

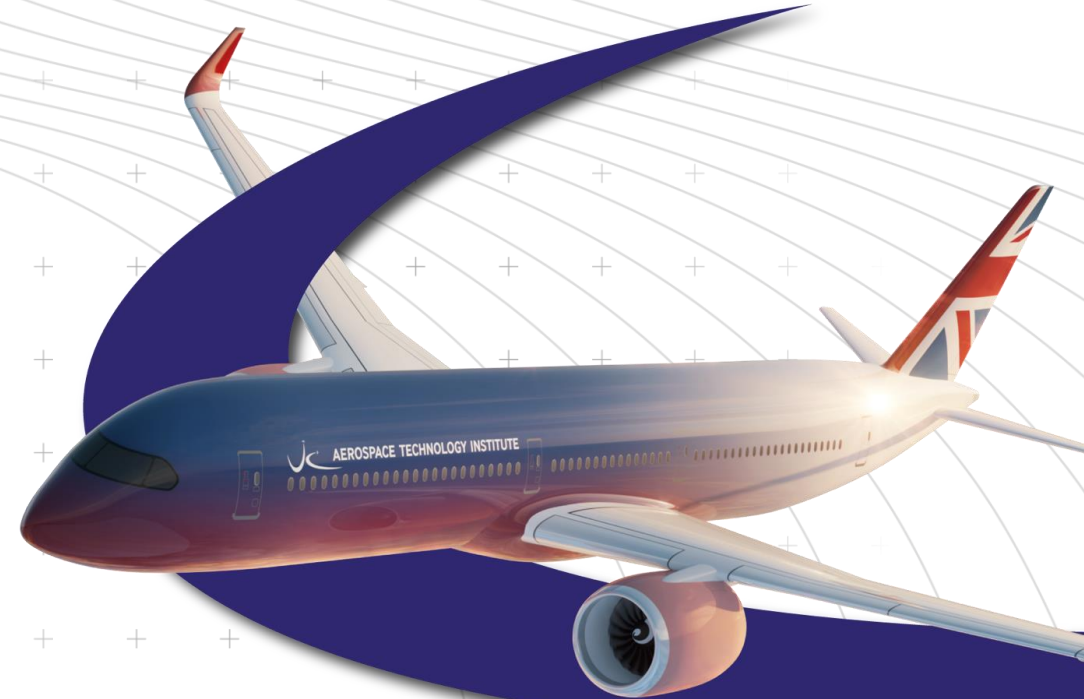
# Hydrogen Capability Network

## Liquid Hydrogen Materials Test Methods Proposal

---

Huw Edwards / Stefanos Giannis

November 2023



- HCN's vision, objectives and work to date
- Materials testing & standards requirements capture
- Key priorities – highlighting proposed intervention focus
- Proposed programme scope, timeline and outputs
- Proposed programme operational model
- Input needed from you

# Reminder of HCN Vision & Objectives

**Vision:** Securing competitive advantage for UK aerospace through a world leading collaborative network. Delivering a coherent approach to skills development, infrastructure and hydrogen supply to secure long-term UK capability

## Why?

The strategic need & case for the UK

HCN acts on key recommendations from FlyZero to become an essential enabler of UK technology development. With other nations acting quickly and other sectors competing for hydrogen, the UK must act to consolidate the aerospace sector's approach to hydrogen and ensure that testing and development remains in the UK

## What?

Our core activities



Coordinating a secure LH2 supply for the UK aerospace sector's test & development needs



Coordinating the approach to skills & research to increase LH2 talent in the UK



Coordinating the approach to test infrastructure & demonstration through an open access network and greater collaboration

