Indago
Partners

Digital Twins in Mining

A View of the Past, Present and Future

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Digital Twins in Mining

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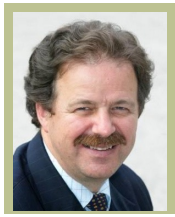

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https://ieeexplore.ieee.org/document/9328190

https://ieeexplore.ieee.org/document/9343728

Introduction

Objective : **Outline recent history of Digital Twins in the mining industry and discuss the major challenges and opportunities going forward**

Agenda

- **Introduction**
- Drivers for Change
- Digital Twins in Mining
- Challenges to Success

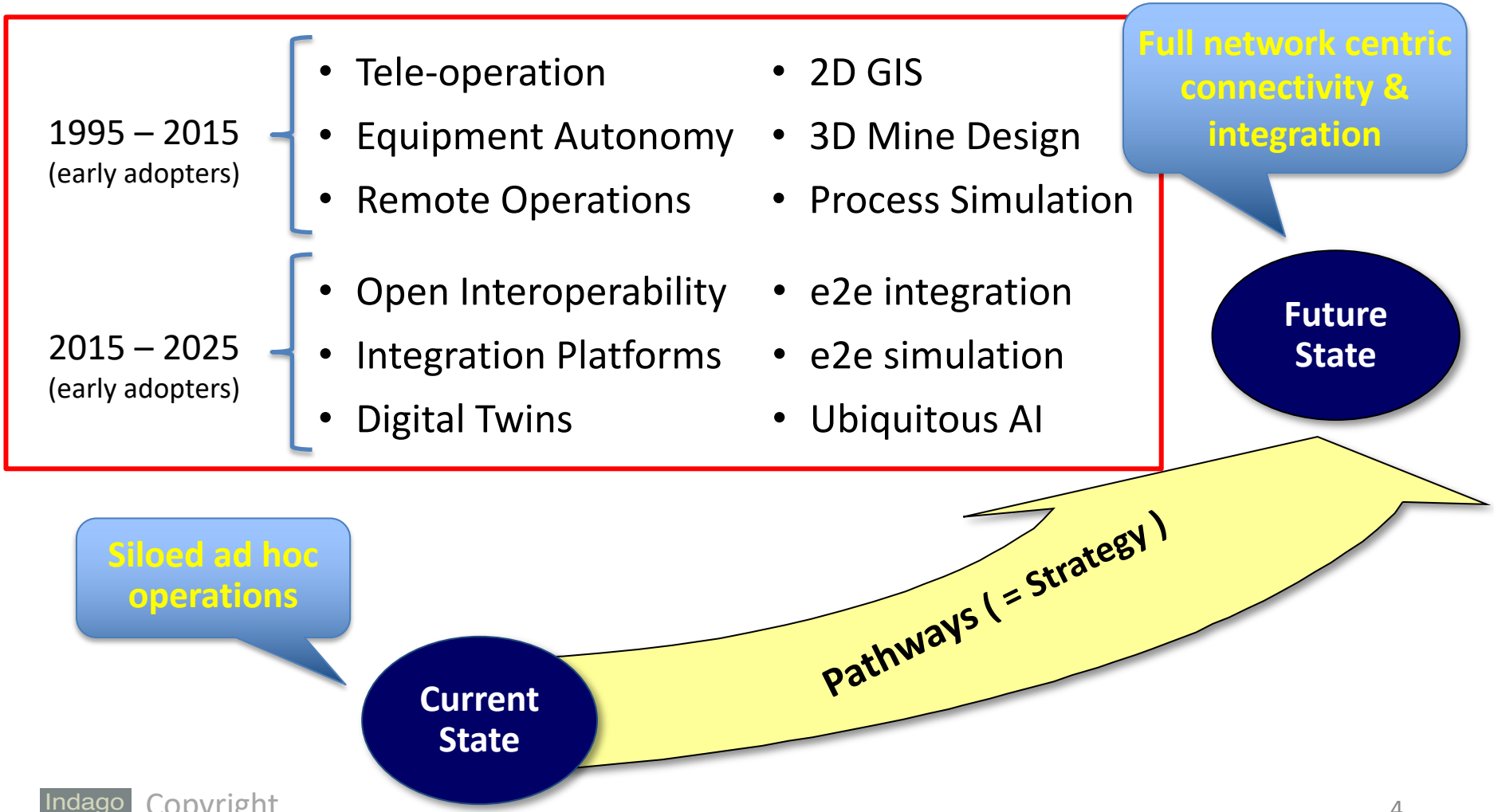
Indago partners

- **Natural Resources: Strategy + Innovation = Transformation**
- We advise business leaders on the benefits and pitfalls of transformational change involving innovation with new technology, and we work closely with other expert advisories to provide depth and breadth in capability.
- We build strong relationships with technology vendors and service providers to bring robust and sustainable solutions to the mining industry.

- **The Pearcey Foundation: In honour of Dr Trevor Pearcey**
- Not for profit independent industry organisation to promote excellence in Information & Communication Technology (ICT) in Australia.
- Promotes the ICT industry in Australia through recognition awards, leading debate and running conferences such as Australia 3.0 to drive innovation in the digital economy in key industries including mining.
- Convening the Pearcey Institute as an independent partnership of research, industry and government for promoting innovation for a more competitive Australia

Introduction

The journey to the Digital Twin in the mining industry has been following parallel pathways to the fully networked operation



Drivers for Change

Strategic Industry Priorities for Mining & Defence

- **Value Drivers & Challenges**
  - Changing geopolitical & economic environment
  - Maintaining competitive superiority with best Assets
  - Rising cost of acquisition & sustainment
  - Nurturing human capital – capability & safety
  - Maintaining community support – social licence to operate
- **Technology Drivers**
  - Consumer markets are driving digital disruption
  - Industrial markets are moving to Industry 4.0 level
  - Industrial IoT platforms are proliferating and yet to consolidate
  - Ubiquitous Robotics, Automation and AI
  - Digital Twins are moving from Design & Build to Operate & Sustain

Drivers for Change

Similarities with defence versus the petroleum industry

Military (Battlefield*)	Mining	Petroleum
Large workforce in the field	✓	Small workforce in the field
Mobile equipment is vital	✓	Fixed plant is vital
Logistics focus – over large areas	✓	Facility focus – over restricted areas
Federated outlook and structure	✓	Global outlook and structure
Many specialist suppliers	✓	Few specialist suppliers

