CATAPULT
High Value Manufacturing

Developing 21st Century Formulated Products & Manufacturing Processes
Challenges & Opportunities

John Carroll
Technical Strategy Director, Formulation; CPI

High Value Manufacturing Catapult

cpi

£460 million invested to date

Over **£240 million** for the next 5 years

Over **2300** industry clients

A combined **1300** staff and growing

Who are CPI?

CPI is a UK technology **innovation** centre and the process element of the Government's **High Value Manufacturing Catapult**.

National Printable Electronics Centre

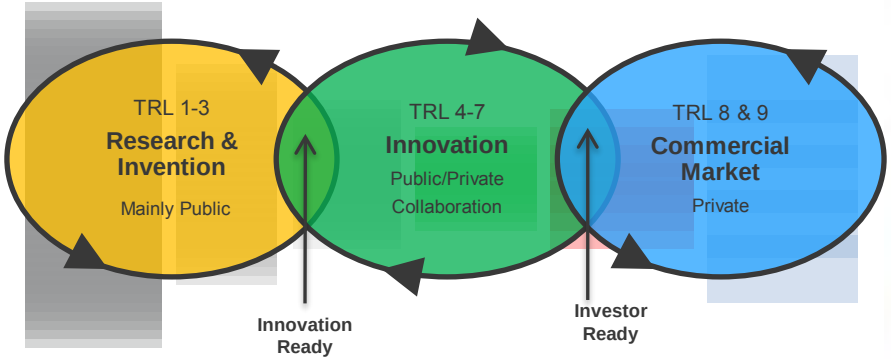
National Industrial Biotechnology Facility

National Biologics Manufacturing Centre

National Formulation Centre

We use applied knowledge in science and engineering combined with state of the art facilities to enable our clients to **develop, prove, prototype** and **scale-up** the next generation of products and processes.

De-risking Translation from Invention to Invoices



WE SUPPORT COMPANIES CROSSING THE GAP BETWEEN RESEARCH AND COMMERCIALISATION

Formulation (Integrate to Deliver Surprising Benefits)

Formulation, the creation of multi-component, multi-phase products, is an **enabling capability**

Creating value through intricate **microstructures** and powerful **ingredient synergies**

Underpins many **sectors** in our economy and **high-value manufacturing** industries globally.

The formulated products market in the UK is worth around **£180 billion per annum** with a potential for companies in emerging overseas markets of around **£1,000 billion per annum**

The National Formulation Centre - Overview

Create value for UK-based companies through formulation science by enabling bigger, cheaper or faster innovation

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Productivity from value-creating strategic alliances with industry and the wider UK formulation eco-system (inc SME/supply chain and Knowledge Base (Academic) partners)

Create and use an **industry-led portfolio of advanced capabilities. Sweat the UK assets** by best harnessing current capabilities and then plugging any critical gaps identified

Sustainability from enduring access and **application of advanced capabilities**

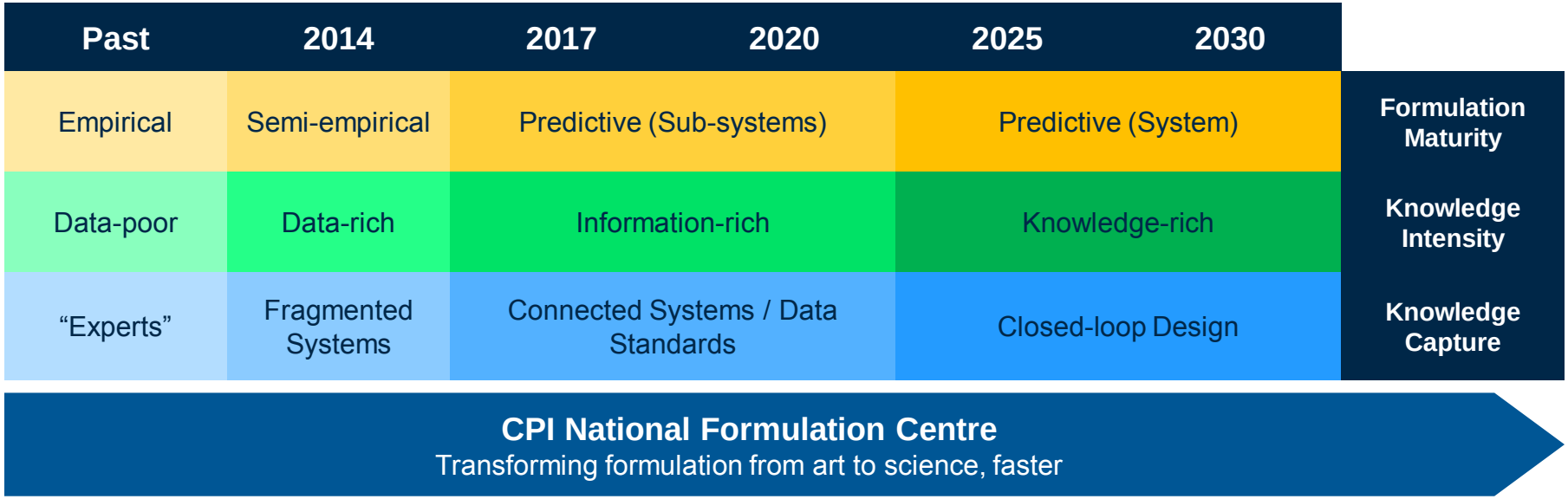
Structure – Activating the Innovation Eco-system

FRAMES CAPABILITY CHALLENGES
(WHAT'S NEEDED)

CO-DEVELOPS ASSOCIATED TECH
(WHAT'S POSSIBLE)

PROVIDES SCIENTIFIC UNDERSTANDING AND ENABLING CAPABILITIES
(POSSIBILITY)

Potential for UK Leadership in a Global Capability Race



- Transformation potential through advances in enabling technologies such as informatics, modelling, measurement and sensors (Telemetry), and automation - robotics
- Faster progress through integration model

