



CAP Panel  
Discussion

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# Connected and Autonomous Plant (CAP) – PDWG 34 Update

Amer Essa  
Supply Chain Innovation, Senior Advisor  
Thursday 25<sup>th</sup> January 2024

NH CAP dedicated webpage:  
<https://nationalhighways.co.uk/our-work/innovation-and-research/connected-and-autonomous-plant-to-2035/>

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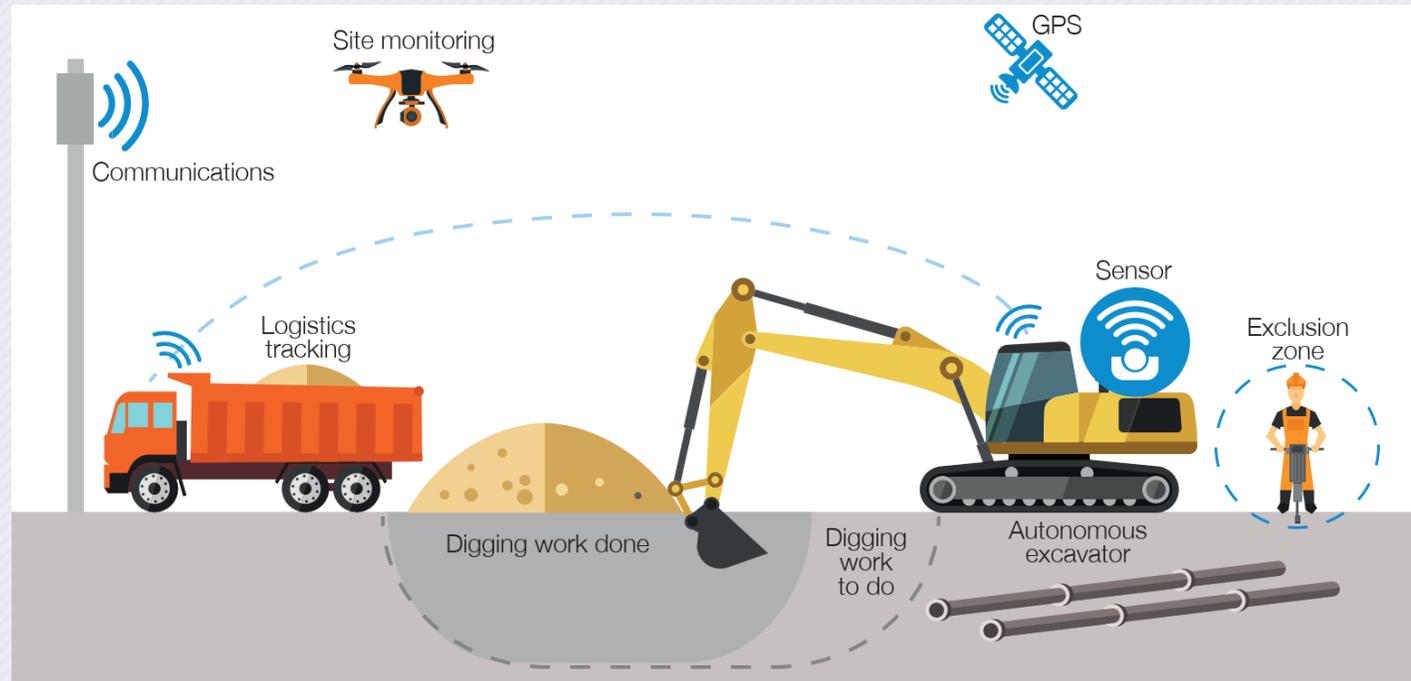
*DfT Activities*

*CAP – What success looks like & looking to the future*

# 2021: Phase 1 CAP Roadmap to 2035

## Connected and Autonomous Site (CAP) – Connected Site

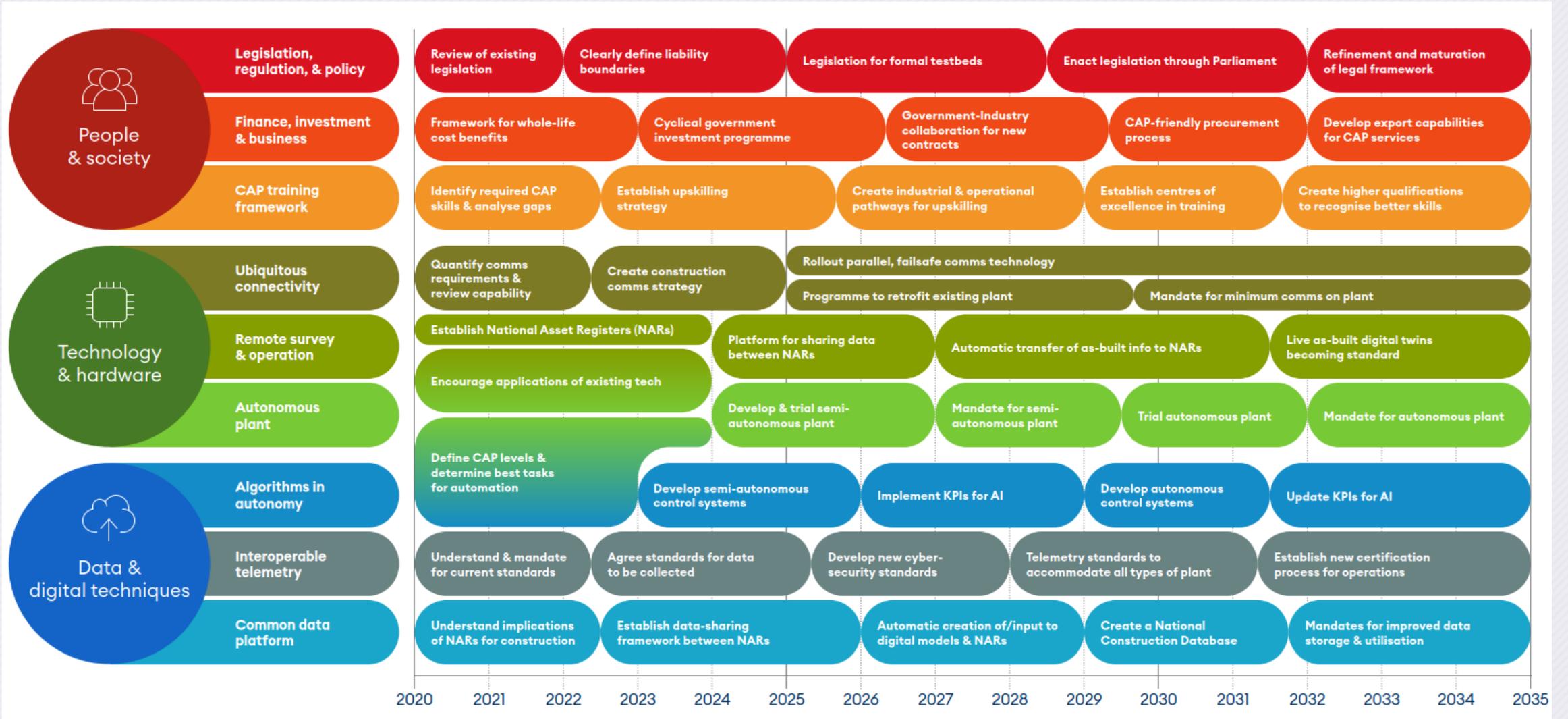
*“By 2040, National Highways aspires to realise a step change in efficiency, with roads projects and maintenance delivered **30% - 50%** cheaper than today.”*