## How?

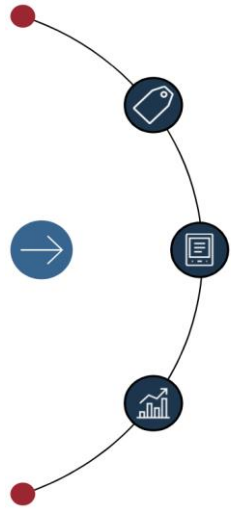
Our approach

**Collaborative** – A network of stakeholders with a common aims, aligning aerospace with cross-sector initiatives

**Agile business model** – Allowing for growth and reacting to market opportunities

**Common vision** – Securing UK capability, and driving the aerospace industry to its shared net-zero aims

# Phase 0 - Evaluation of the sector



We have engaged the sector through multiple touchpoints:

**Pre-Market Engagement** – multiple workshops convened with industry and academia to collate and identify the sector’s requirements

**Surveys** - surveys issued to understand the detailed testing, supply and skills needs and identify gaps in current landscape

**Industry Secondees** – Secondees in the HCN team have been able to provide valuable subject matter expertise

**Coordination with other groups** – The HCN has engaged with other adjacent organisations such as HII, AGP, ZEFI , ARC and others to ensure actions and delivery are aligned

- 200+ organisations engaged via a HCN Survey
- 80+ face to face discussions & site visits
- 50+ testing workshop attendees
- 40+ skills workshop attendees
- 50+ research workshop attendees
- Publication of current landscape, expertise and facilities

- Identification of the sector’s requirements
- Capturing source, criticality and benefits

**Capture Requirements**



**Solution Options**



**Proposing Interventions**



**Refinement & Business Case**

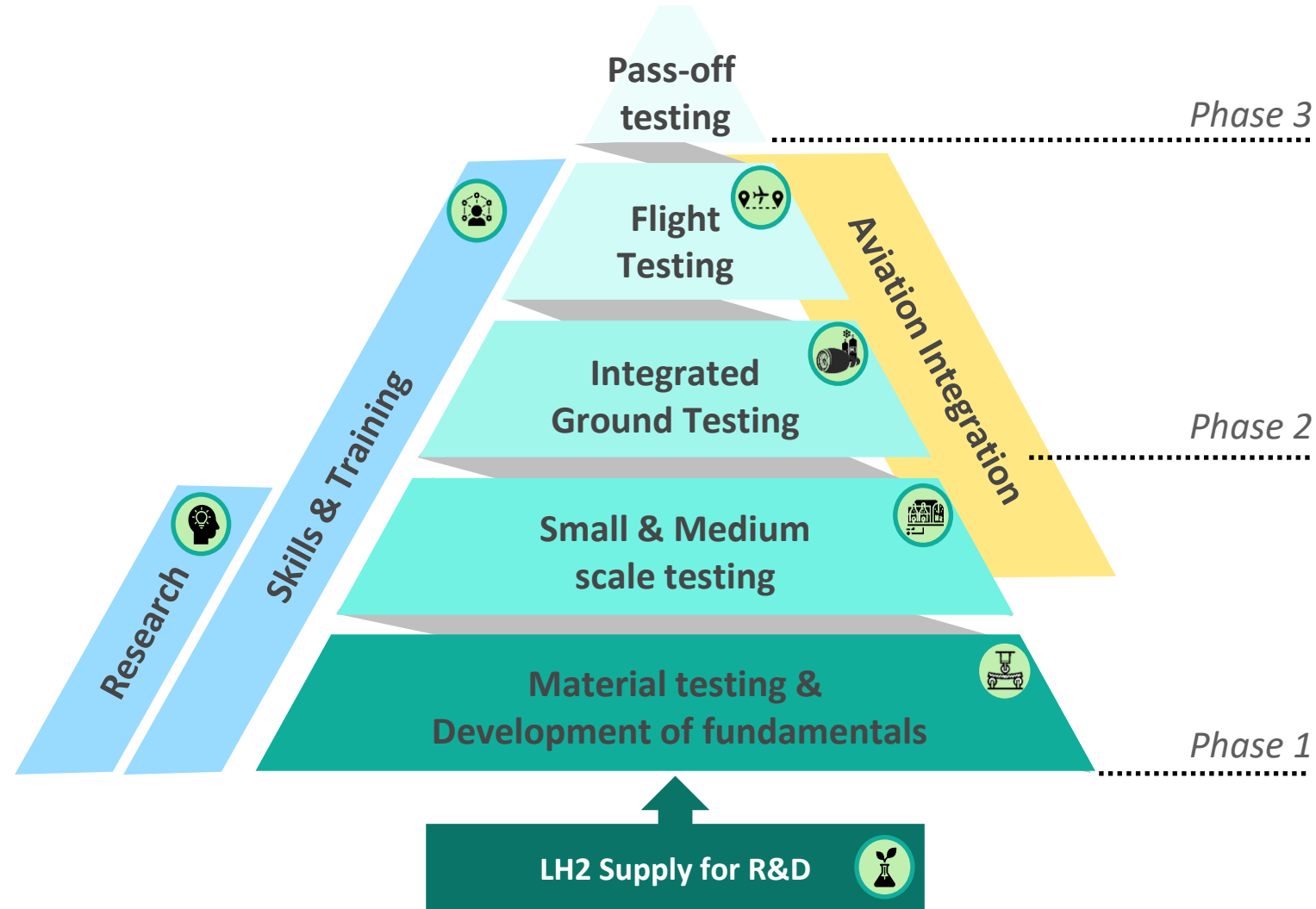
- Identification of proposed solutions
- Establishing potential partners, costs and commercial considerations