Capability Themes to Work Against

Revalidated by Industry Steering Group (ISG)

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Predictive Designs

Faster Innovation

Faster, more reliable approaches to get to ideal formulation design

Radical Effects

Bigger Innovation

Unexpected synergistic effects to deliver bigger/disruptive benefits

Manufacturability

Process Innovation

Optimised, reliable system to guarantee ideal formulated product delivery

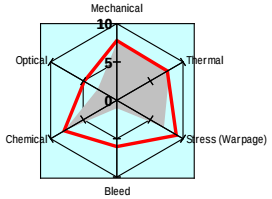
4IR Capable

Innovation Enabler

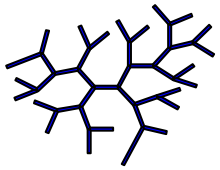
Critical foundational component for knowledge management and connectivity

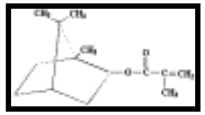
Formulations operate at different length & time scales to deliver required functional effects

High Throughput Formulation and Product Development



Functional Properties
Mechanical, Surface,
Electrical, Optical, Thermal
Chemical, Biological, Sensory





Final Form

Secondary Structure

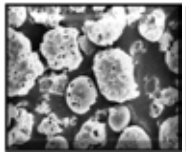
Primary Structure

Increasing comlpexity

Material in End-Use

Functional Materials or Formulations

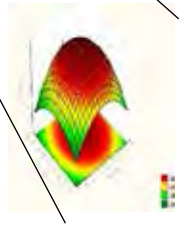
Raw Material(s)



The Spectrum of Knowledge

Empirically Driven

Complete understanding



- **Very little is really known.**
- **Progress is made mostly by leveraging previous experience /guesswork and trial and error**

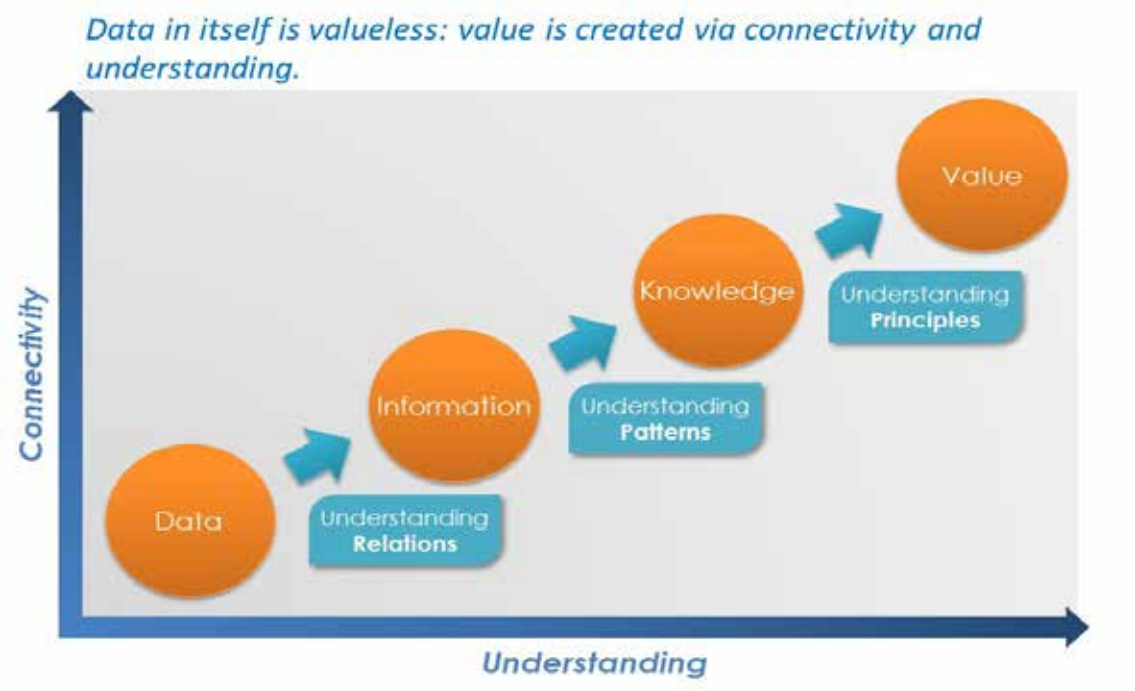
- **Pockets of knowledge**
- **Little or no transferability**
- **No real learning or understanding generated**