*“If the benefits to manufacturing are mirrored in construction, productivity improvements achieved via CAP could exceed £200Bn by 2040.”*

*Published to industry June 2020 via Webinar*

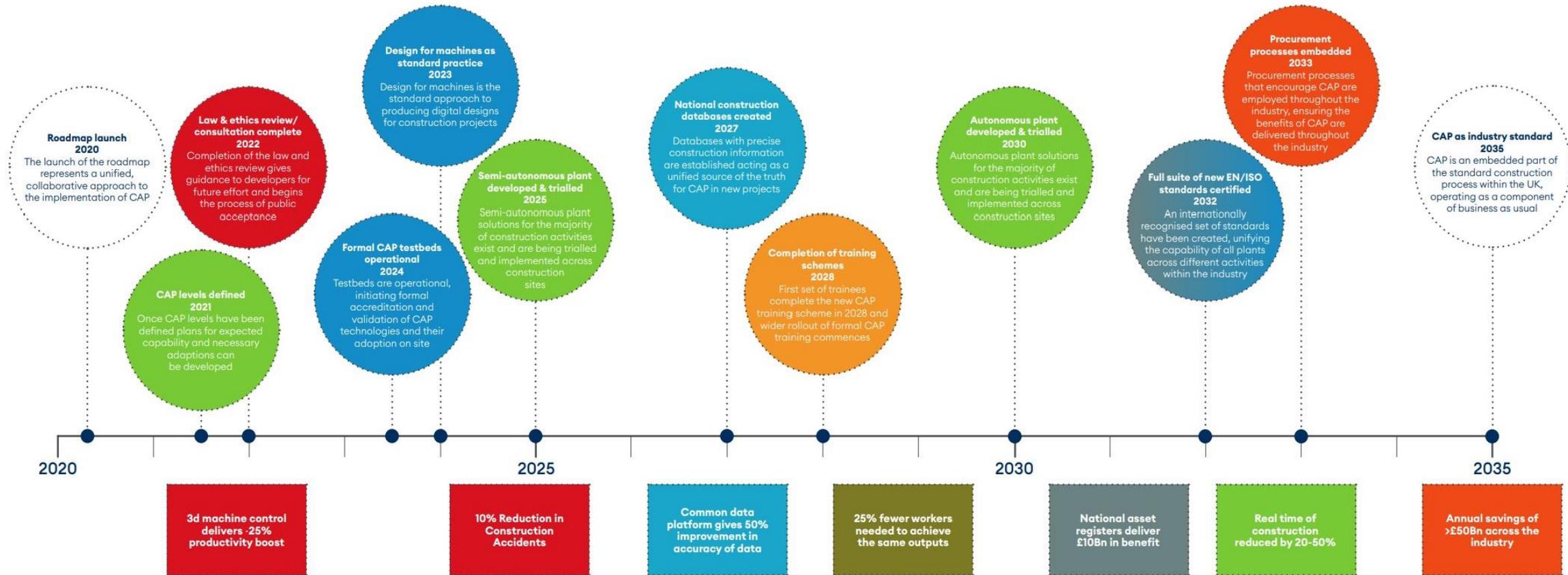
# CAP Phase 1 – Roadmap



Published to industry June 2020 via Webinar

# CAP Phase 1 – Key milestones

Each milestone marks a turning point in the Roadmap, or the establishment of a key enabler that unlocks the next stage