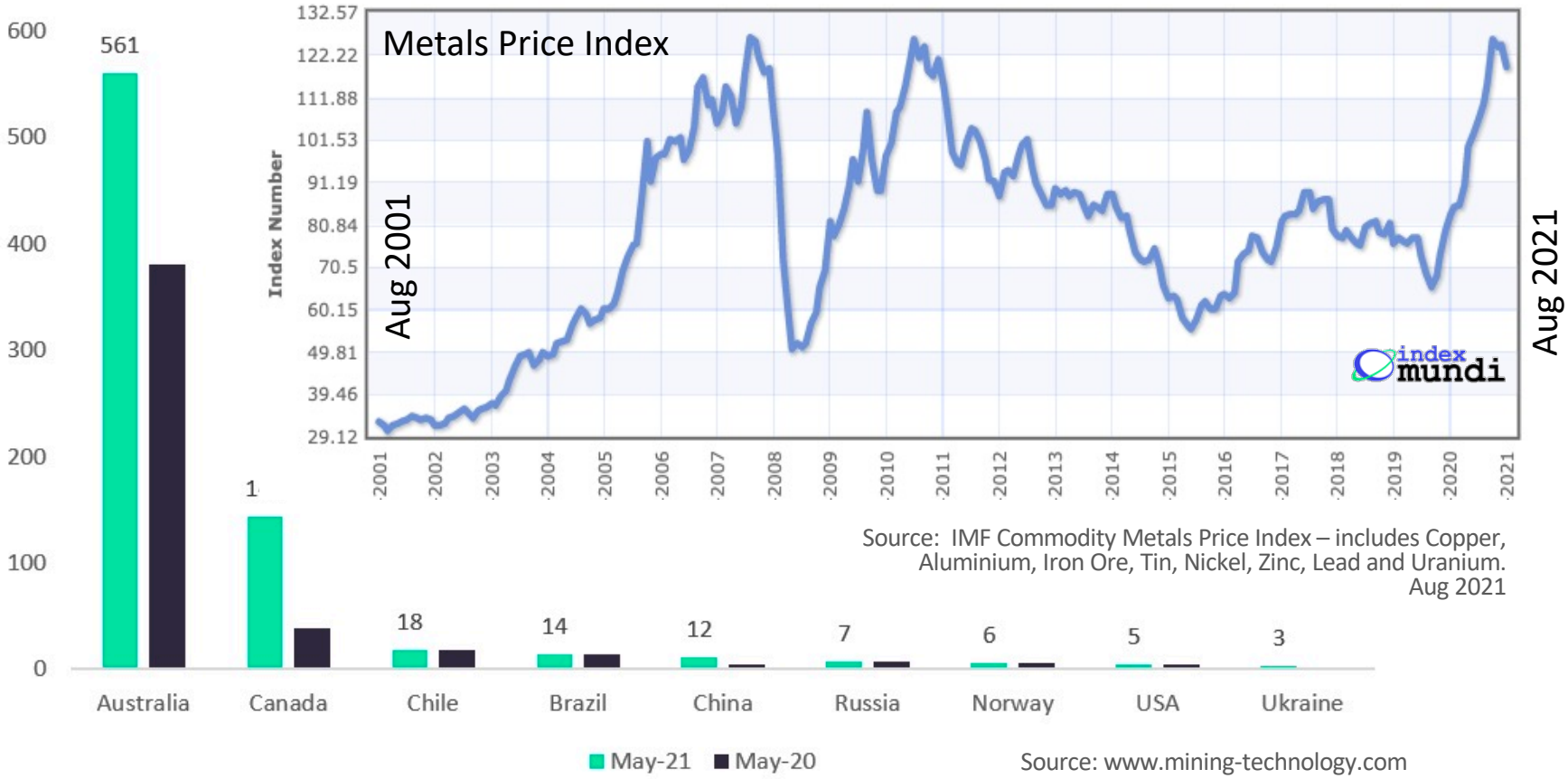
Common characteristics not shared with mining
Innovative with significant R&D budgets
Collaborate competitively on difficult problems
Willing to spend big on technology and standards

* Note: Battlefield refers mainly to land operations. Naval sustainment is more akin to Petroleum

Drivers for Change

The boom & bust nature of the mineral commodity market also leads to a boom & bust in technology transformation

Number of Autonomous Haul Trucks by Country, May 2021 vs May 2020

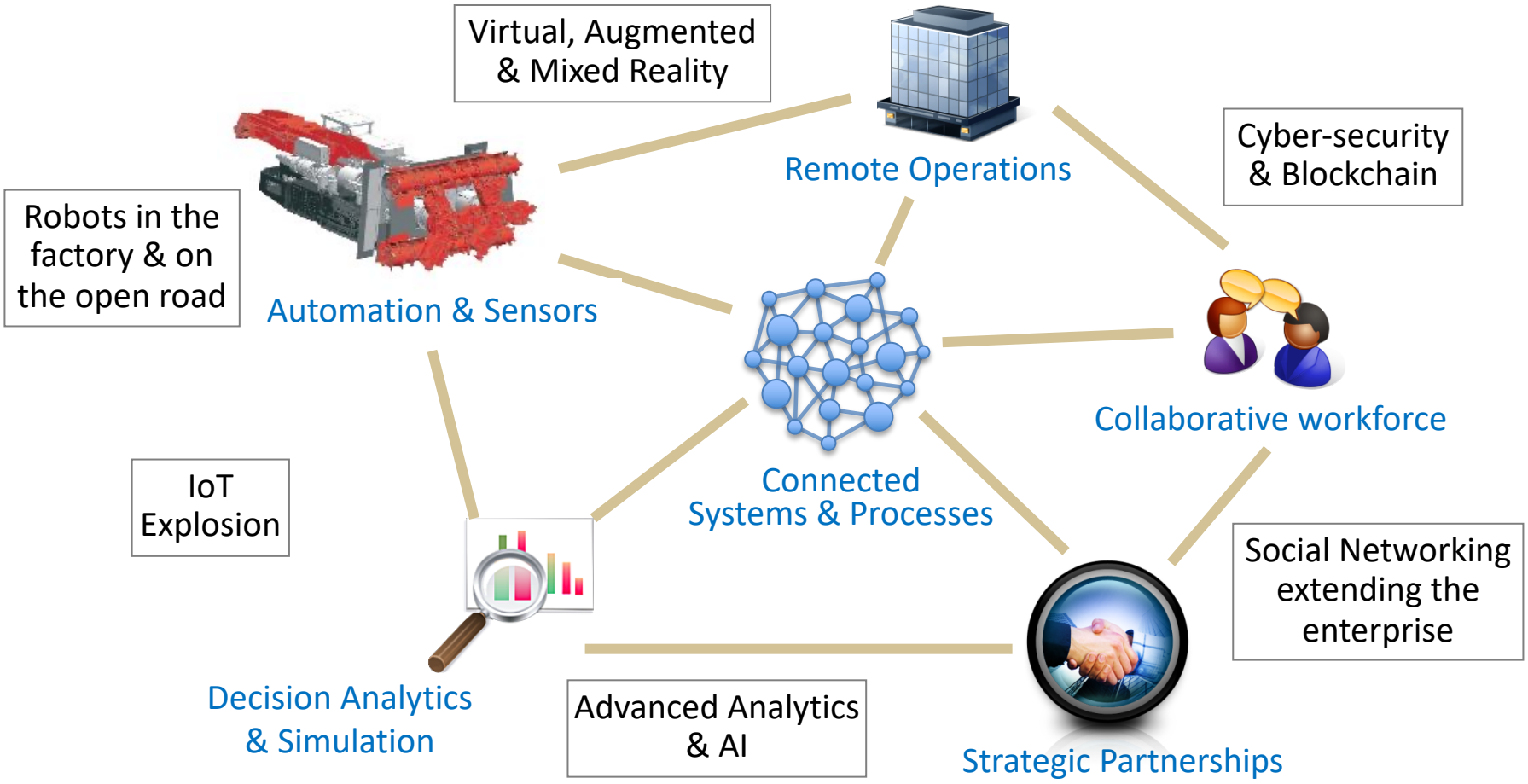


Source: IMF Commodity Metals Price Index – includes Copper, Aluminium, Iron Ore, Tin, Nickel, Zinc, Lead and Uranium. Aug 2021