- Consolidating solutions into possible interventions
- Defining levels of ambition, cost, benefits and risk

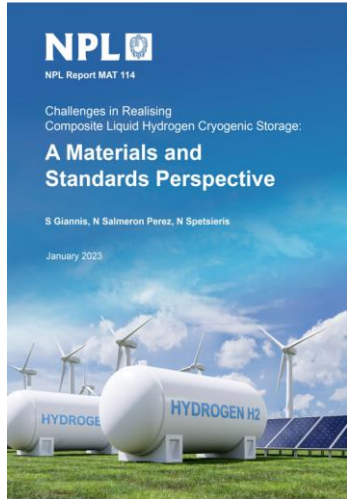
Today

- Refining proposed interventions
- Development of business case

# Potential HCN focus areas across test pyramid



# Materials Level Test Requirements Capture



High level **cross-sector materials test standards needs** captured independently by NPL via a virtual workshop attended by 13 organisations and published in an NPL open report (Jan 2023)



A HCN run LH2 testing workshop was used to engage across the wider aerospace sector, attracting 32 organisations (June 2023) **Material test standards were highlighted as a critical area**



A more focused group of aerospace organisations convened by ATI and NPL highlighted the **opportunity for a collaborative non-competitive package of work in cryogenic materials testing**

The group also provided detailed prioritised test requirements to the team

# High Priority Material Properties

| Property Type   | Material  |            |
|---|-----------|------------|
|   | Metallics | Composites |
| <b>Mechanical</b>   |           |            |
| Tension (un-notched and notched)                            | ✓         | ✓          |
| Low & High cycle fatigue                                    | ✓         | ✓          |
| Slow strain rate tensile                                    | ✓         |            |
| Fracture toughness  | ✓         | ✓          |
| Thermal Cycling (fatigue) & Thermal shock                   | ✓         | ✓          |
| Impact (Charpy)   | ✓         |            |
| Interlaminar shear  |           | ✓          |
| <b>Thermal</b>  |           |            |
| Thermal Expansion   | ✓         | ✓          |
| Thermal Conductivity / Heat Capacity / Diffusivity          | ✓         | ✓          |
| <b>Physical</b>   |           |            |
| H2 Mass Transport Properties incl. diffusion and permeation | ✓         | ✓          |
| He Mass Transport Properties incl. diffusion and permeation | ✓         | ✓          |