Published to industry June 2020 via Webinar

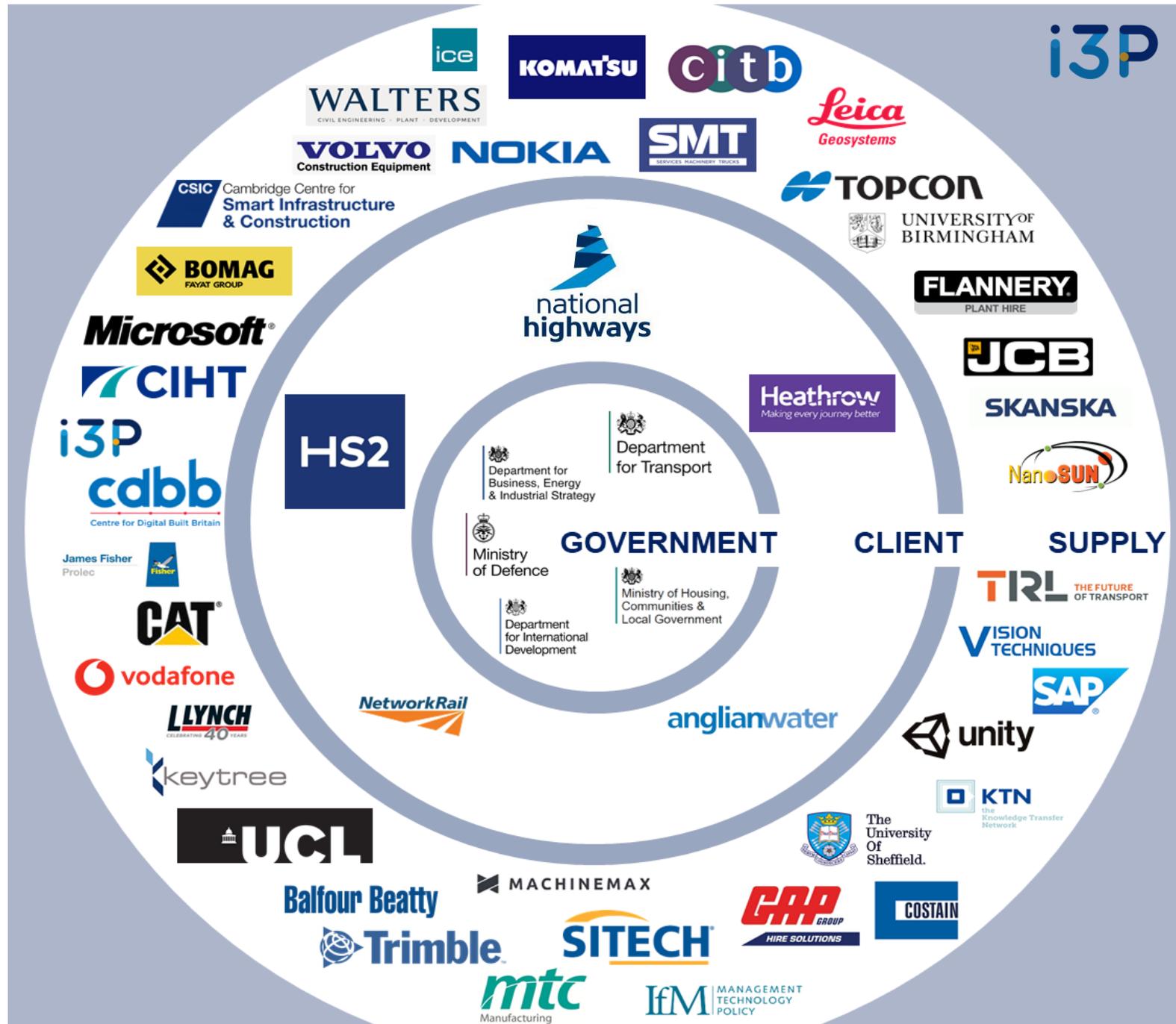
Disseminated via webinar to capture wider audience & legacy piece.

i3P served as the conduit to deliver the message to relevant stakeholders.

Why we did it

- \* Leadership
- \* Bring Industry together
- \* Set direction of travel

Huge opportunities to improve safety, productivity and carbon agenda



# 2022: Phase 2 CAP Levels



**Legislation, regulation, & policy**

**Finance, investment & business**

**CAP training framework**

Review of existing legislation

Clearly define liability boundaries

Legislation for formal testbeds

Enact legislation through Parliament

Refinement and maturation of legal framework

Framework for whole-life cost benefits

Cyclical government investment programme

Government-Industry collaboration for new contracts

CAP-friendly procurement process

Develop export capabilities for CAP services

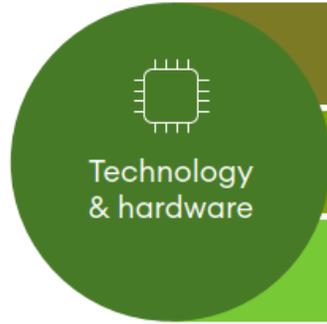
Identify required CAP skills & analyse gaps

Establish upskilling strategy

Create industrial & operational pathways for upskilling

Establish centres of excellence in training

Create higher qualifications to recognise better skills



**Ubiquitous connectivity**

**Remote survey & operation**

**Autonomous plant**

Quantify comms requirements & review capability

Create construction comms strategy

Rollout parallel, failsafe comms technology

Programme to retrofit existing plant

Mandate for minimum comms on plant

Establish National Asset Registers (NARs)