Source: www.mining-technology.com

Drivers for Change

A range of new technologies have been enabling the transition to the Network Centric Mine



Source: Farrelly et al (2012) The Network Centric Mine *in* International Mine Management 2012 conference

Drivers for Change

The major transition has been to Remote Operations

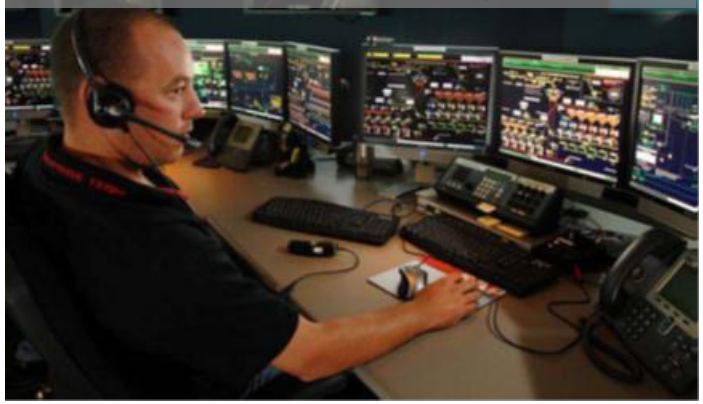
Rio Tinto Iron Ore – Mine of the Future™– the first large scale and very remote ROC (Perth to Pilbara WA)

Trial – 1 function, 1 mine

$100M project, designed in 2008, built in 2009, opened in 2010

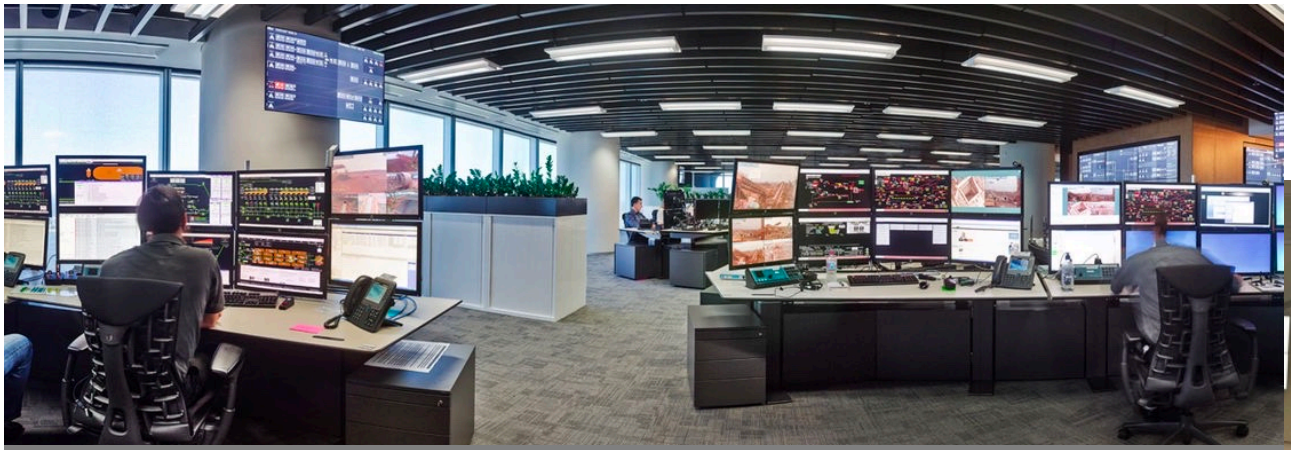
Operations Centre – 10 mines, 3 Ports, Rail ops

Pilot – more functions, 3 mines

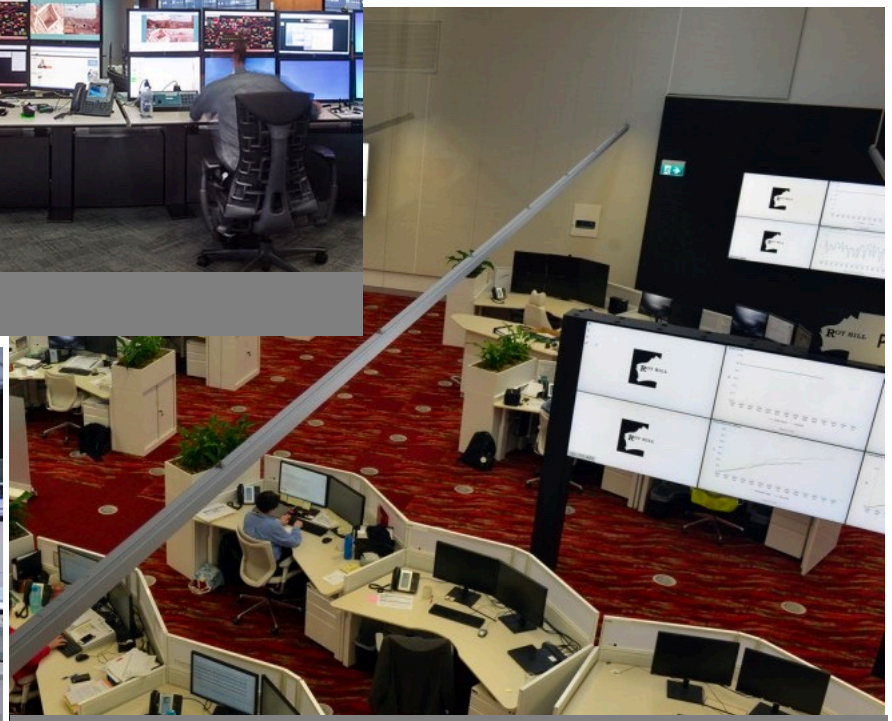


Drivers for Change

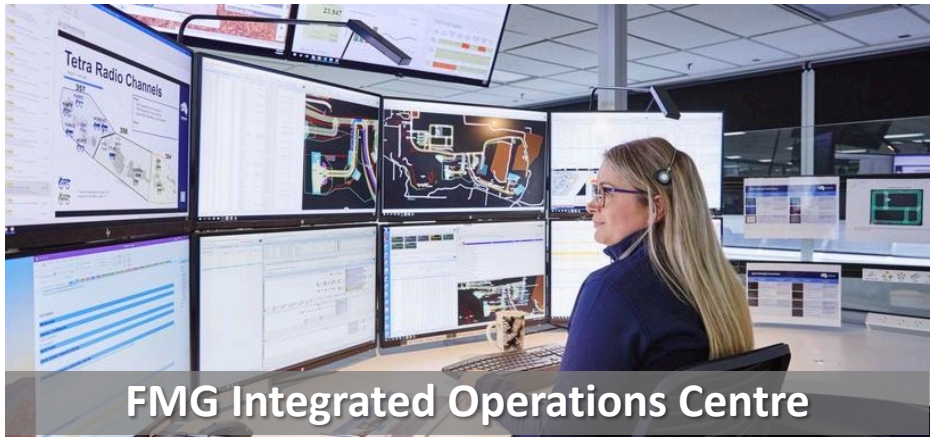
Mid 2010s: Other Iron Ore operations with Remote Operations in Perth connected to Pilbara