- **Can write equations to describe every aspect of the problem**

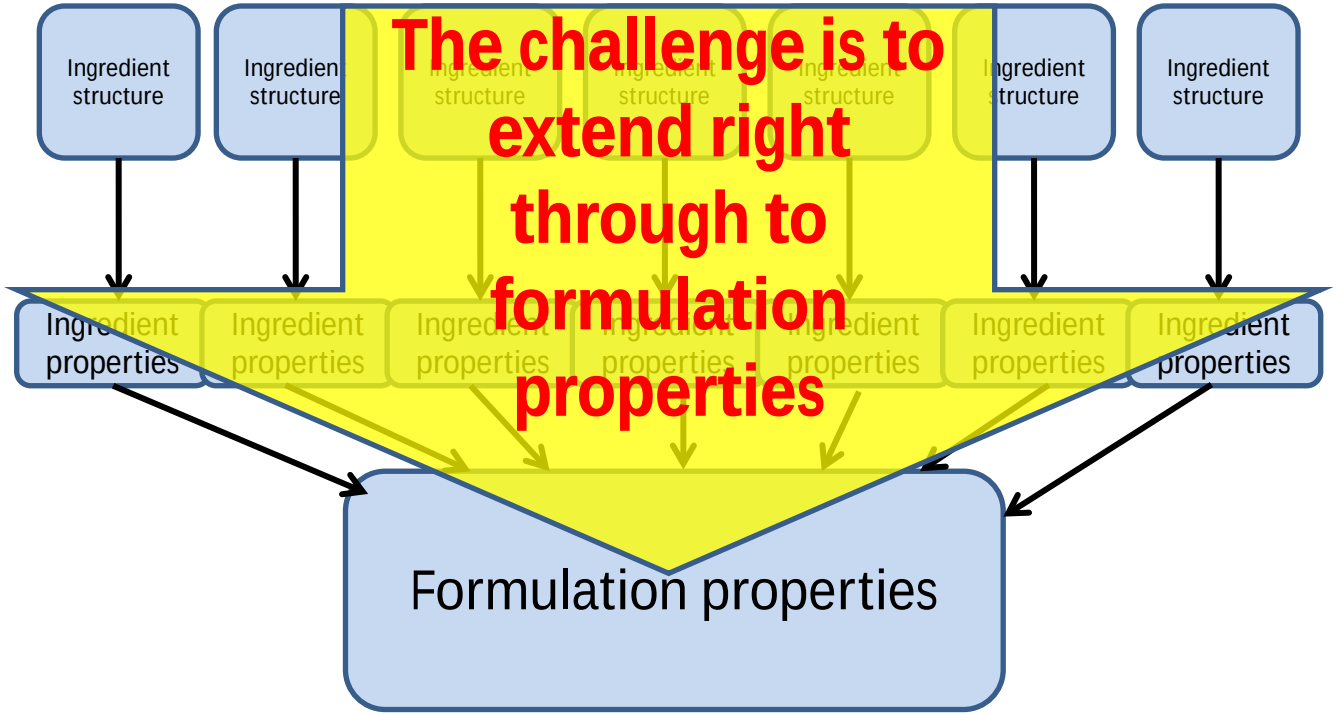
The difference between data and knowledge

- We have a huge amount of formulation data
  - But what do these data teach us about achieving the required functional properties that add commercial value to products

Data ≠ knowledge



Can we change this?



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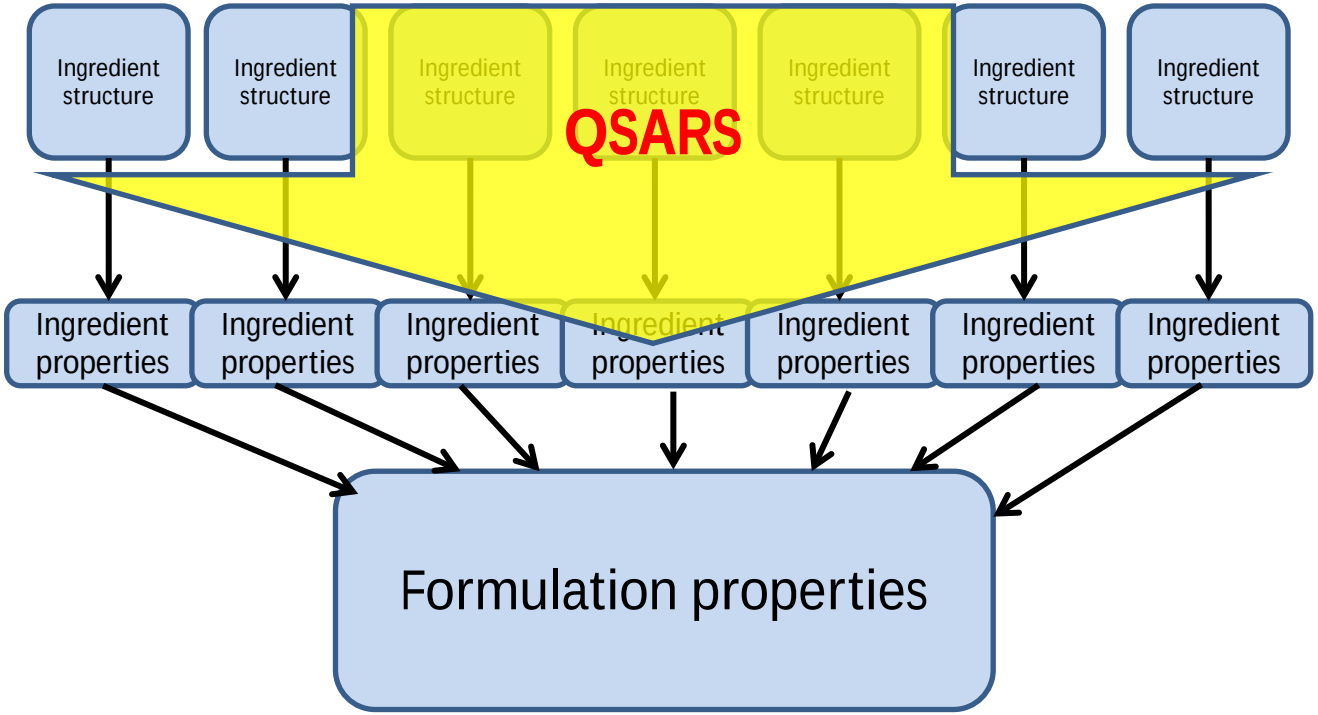
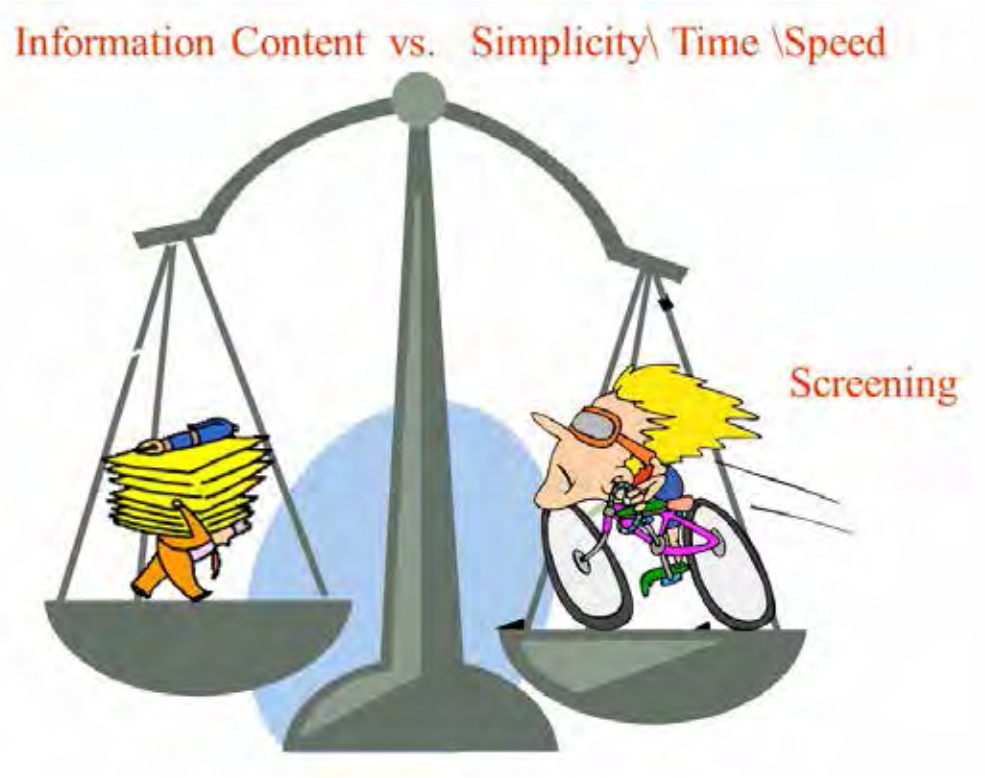