Non-competitive materials for test method development: **(1) Stainless steels** e.g., 316L **(2) Nickel alloys** e.g., IN625, Hastelloy X, IN718 **(3) Al alloys** e.g., 2xxx, 5xxx, 6xxx series **(4) Composites** e.g., Carbon/epoxy, Glass/epoxy

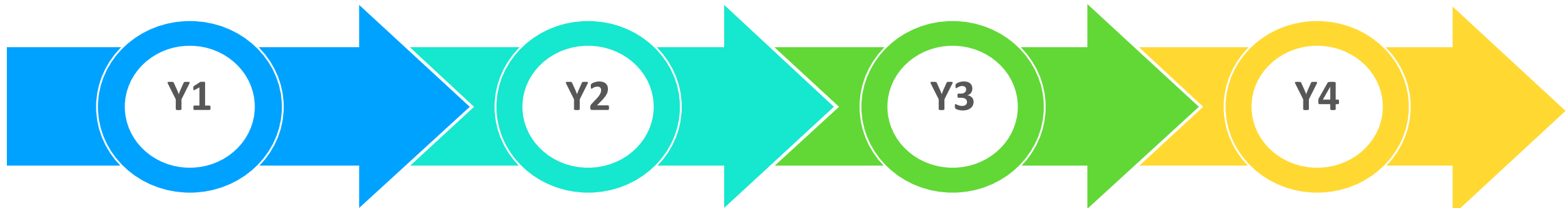
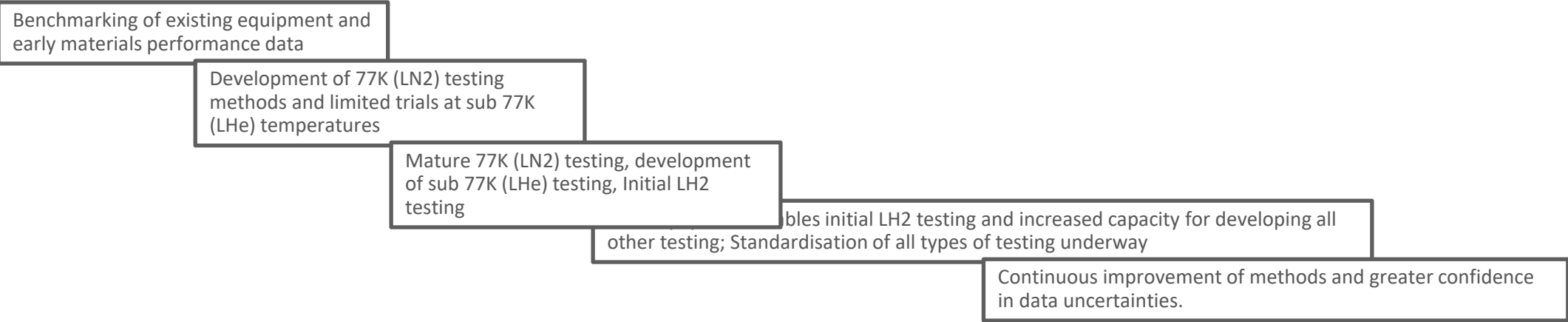
# Proposed Work Packages