BHP iROC



Roy Hill ROC



FMG Integrated Operations Centre

Drivers for Change

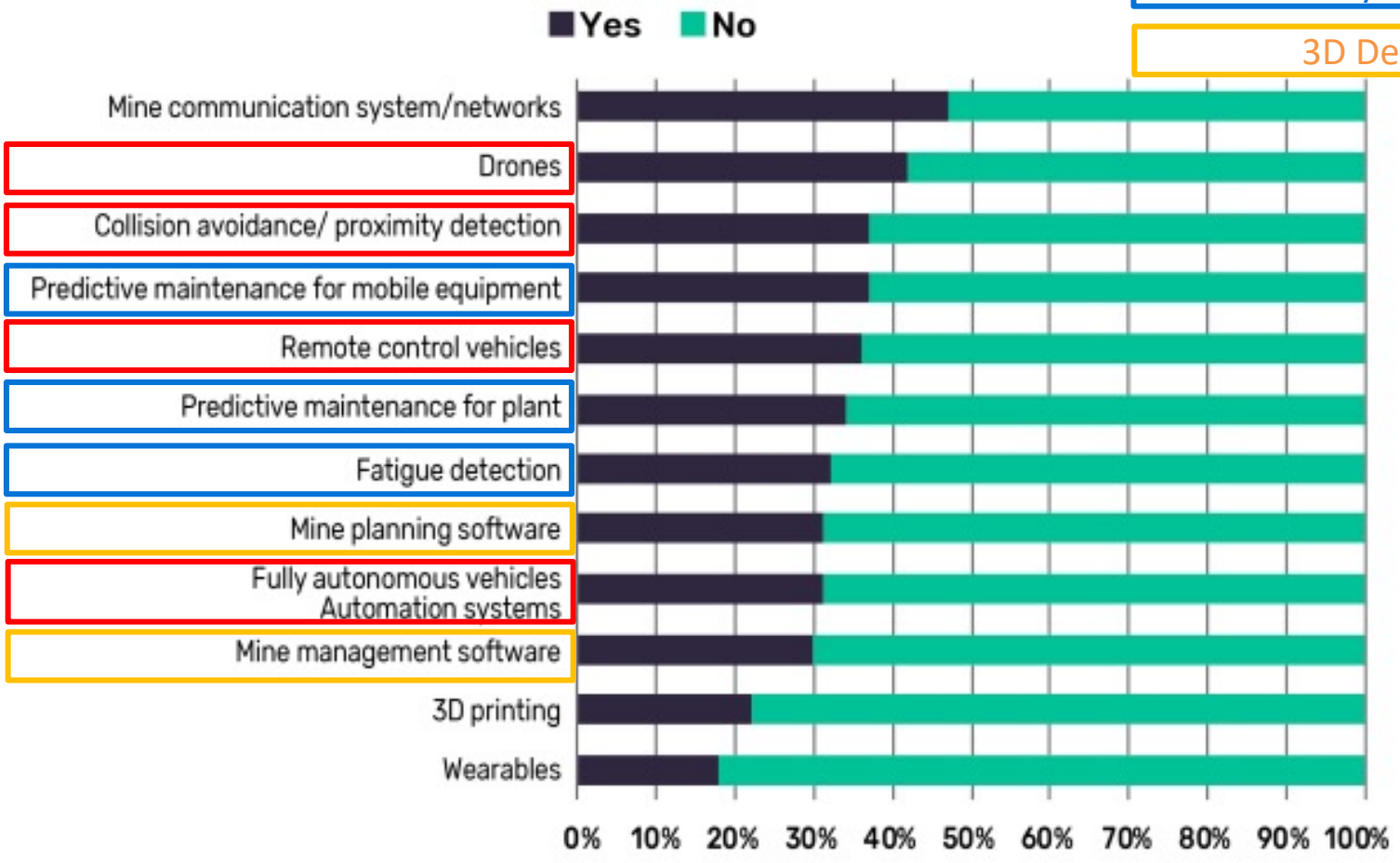
Autonomy and AI are now drivers for the interest in Digital Twins

Technologies mining companies expect to invest further in over the next two years (from 2019)

Autonomy-Robotics

Analytics-AI

3D Design



Source: www.globaldata.com/

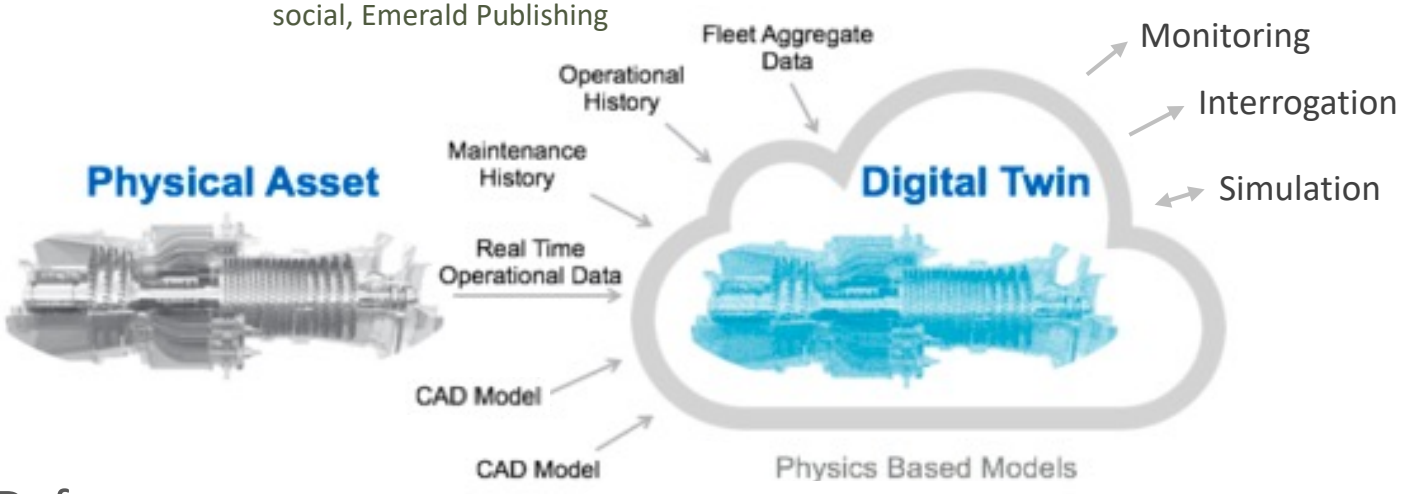
Digital Twins in Mining

Agenda
- Introduction
- Drivers for Change
- Digital Twins in Mining
- Challenges to Success

Digital Twin – What is it?