To screen or not to screen



Functional Requirements – Coatings

Appearance
Colour, texture, opacity

Stay Clean
Antibiofouling, antibacterial, appearance

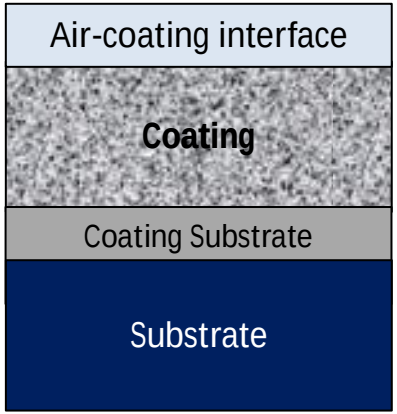
Thermal Management
Heat protection, efficient energy coupling

Structural / Mechanical
Anti scratch, non cracking etc.

Protective
Anti corrosion, packaging, chemical resistance

Electrical / Magnetic
EM, shielding, transmission

Extended Durability
Light Stability, weatherability



Uncured Coating Properties
Rheology
Wetting behaviour, surface tension
Shelf life, colloidal stability
Thermal stability
Appearance
Reactivity, cure behaviour

Surface Properties
Light reflection
Hardness
Scratch resistance
Friction/surface roughness
Repellent properties
Erosion resistance

Bulk Coating Properties
Opacity
Colour
Flexibility
Barrier
Chemical resistance
Environmental resistance

Coating Substrate Interface
Adhesion
Durability
Anti corrosion

Functional Requirements – Inks

Appearance
Colour, opacity

Hiding Power
Colour, opacity, particle size?

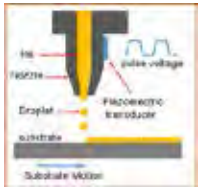
Compatibility with Print head
Evaporation, chemical compatibility

Dispensability
Flow properties, droplet formation

Surface Coverage
Flow properties, substrate wetting

Electrical / Magnetic
Conductivity, magnetism

Extended Durability
Light stability, environmental resistance



Air-Ink Interface

Bulk Ink Properties

Ink Substrate Interface

Substrate

Properties of Dispensed Ink
Surface tension (droplet formation)
Flow properties
Colour
Opacity
Chemical Compatibility

Surface Properties
Light reflection

Bulk Ink Properties (on substrate)
Opacity
Colour
Flexibility
Conductivity
Environmental resistance

Ink Substrate Interface
Adhesion and spreading
Durability

Functional Requirements – Composites

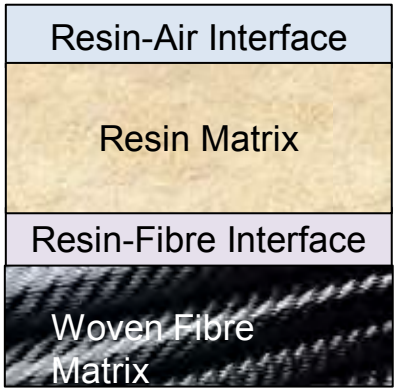
Structural / Mechanical Properties
Anti crack, scratch resistance, toughness, lightweight

Environmental Resistance
Extended durability, chemical resistance

Thermal Management
Thermal stability, heat dissipation

Electrical Properties
Conductivity

Adhesive Properties
Fibre-resin interaction



Resin – Air Interface
Hardness
Scratch resistance
Friction/surface roughness
Repellent properties
Environmental resistance
Chemical resistance
Light reflection

Resin Matrix
Tensile strength of resin and composite
Impact resistance
Cure, flexibility, morphology

Resin – Fibre Interface
Interfacial bonding
Durability
Fibre volume fraction

Woven Fibre Network
Tensile strength of individual fibres
Interconnectivity (weave, shape, orientation)

The Real Challenge for Formulation Product Development & Manufacturing

- Data Space is vast not tractable even with HTE
- Need Predictive Models that allow rapid selection of candidate systems
- Information about ingredients and their relevant chemistry/material properties is linked to formulation data
- Experiments are designed to reveal fundamental science and inform models
- Informatics is used to recognize clues hidden in the data that contain real learning
- Discovery properties are scalable into flexible manufacturing processes
- We make a conscious effort to move the state of the art forward in a way that adds real value to companies and the way they approach formulation