Platform for sharing data between NARs

Automatic transfer of as-built info to NARs

Live as-built digital twins becoming standard

Encourage applications of existing tech

Develop & trial semi-autonomous plant

Mandate for semi-autonomous plant

Trial autonomous plant

Mandate for autonomous plant



**Algorithms in autonomy**

**Interoperable telemetry**

**Common data platform**

Define CAP levels & determine best tasks for automation

Develop semi-autonomous control systems

Implement KPIs for AI

Develop autonomous control systems

Update KPIs for AI

Understand & mandate for current standards

Agree standards for data to be collected

Develop new cyber-security standards

Telemetry standards to accommodate all types of plant

Establish new certification process for operations

Understand implications of NARs for construction

Establish data-sharing framework between NARs

Automatic creation of/input to digital models & NARs

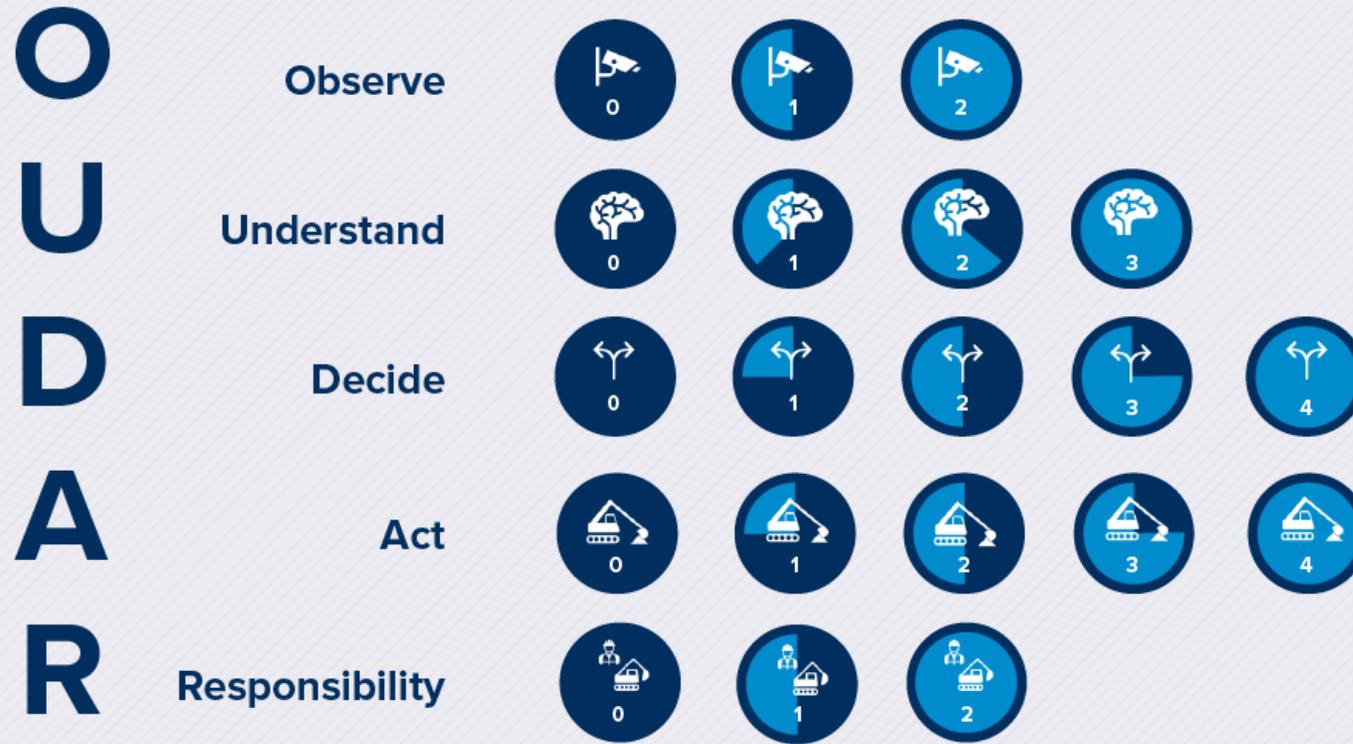
Create a National Construction Database

Mandates for improved data storage & utilisation

2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035

# CAP Levels

The levels enable a standardised measure to describe machine capability. They can be used across the industry and through supply chain to track and specify autonomous machines. There are 5 factors that are scored, based on the same process that humans use to carry out tasks - these are described below.



**Note: this is the 1<sup>st</sup> iteration of the CAP Levels. Further work is required to establish their application, including certification scheme.**

# CAP Levels – examples

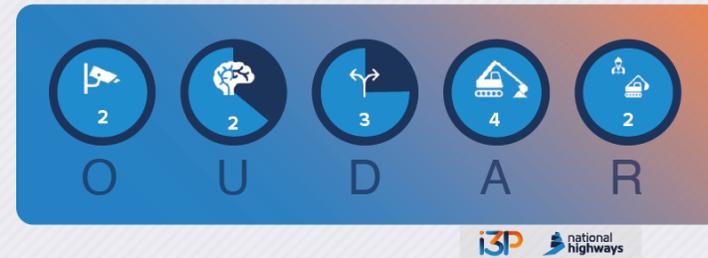
## Autonomous Compaction Plant



CAT Command for Compaction



BOMAG ROBOMAG



# CAP Levels – International Reach

Construction In the 21<sup>st</sup> Century Conference (CITC) - May 2022, Jordan  
(General focus)



The Twelfth International Conference on Construction in the 21<sup>st</sup> Century (CITC-12)

Amman, Jordan | May 16 – 19, 2022

## The Future of Automated Plant in Construction – A UK Perspective

Cormac Browne<sup>1\*</sup>, Ross Walker<sup>2†</sup>, Ianto Guy<sup>1</sup>, Tim Embley<sup>3</sup>, Muneer Akhtar<sup>4</sup>, Amer Essa<sup>4</sup>, Annette Pass<sup>4</sup>, Simon Smith<sup>2</sup>, Alex Wright<sup>1</sup>

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### Abstract

Within the construction industry, heavy mobile machinery is typically known as plant. Plant has seen a transformation from its earliest, animal powered form, through steam and combustion engine driven machines through to the modern multifunctional devices applied in construction across the globe. However, construction is facing a number of significant social, environmental, and technical challenges. In response there has been a rising interest in the use of digital and automated technologies which can be applied to the construction sector. One particular aspect of this is the use of Connected and Autonomous Plant (CAP) to replace traditional, human operated machinery. Incorporating CAP as part of the wider digitalisation of the construction industry promises to deliver gains in productivity, safety, welfare, sustainability, quality, and cost. However, the achievement of these benefits will require a step change in the approach to the design and construction of plant, and in the way that plant operates on construction sites.