"A dynamic virtual representation of a physical object or system across its lifecycle, using real-time data to enable understanding, learning and reasoning"

Source: Bolton, McColl-Kennedy, Cheung, Gallen, Orsingher, Witell & Zaki, (2018) - Customer experience challenges: bringing together digital, physical and social, Emerald Publishing



Source: Vizexperts.com

Key Industries:
- Aerospace & Defence
- Manufacturing – automotive, Industry 4.0
- Process industries – petroleum, metals, mining
- Smart cities – infrastructure, buildings, transport

Digital Twins in Mining

The mining life-cycle presents different challenges & solutions

- 2D GIS & Image processing
- 3D Geological Modelling

- 3D Mine Design
- 3D Pit Simulation
- 3D CAD

- Remote Operations
- Planning Optimistation
- ERP + MRP

- Mine Production Systems
- Equipment Autonomy

- Reliability Management
- Process Plant Simulation

- Pit-to-port Product Simulation

Precursors to Digital Twins

Digital Twins in Mining

AI & Digital Twins will revolutionise decision making, across different levels and across the life-cycle of new Assets

Explore | **Develop** | **Mine** | **Process** | **Deliver**

Strategic – Level 4 Decisions (months – years)

e.g.
- Organisation wide planning
- Resource allocation
- Performance forecasting
- Enterprise risk management

Operational – Level 3 Decisions (weeks – months)

e.g.
- Operations planning
- Logistics Planning
- Performance assessment
- Risk audits

Tactical – Level 2 Decisions (days – weeks)

e.g.
- Operations optimisation
- Reliability engineering
- Performance management
- Risk management

Executional – Level 1 Decisions (minutes – hours)

e.g.
- Operations supervision
- Maintenance activities
- Performance recording
- Incident management

Thinking (information centric)

(data centric) Doing

Collaboration (People centric)

(equipment centric) Automation

Digital Twins in Mining

All major processes are enabled by a variety of existing systems

Operational

- Integrated Planning, Budgeting & Reporting (Corporate, Divisional, Asset, Site)
- Geological Modeling & Mine Planning
- Plant Planning & Scheduling
- Marketing
- Prospect Evaluation
- Mine Scheduling
- Development Options
- Ore Inventory Tracking & Reconciliation
- Sales

Tactical

- Tenement Mgt
- Project Mgt
- Construction & Commissioning
- Maintenance & Reliability Management
- Environmental Management
- Contracts
- Geoscience Investigations
- Environmental Assessment
- Production Recording & Reporting
- Transport Mgt

Executional

- Sample Despatch & Laboratory Analysis and/or On-site Analysis
- Drilling & Geospatial Data Collection
- Inbound Logistics
- Fleet / Mobile Equipment Mgt
- Fixed Plant Mgt
- Product Blending / Stockpile Mgt
- Automation & Process Control

Support

- Workforce Management (OH&S, HR, Travel & Accommodation, Training)
- Commercial (Financial Evaluations, Portfolio Management, Auditing etc)
- Infrastructure Management (including Site Security & Access)

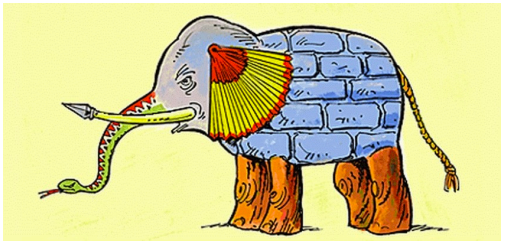
Source: Farrelly et al (2010) adapted from Morison (1996) BHP Minerals FRM

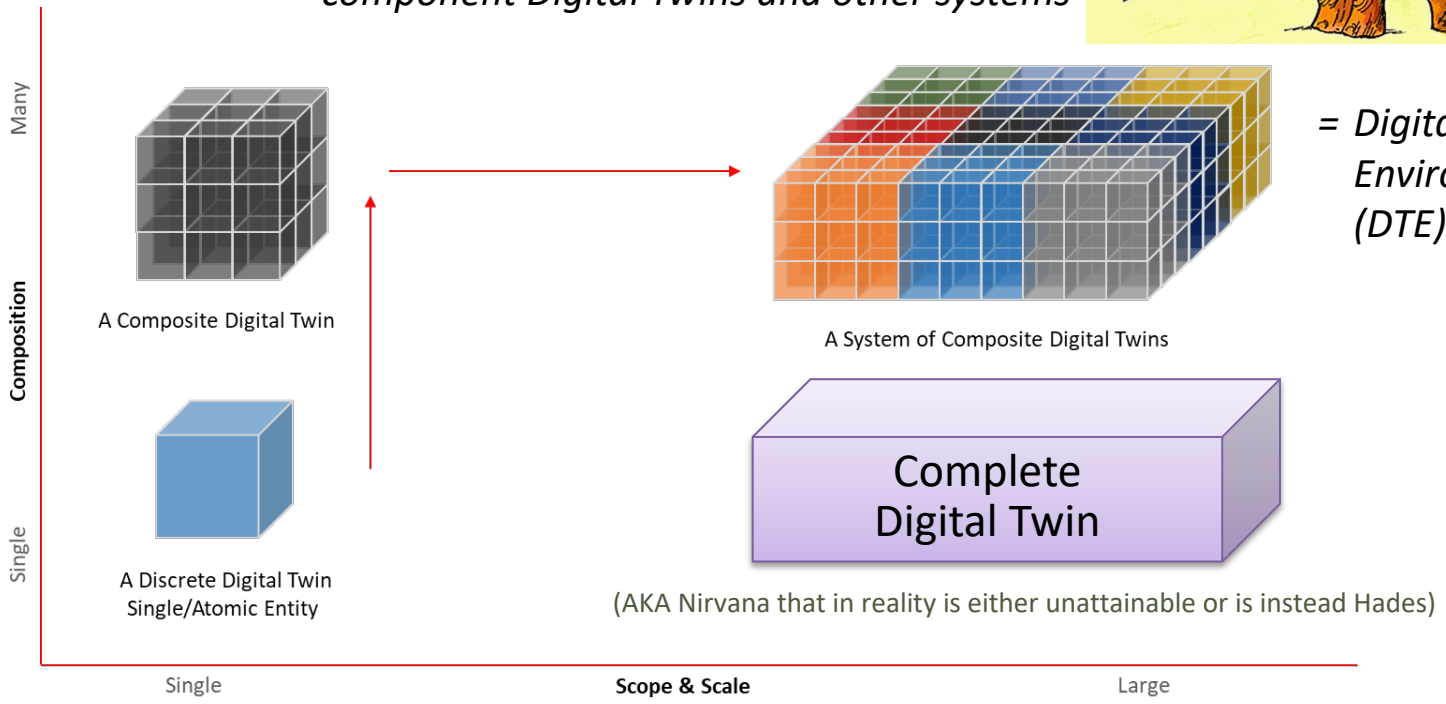
Core Mining Systems **Support Systems**

Digital Twins in Mining

The Digital Twin for a large part of the mining value chain will be a Digital Twin Environment (DTE)

The complete Digital Twin Environment is indeed an elephantine combination of component Digital Twins and other systems