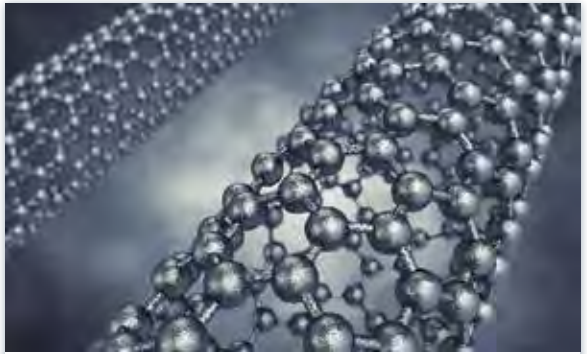
Integrating Existing and Developing Capabilities

CENTRE FOR INNOVATIVE FORMULATION

Power of serving NE innovators

NATIONAL FORMULATION CENTRE

Power of UK innovation ecosystem



GRAPHENE APPLICATIONS CENTRE

Power of nano-expertise to application

SHARED CAPABILITIES THAT SPAN GENERAL FORMULATION TO SPECIFICS IN NANO-MATERIALS

Current Capabilities

OVERARCHING CAPABILITY TO ENABLE OUTSTANDING R&D

i. Digital Infrastructure- Informatics and Modelling
ii. Experimental Design
iii. Data Analytics

COMPLEX SOLIDS HANDLING AND PREPARATION

i. SHEQ Enabled for powders and Nano-materials
ii. Milling
iii. Plasma functionalisation
iv. Mixing (high shear, low shear, turbine)
v. Atomic layer Deposition/ Chemical vapour deposition

COMPLEX LIQUIDS HANDING AND PREPARATION

i. Flow reactors
ii. OBR
iii. Microfluidics

FORMULATION PREPARATION

i. High Throughput Experimentation
ii. Draw downs (coatings)
iii. Plaques (composites)
iv. Injection Moulding

FORMULATION APPLICATION TESTING

i. Electrical
ii. Thermal
iii. Abrasion
iv. Lubricity

PROCESS SCALE-UP AND METROLOGY

i. Metrology
ii. Modelling

Real Physical Facilities in Place at NETPark

Temporary solution to enable accelerated company support

Capability Themes to Work Against

Revalidated by Industry Steering Group (ISG)

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Predictive Designs

Faster Innovation

Faster, more reliable approaches to get to ideal formulation design

Radical Effects

Bigger Innovation

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4IR Capable

Innovation Enabler

Critical foundational component for knowledge management and connectivity

Microstar: Microfluidic Platform for prediction of stability and rheology of complex fluids

INTEGRATED LIQUID STABILITY AND RHEOLOGY PREDICTION TOOLKIT

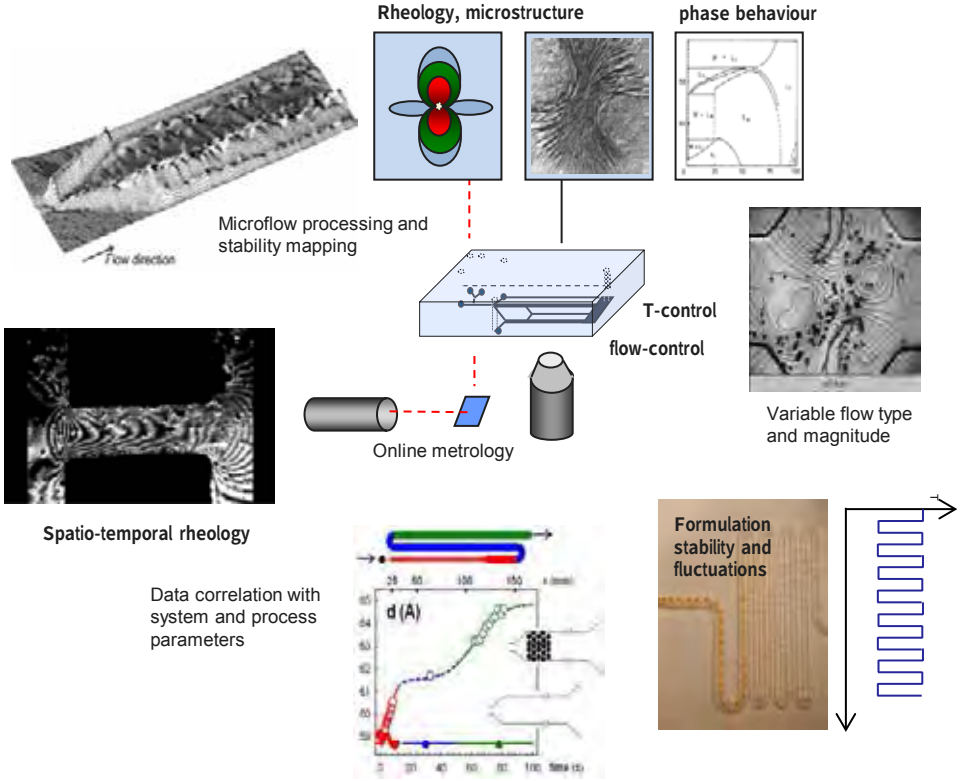
- Novel micro-flow methods for rapid screening of phase and metastability with relevant process variables
- Accelerated ageing tests; structural/dynamic metrology
- Cross-sector open-access test rig (Research Infrastructure)

PHASE BEHAVIOUR/STABILITY MAPS OF COMPLEX MODELS AND REAL-WORLD SYSTEMS

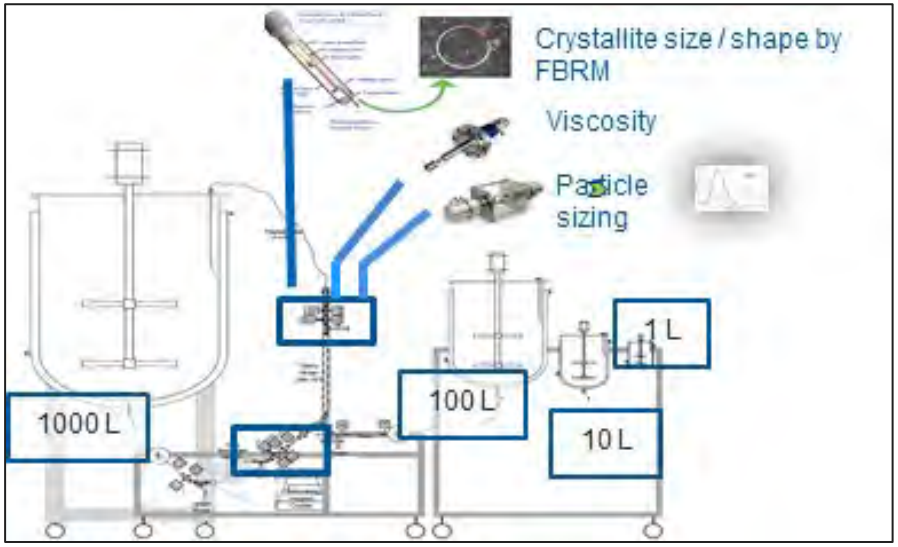
- Generic open-learning
- Company-specific private-learning