This paper presents a potential future for the deployment of plant on construction sites. It discusses how sites could evolve to accommodate the new role of CAP and how people and CAP will need to work together. It discusses how National Highways have been seeking to drive transformation in construction through the development of a vision and roadmap for CAP, which encourages all stakeholders to collaborate and aims to catalyse the development and adoption of these technologies.

### Keywords

Connected Autonomous Plant, Construction, Automation, Autonomy, Digitalisation.

International Symposium on Automation and Robotics in Construction (ISARC)  
Conference in July 2022; Colombia  
(Technical focus)

39<sup>th</sup> International Symposium on Automation and Robotics in Construction (ISARC 2022)

## A Taxonomy for Connected Autonomous Plant

Cormac Browne<sup>1</sup>, Ross Walker<sup>2</sup>, Tim Embley<sup>3</sup>, Muneer Akhtar<sup>4</sup>, Amer Essa<sup>4</sup>, Annette Pass<sup>4</sup>, Simon Smith<sup>2</sup>, Alex Wright<sup>1</sup>

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### Abstract -

National Highways commissioned the development of a Roadmap for Connected and Autonomous Plant (CAP), which proposed a programme of activities which would aim to deliver the widespread deployment of CAP. A particular milestone activity identified as an early target within the Roadmap was the development of a taxonomy for understanding the capability of construction plant for operating without human involvement. This would provide a unified language to understand how plant can be used to achieve tasks with reduced or no human intervention. This paper presents an overview of the process used in developing a taxonomy to achieve this purpose, including the principles underlying the taxonomy, and the taxonomy itself. This builds on previous automation taxonomy work and applies it to the construction context and is further applied to two examples of autonomous compaction plant. It is concluded that the levels establish a unified language for the capability evaluation of automation of plant. This will support and catalyse the development of technology roadmaps amongst plant and technology manufacturers, enable procurement processes that incentivise the deployment of CAP within construction management, and support innovation practices by providing an understanding of the safety and operational implications of deploying automation on construction sites. It is also identified that the application of this taxonomy is not limited to the Construction environment.

### Keywords -

Connected Autonomous Plant (CAP); Taxonomy; Automation; Autonomy; Plant.

est to the industry, with new technologies being applied to a wide range of activities, such as geofencing of plant operation, the use of 3D machine control to meet the design requirements, remote collection of data for both design and as-built, semi-autonomous extraction and movement of materials, and the introduction of offsite and robotic construction methodologies.

However, the UK construction industry has not adopted a unified approach to this transformation, resulting in varying levels of deployment of CAP across sites, and poor information transfer between organisations. For example, the use of continuous compaction control has been a standard industry practice within mainland Europe for over 15 years but has not seen significant adoption in the UK until recent years. However, while some major projects (e.g., HS2) are implementing it, widespread adoption remains some years away [1]. To alleviate this, National Highways commissioned the development of a Roadmap for Connected and Autonomous Plant, [2]. Development of the Roadmap drew on the expertise of over 75 stakeholder organisations, through a series of questionnaires and workshops. This stakeholder engagement identified a number of barriers to the adoption of CAP including: a lack of a legislative framework that permits and facilitates the use of automation; the need for sufficient financial investment with appropriate recognition of the benefits achieved; contractual programmes which do not incentivise the use of CAP; and the difficulties in developing technology and connectivity across the wide range of plant used in the construction sector. To address these barriers the Roadmap proposes a programme of activities across 9 workstreams, which would aim to deliver the widespread deployment of CAP as milestones are achieved.

Also presented to Brussels Knowledge Day (March 2022), publications in ICE/NCE, CIHT, etc.



# 2023: Phase 3 Design for Machines

# CAP – (Current) Phase 3; Northstar statements

## Task 1: Legislation & Ethics / Commercial & Standards Review

*To answer... 'If a fully autonomous plant fleet was available tomorrow, what would the barriers be to adoption in terms of standards and commercials?'*

## Task 2: Design for Machines

*To provide good practice guidelines to maximise adoption of 3D machine control, removing barriers to getting compatible designs into machines.*