Source: Industrial Internet Consortium, Digital Twins for Industrial Applications – Definition, Business Value, Design Aspects, Standards and use Cases. IIC White Paper, Version 1, 2020. Primary author: Pieter van Schalkwyk, XMPro

Digital Twins in Mining

Separate focus areas are emerging for Digital Twin Environments

Operational

Tactical

Executional

Support

Geoscience Modelling & Mine Design

Business Support & Logistics (ERP+)

c.f. C4ISR

Operations Management

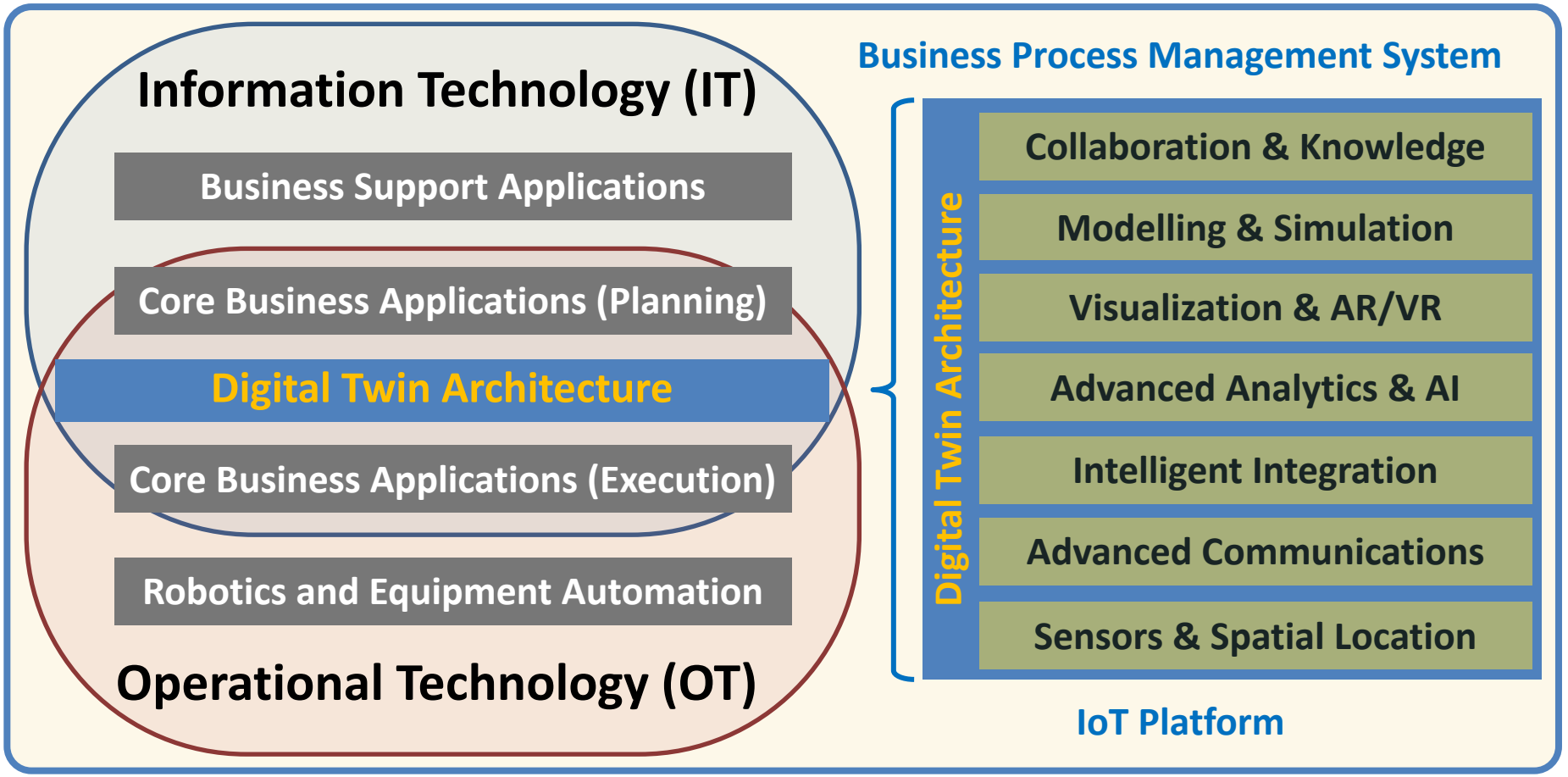
Fixed Infrastructure (3D CAD+)

Environmental Management

Core Mining Systems | Support Systems

Digital Twins in Mining

Most implementations in mining have covered only some components in a complete Digital Twin Architecture



Digital Twins in Mining

The DTE needs to built up over the life-cycle of a new mining operation, but are currently served by separate combinations

Optimise Design by:

- Combining multiple nested 3D designs
- Coherently incorporating all relevant data from all sources
- Simulating entire system of systems
- Testing impact of any proposed changes

Optimise Build by:

- Sequencing order of build in time & space
- Track & trace of inbound material
- Orchestrating all suppliers in a consistent manner
- Collecting configuration history
- Avoiding confusion over versions of 3D models and assoc. engineering data

Optimise Transition by:

- Orchestrating all commissioning activities
- Early escalation of conflicts between actual & planned items
- Properly documenting "As Built" information
- Training in virtual reality with simulated processes in 3D

Optimise Operations by:

- Orchestrating all people and equipment in 3D
- Track & trace of outbound product
- Monitoring changing mine against plans and updating all models
- Maintaining an updated configuration & maintenance history

Optimise each stage (common objectives) by:

- **Improved visibility and reliability of all critical data, information and models (situational awareness)**
- **Knowledge retention within and between stages including continued update over time**
- **Coordinating cross-disciplinary teams and processes including rapid response to unexpected events**

Digital Twins in Mining

The major benefits to mining companies

A digitally aware, dynamic, automated, integrated and interactive technology environment will enable:

- **Faster, more successful capital projects leading to:**
- **Intelligent, productive, safe, and sustainable mining operations with:**
  - Increased agility and lower operational risk
  - Improved safety and lower environmental footprint
  - Optimized mineral resource recovery
  - Higher productivity and throughput
  - Lower cost inputs (labour, energy, and materials).

Source: Farrelly and Davies (2021) Interoperability, Integration, and Digital Twins for Mining , IEEE Industrial Electronics magazine, Special edition on automation in mining

Challenges to Success

Major inhibitors to successful implementations

- **Lack of collaboration and knowledge sharing**
  - Too much influence from the petroleum industry, leading to outdated approaches and solutions (e.g. for remote operations and 3D CAD integration) – lessons need to also come from other industries
  - Fragmented and overlapping interoperability initiatives with little collaboration – this is one area where the petroleum industry excels
  - Major automation vendors and OEMs have been acquiring mining software companies – this may inhibit open interoperability
  - Major engineering companies dominate the design and build phase and show little interest in handing off a worthwhile digital asset
- **Lack of proper transformation processes**
  - Boom and bust nature of the industry does not allow for long term transformations
  - Growth of inhouse point solutions (often AI based) has led to a lack of experience in IT staff in major digital transformations

Challenges to Success

Major inhibitors to successful implementations

- **Lack of proper transformation processes**

  Not following lessons learned from complex digital transformations, e.g.