PARTNERS:

P&G, BP, Imperial, Durham



PROSPECT: Proving of Real-wOrld Scalable PrEdiCtive Tools / Technologies



LIQUID SCALE-UP LEARNING LOOP

Simple, flexible, multi-scaled rig to screen/trial sensor and control scheme technologies

ASSOCIATED MODEL LIQUID FORMULATION

Enables closer to real-world studies - complex material structures and properties.

PLATFORM TO IDENTIFY PROXY MEASURES

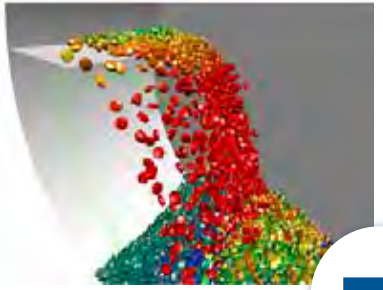
To enable cost efficient and operator friendly process sensing upgrade – cheap, 24/7, widely adopted, info-rich sensing.

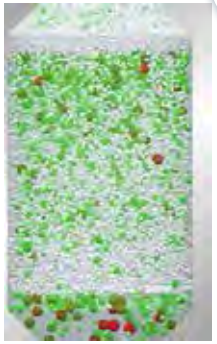
PARTNERS:

Birmingham, Leeds, Edinburgh

Implementation of Particle Models for Industry

Currently major capability gap to transfer models from Academia to Industry.





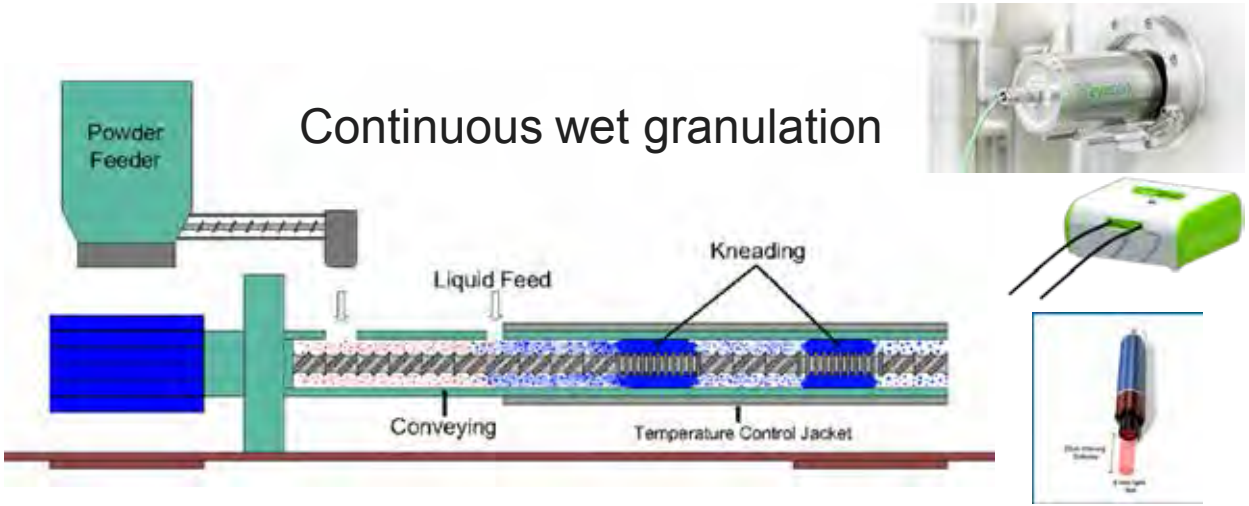
METHODOLOGY AND FRAMEWORK FOR TRANSLATING MODELS TO INDUSTRY

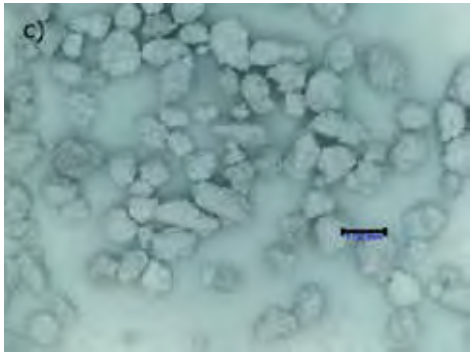
- Wet granulation case study which will fit as a tool within CPI- Chariot granules facility

METHODOLOGY /BEST PRACTICE GUIDE AND SUPPORT NETWORK CAN BE APPLIED TO OTHER MANUFACTURING PROCESSES

- Driving step-change modelling adoption
- Complement commercial vendors
- Creating UK hub for model commercialisation and in-slico development

Supporting Pharmaceutical Product Development



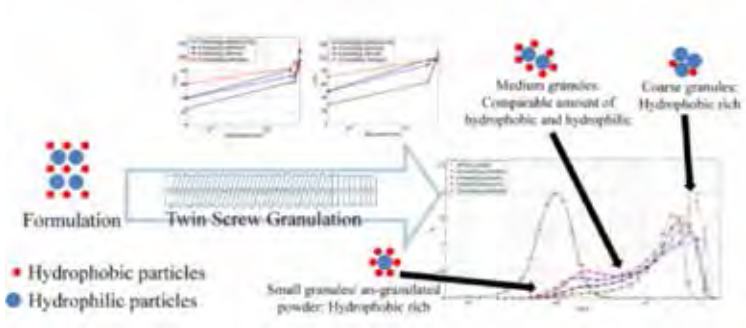


Creating and validating a national open-access contract development facility to support the development and registration of new products and processes