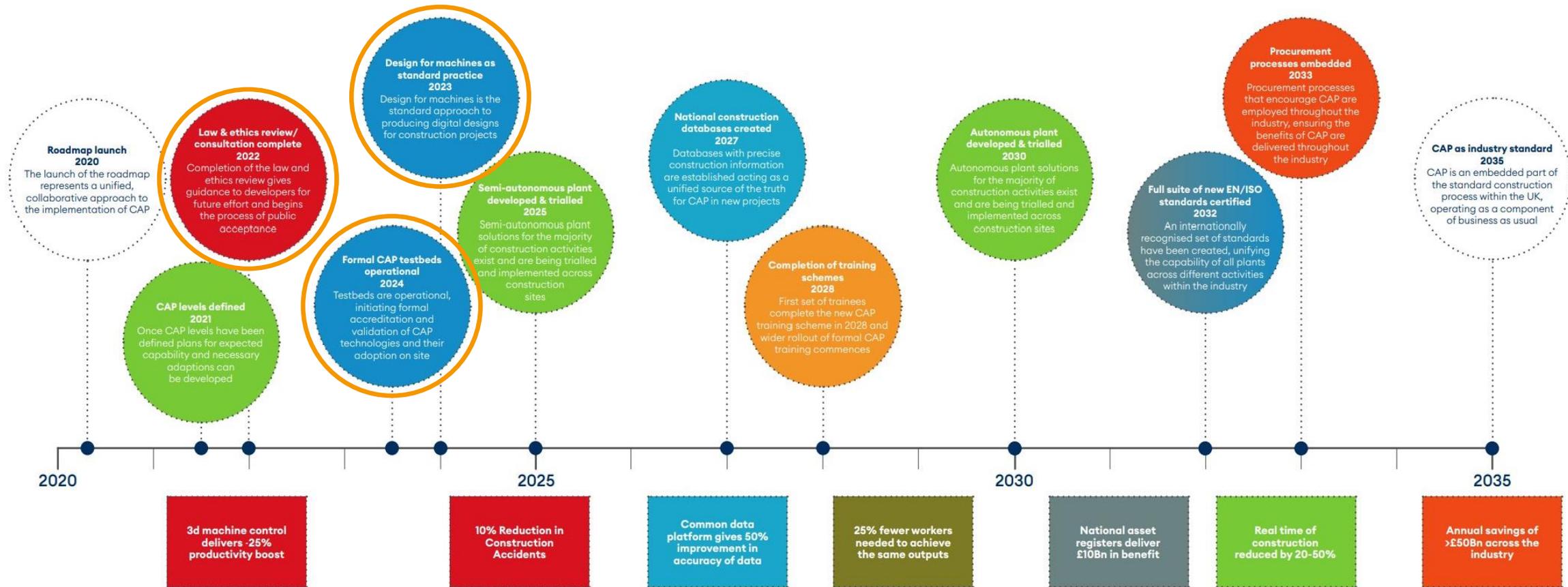
## Task 3: Virtual Testbed creation

*To provide a real-time and over-time view of CAP maturity on National Highways sites.*



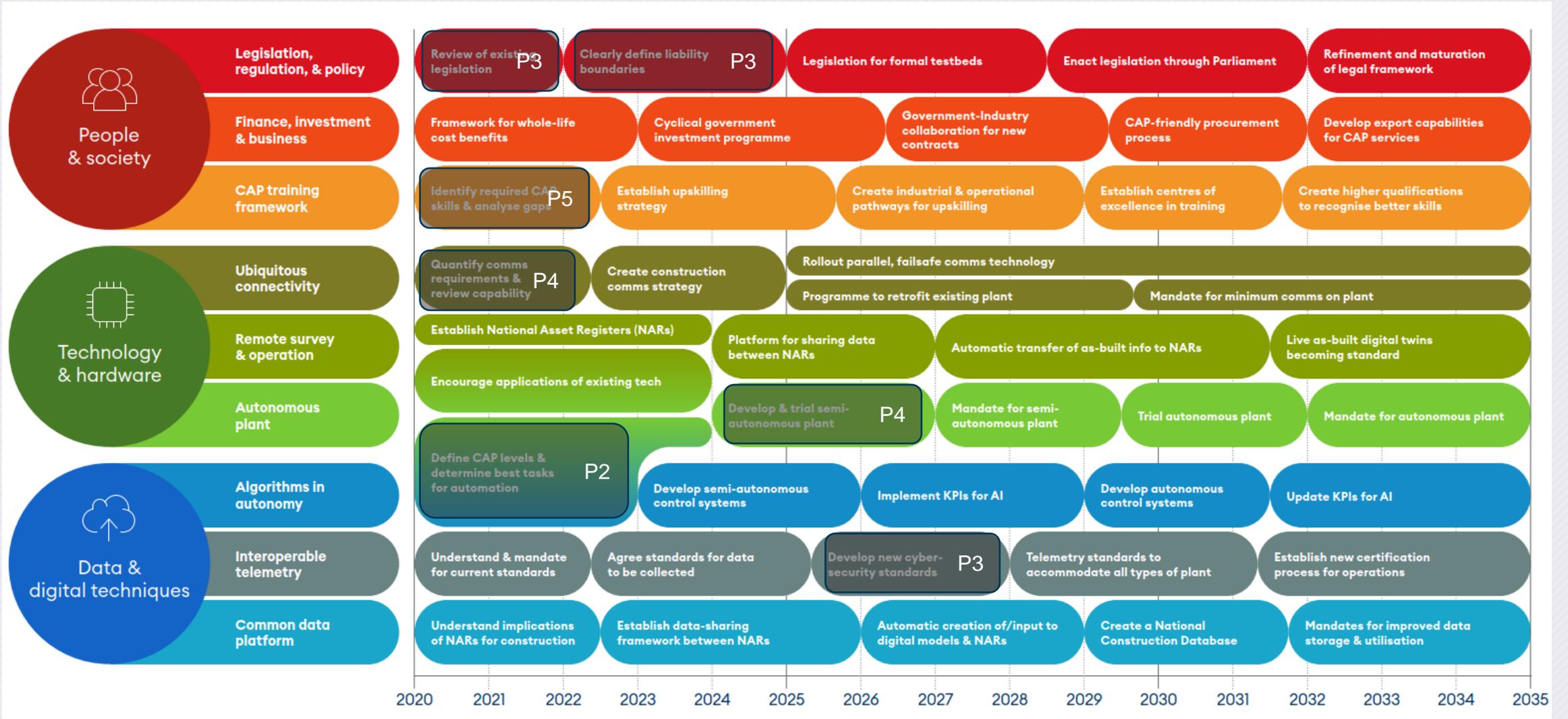
# CAP Phase 3 – Key milestones

Each milestone marks a turning point in the Roadmap, or the establishment of a key enabler that unlocks the next stage



# CAP So Far – at a glance

Note: this is not a comprehensive view of all developments in industry, only where NH work has focused.