| Work Packages   | Description   |
|---|---|
| <p><b>Mechanical - Tensile</b><br/>Quasi-Static<br/>Slow strain rate<br/>Low Cycle Fatigue<br/>High Cycle Fatigue</p>   | <ul style="list-style-type: none"> <li>• Properties - Early testing focuses on tensile moving to fracture and other properties based on initial learnings</li> <li>• Temperatures / Environment - Early testing focuses on LN2 moving to LHe and LH2 after initial trials and as more infrastructure is delivered and commissioned</li> </ul> |
| <p><b>Mechanical - Fracture</b><br/>Fracture Toughness</p>  |   |
| <p><b>Mechanical - Other</b><br/>Impact<br/>Interlaminar shear<br/>Thermal cycling</p>                                  |   |
| <p><b>Mechanical - Testing in LH2</b><br/>As above but in LH2 environment</p>   |   |
| <p><b>Physical</b><br/>Permeation, Diffusion</p>  | <ul style="list-style-type: none"> <li>• Early testing works with existing distributed infrastructure (RT, 77 K, 20 K)</li> <li>• Later testing can be carried out on new infrastructure enabling comparison across systems at 20 K</li> </ul>  |
| <p><b>Thermal</b><br/>Thermal Conductivity<br/>Thermal Diffusivity<br/>Specific Heat Capacity<br/>Thermal Expansion</p> | <ul style="list-style-type: none"> <li>• Early testing works with existing infrastructure recognising that some capability is only available at single source not allowing cross validation</li> <li>• Later testing can be carried out on new infrastructure enabling cross validation across systems at 20 K</li> </ul>                     |

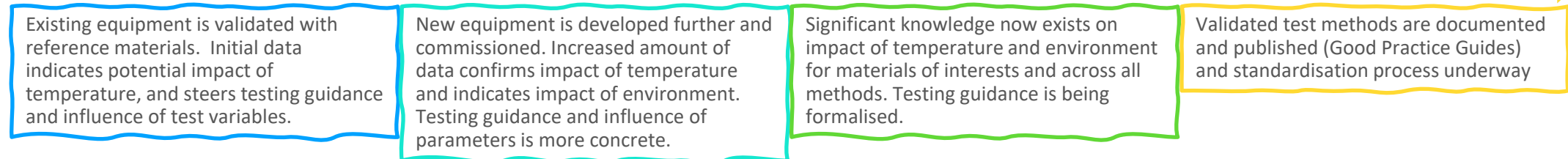


# High Level Activities & Outputs Timeline

Activities



Outputs



# Details of Programme Timeline

## Mechanical Tests

Develop methods (geometry, machining, strain measurement, cooling method & rate, gripping, rate)

Compare LN2 testing with immersion, flow

Specify new equipment to enable LH2 testing

## Thermal & Physical

Thermal – Initial equipment benchmarking with reference materials; ordering PPMS and thermal modules

Permeation – Trials at 77K with existing equipment; ordering of new cryostats

## Mechanical Tests

Initial sub 77 K testing with LHe in existing infrastructure

Delivery of new equipment to enable scale up of LHe Testing

Solid LN2 methods, early LHe methods

Delivery and commissioning of LH2 equipment

## Thermal & Physical

Thermal – New equipment online; benchmarking and data for materials of interest at 20K

Permeation – sub 77K testing with new cryostats

## Mechanical Tests

Compare LHe testing with flow, dry

LHe method development

LH2 method development

## Thermal & Physical

Cross-validation with external organisations and Good Practice Guide documentation