  - Where possible, don't re-invent the wheel - proven capabilities are available by partnering with the right organisations
  - Don't compromise, and don't have your vendors earn while they learn
  - One size does not fit all, so vary your approach
  - Develop a compelling Case for Change linked to clearly articulated business and solution vision and strategy
  - Senior Business and IT Leadership must be committed throughout
  - Collaborative and Innovative Culture
  - Incorporate best available Business and Technical Know How
  - Deliver benefits in every phase to maintain commitment
  - Well Run Program - focus, focus, focus.

Source: Real-Time Enterprise for the Digital Oil Field – Rus Records and Colin Farrelly CSC 2005

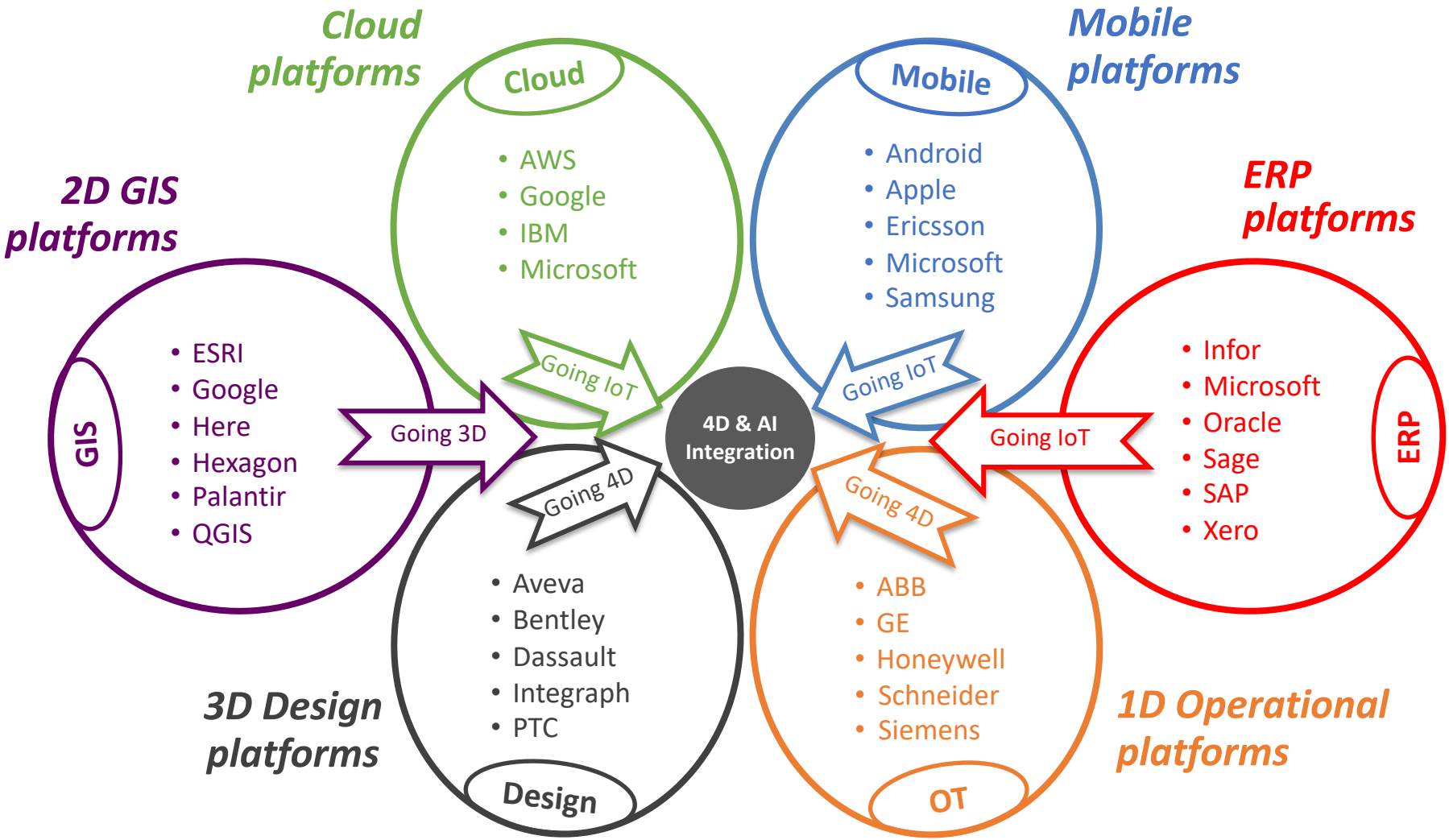
Challenges to Success

Major inhibitors to successful implementations

- **Lack of holistic approach** (each point is covered in appendix)
  - Not covering all dimensions of change: People, Process, Technology, Information and Culture
  - Not taking a whole life-cycle approach and so not getting a proper handover of a digital asset for a new mine
  - Not taking a staged approach to considering all options before detailed design and build of the Digital Twin – need to think hard before eating the elephant
  - Not having a consistent approach to an Industrial IoT platform as an integral component of a Digital Twin roadmap – these platforms have proliferated and are yet to consolidate

Integration Platforms

Industrial IoT platforms – a converging 4D & AI landscape



Source: Farrelly and Davies (2021) Interoperability, Integration, and Digital Twins for Mining , IEEE Industrial Electronics magazine, Special edition on automation in mining

Digital Twins in Mining

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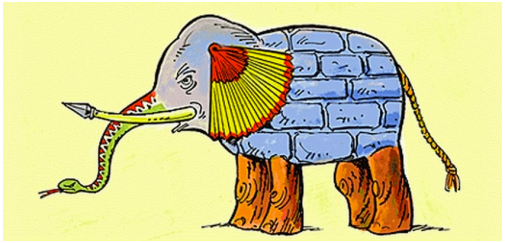
Appendix