- **PAT enabled process understanding to support 'development for launch'**
- **Marrying data from multiple sensors to finished product attributes**
- **Facilitating the industrial implementation of innovative process analytics**
- **Data to inform commercial control strategies – real products, real-life situations**

Innovation Knowledge Flow

Mechanistic insight, modelling, analytical and process innovation



Yu et al; Int. J. Pharm. Sci. 475(1-2) (2014) 82-96

Commercial process understanding

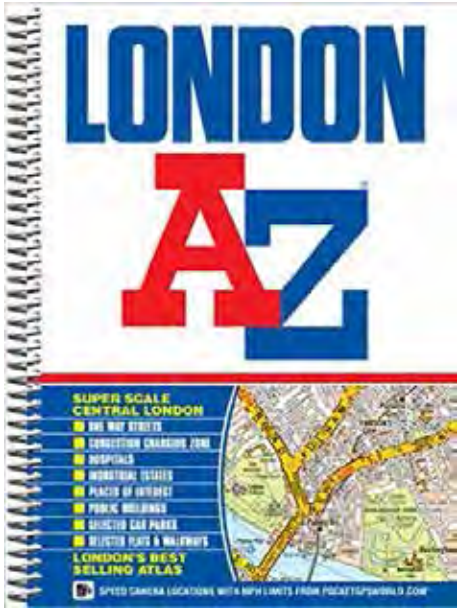
Commercial control strategy

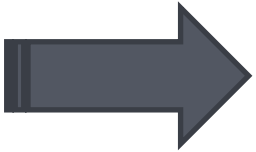
Academia
Discovery & Understanding

CPI Test Bed
Commercial Process Development

Pharma & CMO
Commercial Manufacture

Dynamic Information Availability and Interaction has changed the way we Live





Static Look up

Real time update

Strategic Drivers

Digital Manufacturing
Automation & Smart Factories

Energy
Intelligent Use of Energy & Smart Grid

Healthcare
Tele-medicine & Smart Devices

Digital & Cloud Services
Digitised Services & Business Models

Digital Economy and Society

Supply Chain Integration
Logistics & Supply Chain Management

Smart Cities & Infrastructure
Telecoms. Building & Spaces

Living Spaces
Smart Consumer Products and Homes

Smart Integrated Transport

Embedded electronics seamlessly connects products, equipment and structures to digital and big data services and user interfaces

It's a critical capability to the future of manufacturing and new product innovation.

Critical to UK Manufacturing.

Innovation Enabler
Critical foundational component for knowledge management and problem solving

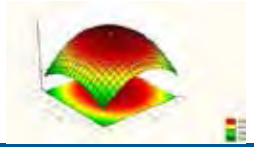
Industry 4IR Capable

IOT

Connected → Interactive → Responsive

Industry 4IR

Formulation Design → Formulation Optimisation → Formulation Manufacturability



Predictive Designs	Radical Effects	Manufacturability
Faster Innovation	**Bigger Innovation**	**Process Innovation**
Faster, more reliable approaches to get to ideal formulation design	Unexpected synergistic effects to deliver bigger/disruptive benefits	Optimised, reliable system to guarantee ideal formulated product delivery

Real Time Data Capture & Interrogation

Connected & Secure Data

Formulation Lighthouse Vision 2030

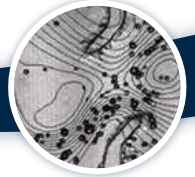
Productivity and **Simplification** in Innovation by Predictive Design

Ultimately created **autonomously**, from self-learning, IoT connected systems

CURRENT ART OF FORMULATED PRODUCTS

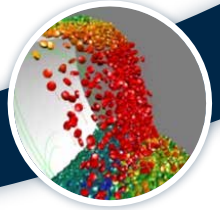
MORE ROBUST UNDERSTANDING OF COMPLEX SYSTEMS TO ENABLE MODEL DEVELOPMENT

- SOLIDS
- LIQUIDS



PREDICTIVE DESIGN FROM MODELS OF EVOLVING SYSTEMS

- INNOVATION EFFICIENCY
- PRODUCTIVITY
- R&D SIMPLIFICATION



DEVELOP TRULY DELIGHTFUL PRODUCTS IN FUNCTION AND DESIGN

(STEM TO STEAM)

AUTONOMOUS LEARNING WITH SYSTEMS IOT ENABLED TO FORMULATE AGAINST REAL NEED/CONDITIONS

Dynamic Adaptive Product Design :
Formula design to real world performance: Automotive Lubricants