## Mechanical Tests

LHe method validation and Good Practice Guide documentation

LH2 method validation and documentation

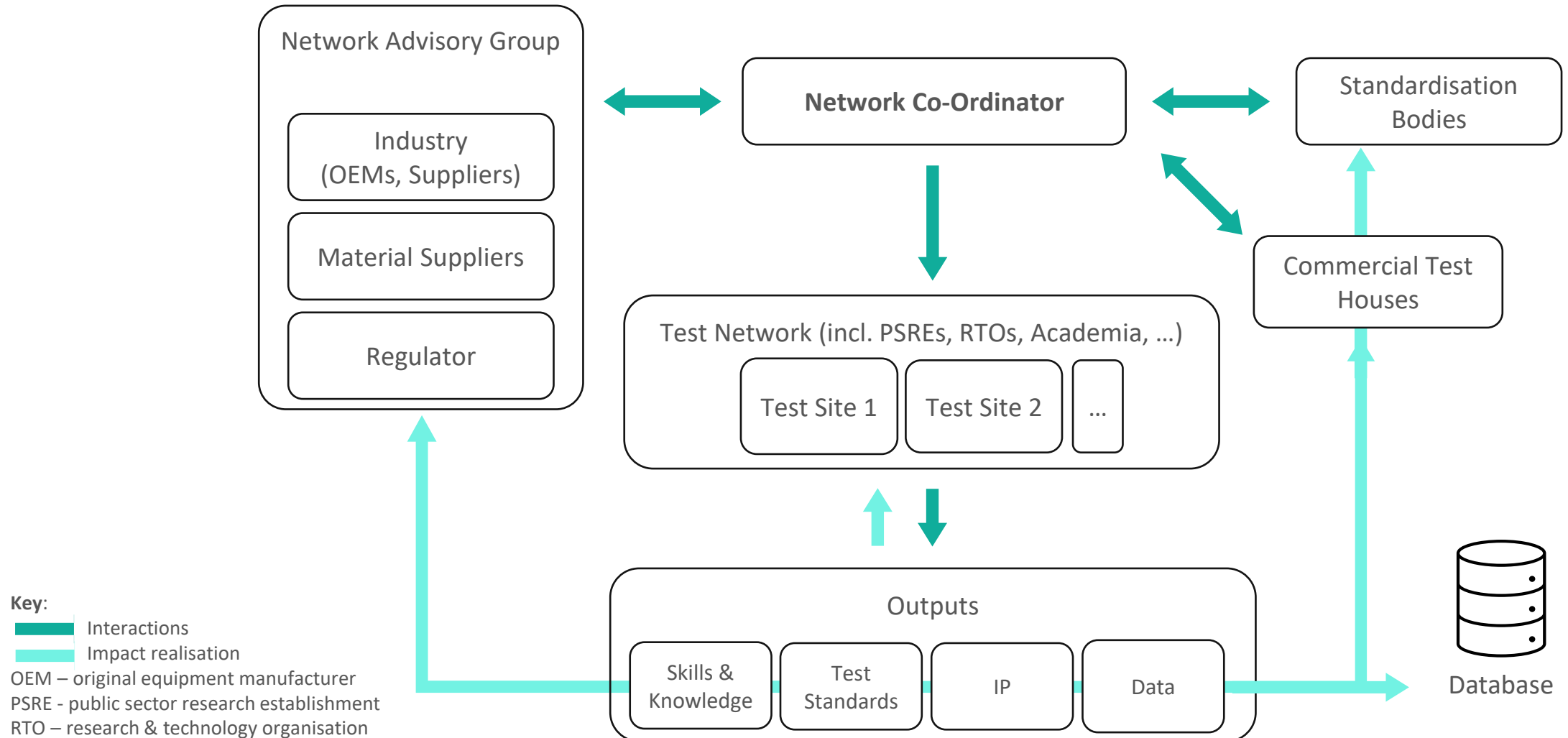
Y1

Y2

Y3

Y4

# Proposed Programme Operational Model



## Key Roles

- **Network Advisory Group:** Provide technical requirements, steer the work programme, supply materials of interest, provide regulatory and certification steer.
- **Standardisation Bodies Group:** Observe and ensure alignment of outputs to standardisation process.
- **Commercial Test Houses Group:** Observe and ensure that outputs can be scaled up and commercialised.
- **Network Co-Ordinator:** Provide programme and technical leadership i.e., define and be responsible for the delivery of the work programme aligned to UK sector needs and provide access to UK capability.
- **Programme Delivery Partners:** Deliver the programme of work and develop enduring UK capability.

## Key outputs

- New Test Standards
- IP
- Materials Data
- Skills and Knowledge

*Note: Initial materials database generated because of this programme will be available to the UK supply chain. In the longer term the upkeep and continued population may move to specialist materials test house, private public partnership or another agnostic organisation.*

# What we need from you...

---

We would appreciate 10 minutes of your time to complete the survey below and provide us with valuable feedback.

<https://forms.office.com/e/rqVKYp3csS>



If your organisation could provide input to more than one role, please complete the survey once for each role.