# *Phase 4 & Phase 5*

*(As anticipated...)*

# Phase 4 – Trials & Dashboard

The below workstreams will provide NH with a real-time and overtime view of CAP maturity at an organisational level. This could inform future policy around mandating CAP adoption on schemes, once the benefits are evidenced.

## Workstream A: Launch Virtual CAP Testbed

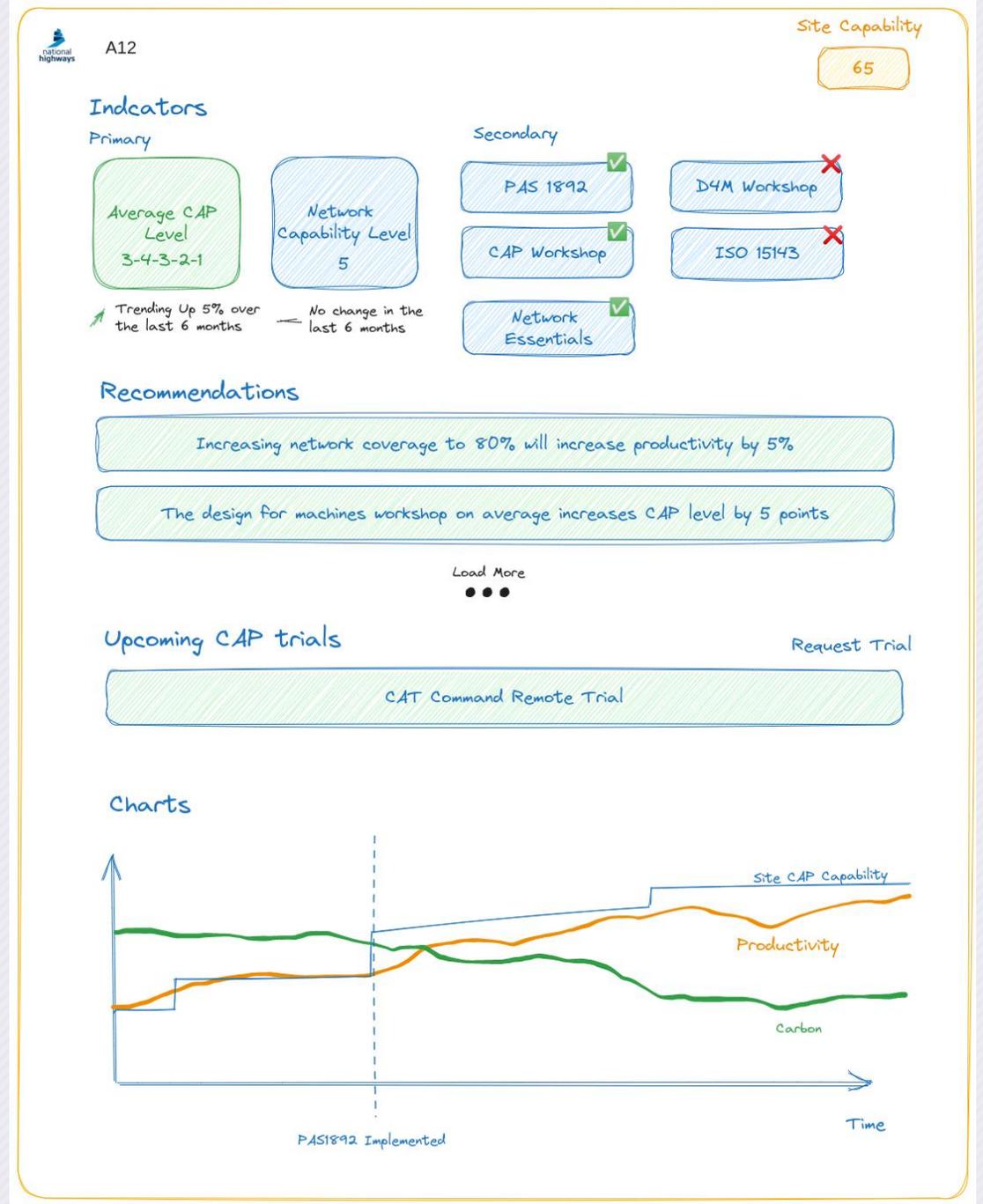
- Launch a virtual, living lab testbed & Dashboard connecting the knowledge and learning from the supply chain's trials of CAP and facilitate access to available testing facilities (e.g. the Manufacturing Technology Centre or NH Development Centre at Moreton-in-Marsh)
- *Deliverables: stakeholder engagement; virtual CAP testbed & dashboard*

## Workstream B: CAP Site Trials

- Targeted, co-funded support to promote pilots and trials with our supply chain, utilising Design for Machines specification developed in Phase 3. We will not be investing in development of any specific CAP technology.
- Gather and utilise data from site trials to populate the Virtual CAP Testbed with real world data
- *Deliverables: stakeholder engagement; match funding for 3 site trials; augmentation of site trial data into dashboard*

## Workstream C: Engagement with Industry through CAP Community

- Engage with Government stakeholders and the CAP community to stimulate the market
- Participate in regional events and exhibitions to identify industry relevant launch events for deliverables
- *Deliverables: stakeholder engagement; case study published; dashboard demonstrating current CAP maturity on NH sites.*



# Phase 5 – Roadmap Review & Workforce of the Future

*The deliverables will clarify how the responsibility on NH for site operatives will evolve over time, whilst also allowing operatives to appreciate a realistic view of how their role will develop with an increase in CAP deployment.*

