	3.40	0.17	0.49	0.26
4	18/09/2021	27	6.33	0.17	0.42	0.23
5	19/09/2021	3	1.05	0.17	0.50	0.35
6	20/09/2021	0	0.00	0.00	0.00	0.00
7	21/09/2021	0	0.00	0.00	0.00	0.00
8	22/09/2021	0	0.00	0.00	0.00	0.00
9	23/09/2021	1	0.17	0.17	0.17	0.17
10	24/09/2021	0	0.00	0.00	0.00	0.00
11	25/09/2021	1	0.18	0.18	0.18	0.18
12	26/09/2021	0	0.00	0.00	0.00	0.00
13	27/09/2021	0	0.00	0.00	0.00	0.00

An NZ Example for Digital Manufacturing Light – Retrofitting of a legacy machine

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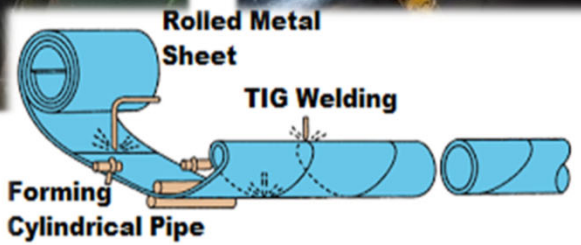
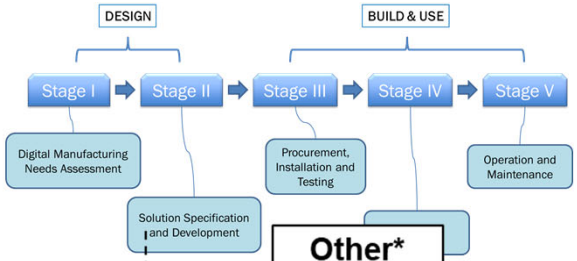


Digital Manufacturing Needs Assessment



	Design	Supply	Produce	Other*
Key business needs			High quality at low production cost	
Current difficulties limiting performance against key business need			Some present systems are controlled manually	
What success would look like if addressed			Automatic operation of critical process	
What would you need from a simple digital solution to facilitate that success?			Retrofitted sensors and actuator with a closed loop control	Note(*) e.g.: Customers, Partners, Channels

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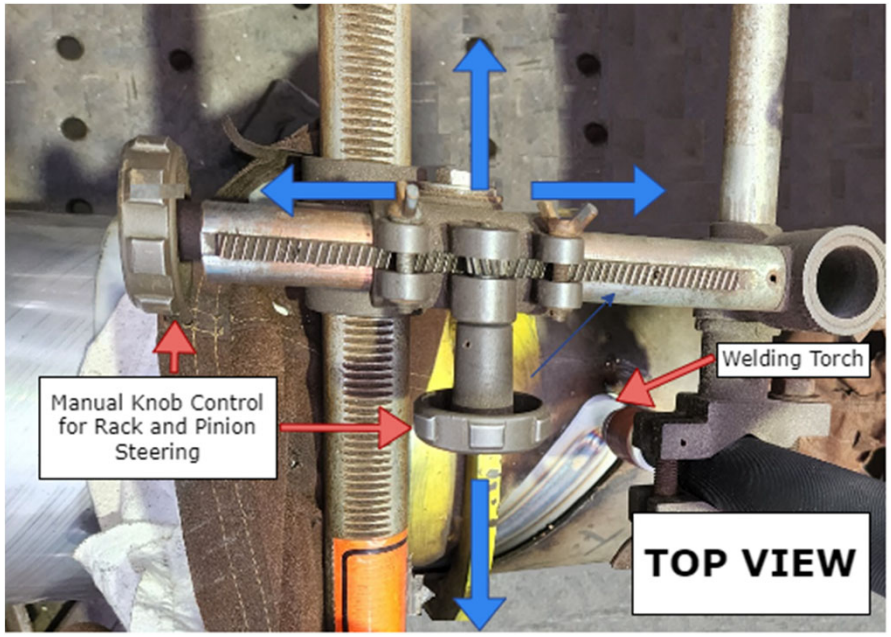
Retrofitting of a legacy machine - a digital solution



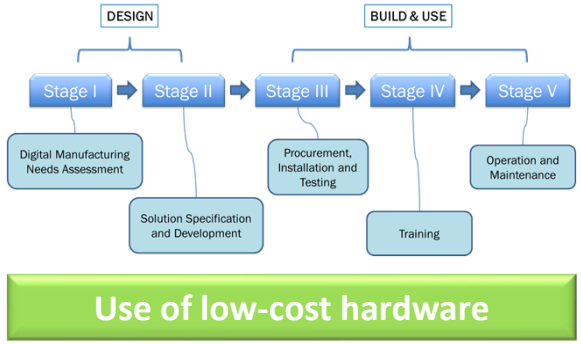
TODAY

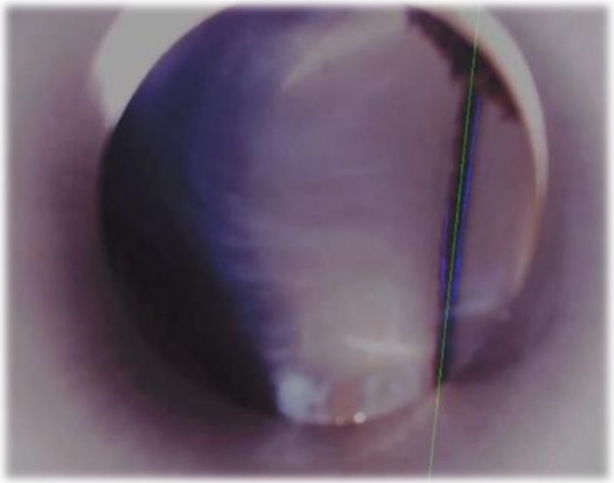
- **Continuous monitoring** of the welding process by an **operator**
- In case of a position **change** of the welding seam, the operator **manually adjusts** the welding torch position
- The **operator** is **tied up** to the station