IOT

Product Model

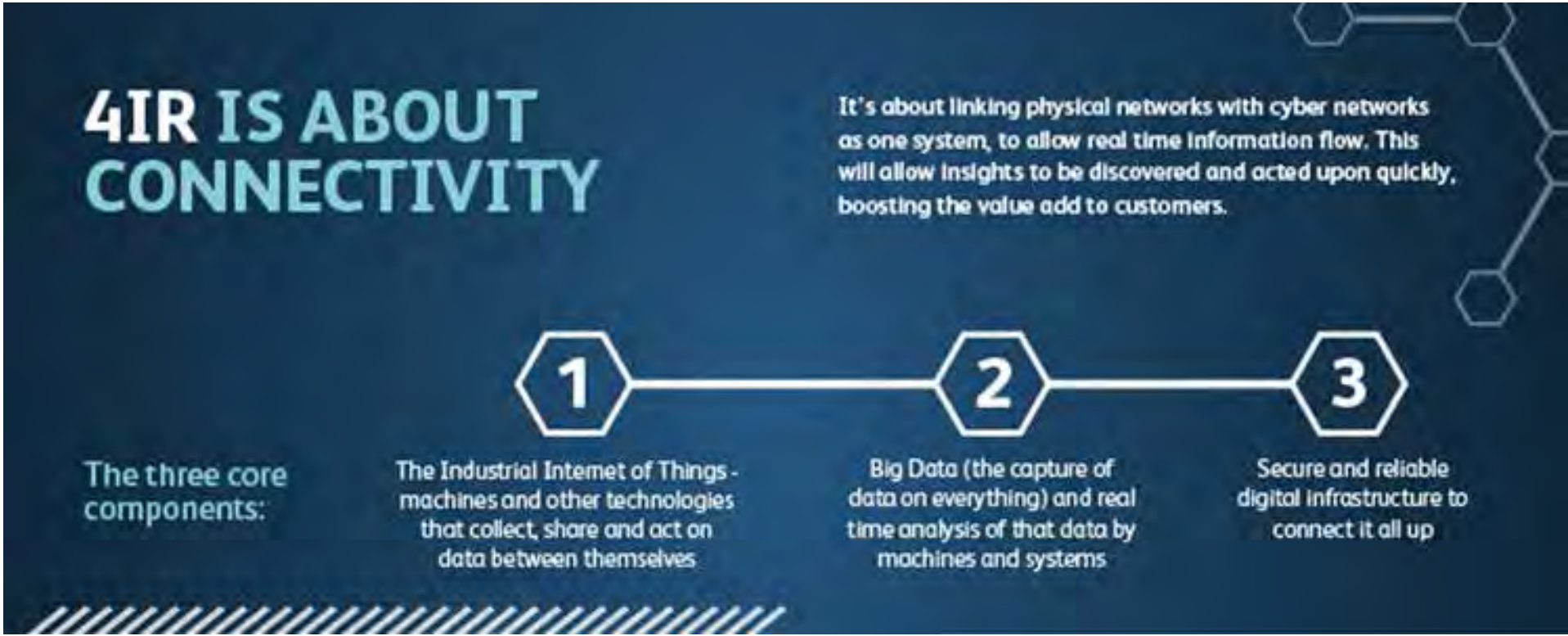
Ideal Product development for the real conditions - Enable Superiority Claims grow business

Real time Monitoring - learning real conditions

New car- first fill

Digital Evolution or Revolution?

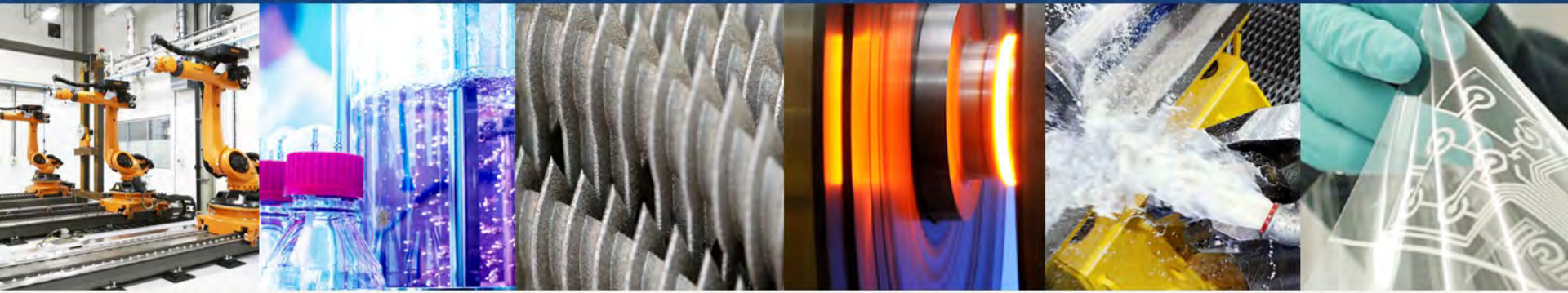
Connecting Digital Product Design To Digital Manufacturing



CATAPULT
High Value Manufacturing

Digital Engineering and Manufacturing Leadership Group

1 December 2016



AFRC ADVANCED FORMING RESEARCH CENTRE UNIVERSITY OF STRATHCLYDE
Advanced Manufacturing Research Centre
cpi
mtc Manufacturing Technology Centre
NATIONAL COMPOSITES CENTRE
NUCLEAR AMRC
WMG THE UNIVERSITY OF WARWICK

The project

7 centres:

4 partners

Supported by:

The Industry Leadership and Collaborators:

The Working Groups

Business models

Implementation

Research

Skills, Work and Society

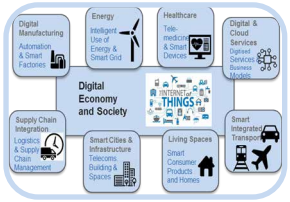
Cyber-Security and Legal Aspects

Standards and Regulation

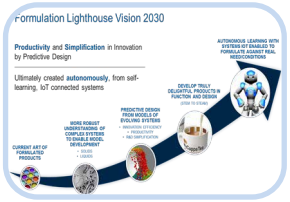
Formulation - What next?

By 2020, 7.7 billion people will be online, 6.1 billion will have smartphones, 200 billion things will be connected to the Internet, and everyone on earth will have one thing in common.

Drivers



Increasingly Digitally enabled world



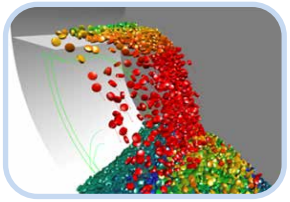
Reatime Feedback on Product Performance

Increased Personalisation

Sustainability/regulatory

Requirements

Computer Designed molecules & materials



Need for Predictive Models to rapidly get to best formulated candidate systems

Integration of Characterisation and HTE formulation for verification of candidate formulation performance

Digitally enabled flexible manufacturing

Thank you...

For more information visit www.uk-cpi.com

Email: info@uk-cpi.com
Twitter: @ukCPI

www.uk-cpi.com

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