## Key considerations:

- *Is NH on track to realise CAP sites by 2035?*
- *What will the future operative 'look' like?*
- *What training will be required?*
- *Can we diversify the workforce?*
- *H&S implications of remote working / working from home?*
- *Does NH have a role in this?*
- *Where is the duty of care if we remove operatives from hazardous site environments? Display Screen Equipment Assessments & allowances?*

## High level outputs & outcomes:

- *Reviewed CAP Roadmap, assessing current achievement against ambitions*
- *A trend report highlighting the evolving role of operatives up to 2035 and how this impacts NH business as usual activities, relating to delivering schemes.*
- *Recommendations report suggesting the measures NH needs to adopt to ensure organisational resilience.*



# *DfT Activities*

# DfT Activities

## Past:

### Commissioned BSI Group to develop PAS 1892

*Defining and specifying the use of Connected and automated plant (CAP) in construction and maintenance works for the purposes of procurement and deployment. (July 2023)*

## Present:

### CAP Market Analysis

*To understand the marketplace and appetite for CAP in the construction sector. From a UK vs. Global perspective. (Nov-23 to Mar-24)*

## Future:

### Centre for Connected & Autonomous Plant

*Dependent on the outcomes of CAP market analysis.*

PAS 1892:2023 Connected and automated plant (CAP). Defining and specifying the use of CAP in construction and maintenance works for the purposes of procurement and deployment. Specification

Source: BSI

Committee:

*ZZ/4 - Generic committee reference used for BSI Standards Solutions projects*

Categories: *Safety, Machinery | Construction equipment*

Supporting Documents:

Filename	Description	Size	
PAS 1892 Draft for Public Comment.pdf	PAS 1892 Draft for Public Comment.pdf	825.33 KB	<a href="#">Download</a>

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#### Standard timeline

> 1. Proposal (Complete)

> 2. Draft (Complete)

> 3. Public Comments (Complete)

> 4. Comment Resolution (Complete)

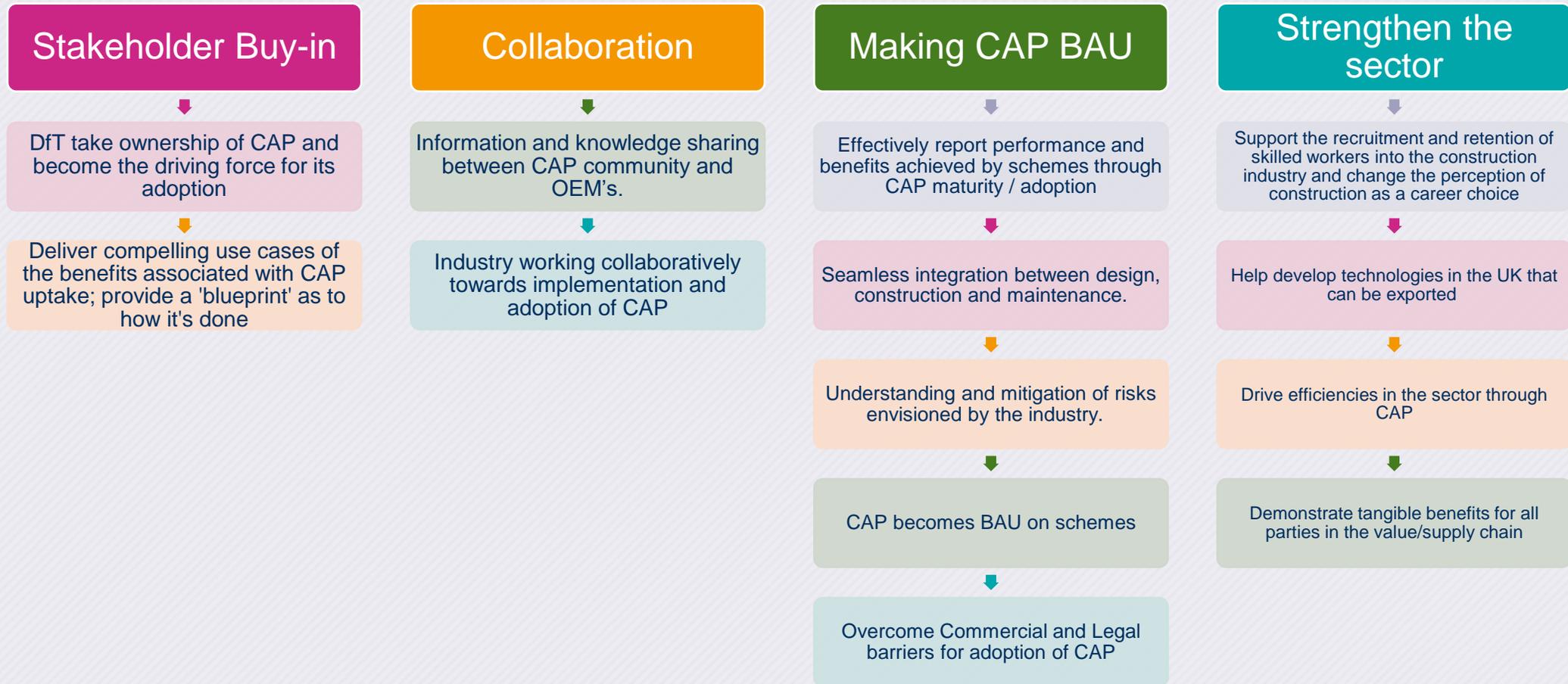
> 5. Approval (Complete)

∨ 6. Publication

Publication start date:

17/07/2023

# What does success look like for the CAP Programme?



# CAP - Looking to the future





Thank you for listening  
Any questions?

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