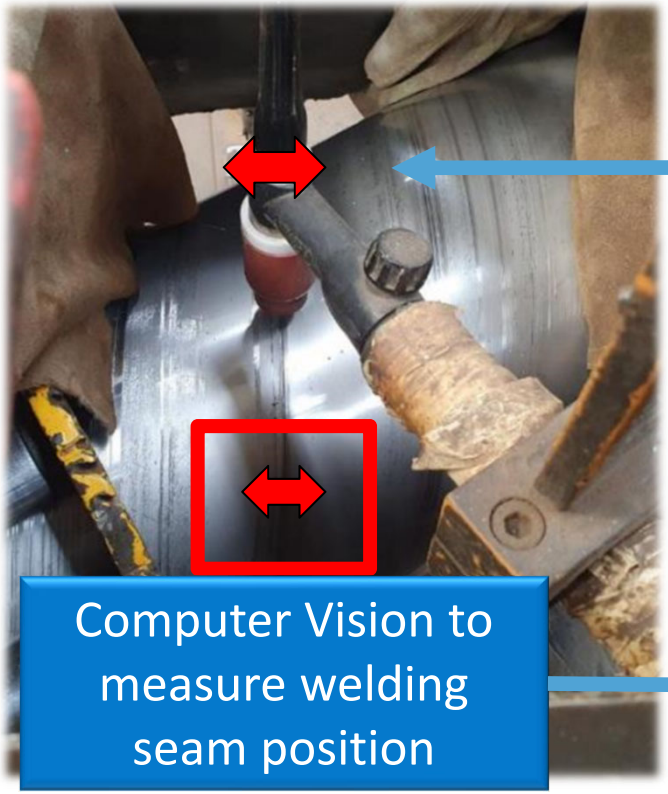
DIGITAL SOLUTION

- **Continuous monitoring of** the welding process by **computer vision**
- In case of a position **change** of the welding seam, **automatically control the position** of the welding torch
- An **operator is freed up**
- **Quality** is assured
- **Legacy** system made “smarter”

Solution Specification and Development







New actuator for torch movement

Computer Vision to measure welding seam position

Closed loop control using a MicroComputer

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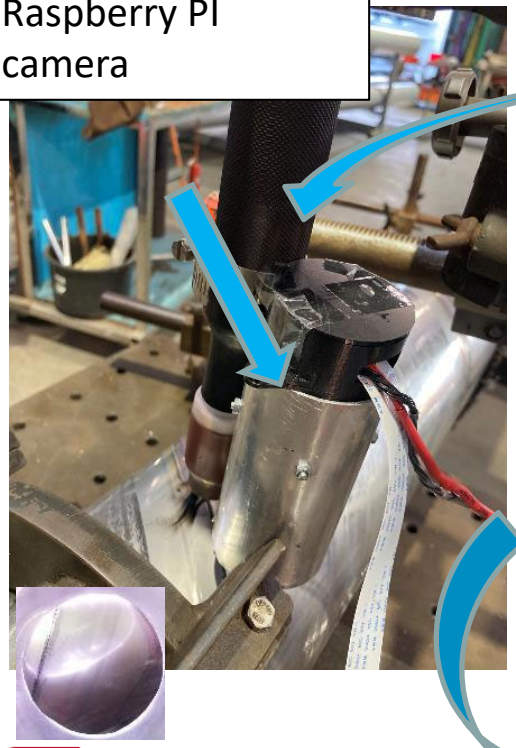
i4.0 UNIVERSITY OF AUCKLAND Waipapa Taumata Rau NEW ZEALAND

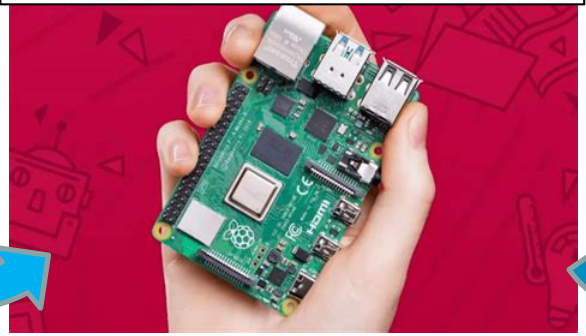
Solution Specification and Development

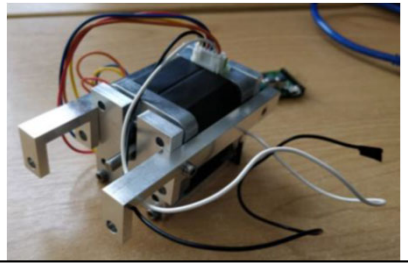
New chassis for the Raspberry PI camera



Mounting position of touch monitor

MicroComputer - RaspberryPi





Mounting position of the new stepper motor

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