– **Eating the Elephant**



A complete Digital Twin will need to cover all major processes

Explore **Develop** **Mine** **Process** **Deliver**

Corporate Strategy & Reporting

Commodity Strategy

Long & Medium Term Mine Planning

Prospect Generation

Tollgate Review

Short Term Planning & Scheduling

Prospect Evaluation

Ore Production Management

Capital Project Design

Operations Management

Geoscience Interpretation & Modeling

Sales & Marketing

Orebody Knowledge & Reconciliation

Transport Management

Geospatial Data Collection & Management

Product Blending/Stockpile Management

Sample & Laboratory Information Management

Regulatory Approvals

Mobile Equipment Management

Fixed Plant Management

Public Data Access

Local or Remote Operational Monitoring & Control

Capital Project Execution

Equipment Reliability & Maintenance

Inbound Supply & Logistics

Process Control & Automation

Non-Process Infrastructure Management

Safety Management

Workforce Management

Environmental & Heritage Management

Government & Community Engagement

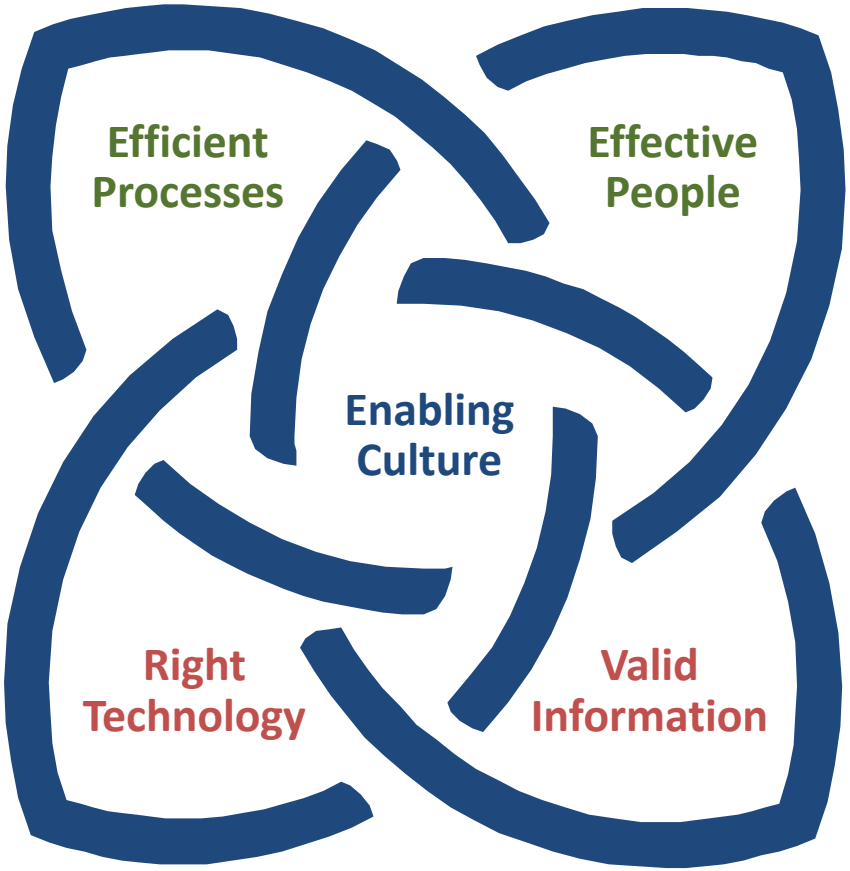
Eating the Elephant

Ensure each Digital Twin considers the whole solution space

Any effective solution needs to balance at least five equally important dimensions

Process:

- business need driven
- focussed
- flexible
- disciplined
- widespread
- repeatable
- improving



People:

- empowered / available
- innovative
- connected to experts
- supported in teams / communities
- trained / capable / knowledgeable

Technology:

- globally accessible
- fit-for-purpose
- easily used
- reliable
- integrated
- extendable
- functional

Information:

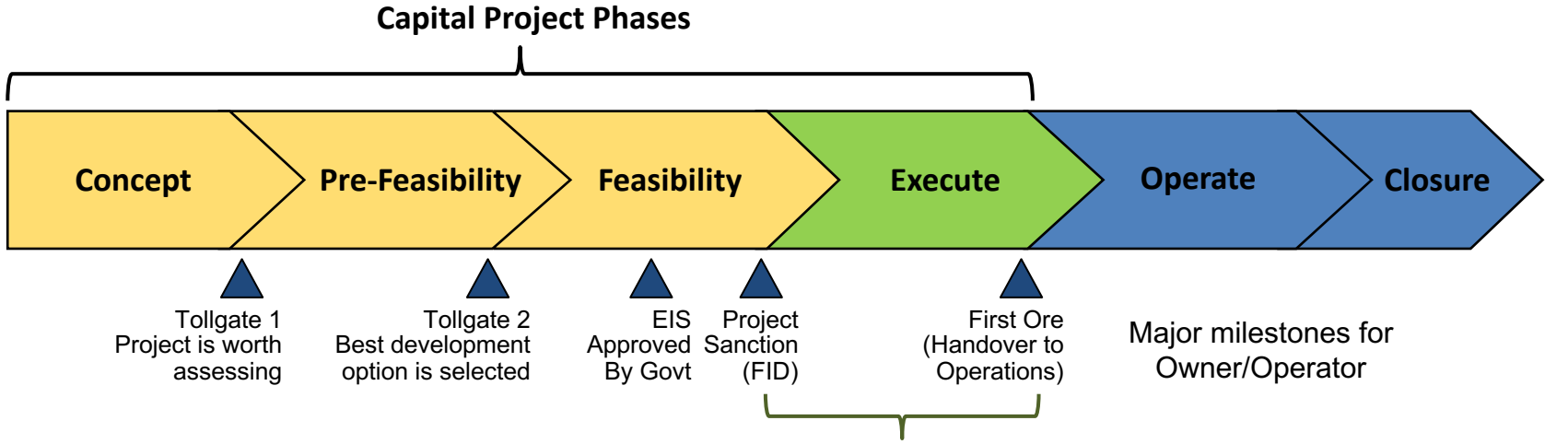
- timely
- secure
- visible / accessible
- digestible / relevant
- related / connected
- accurate / complete
- known provenance

Culture: leadership, collaboration, innovation, commitment, discipline

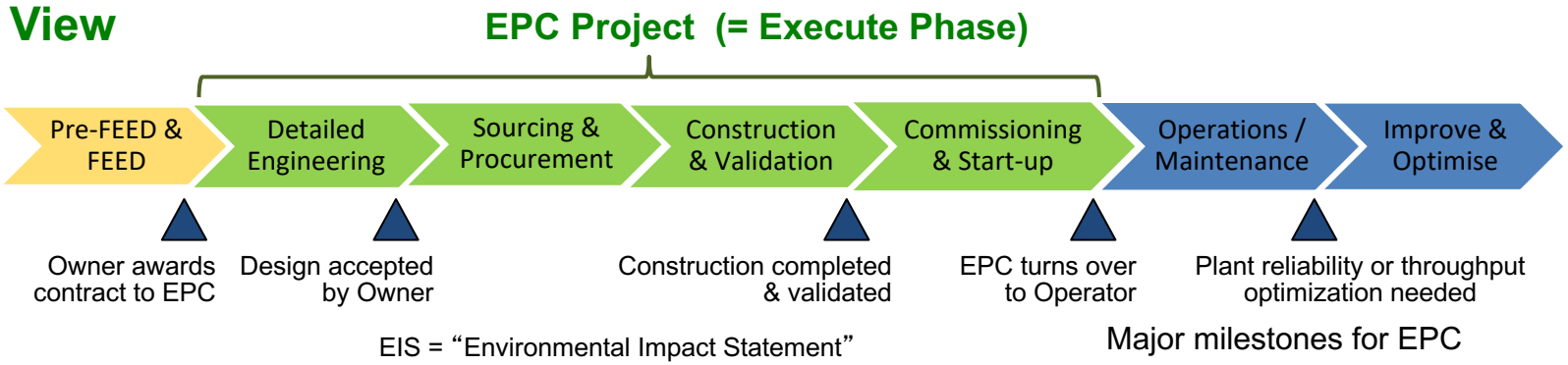
Eating the Elephant

A Digital Twin is best implemented during a major capital project, before the end of Feasibility and before involvement of an EPC

Project Lifecycle – Owner / Operator View



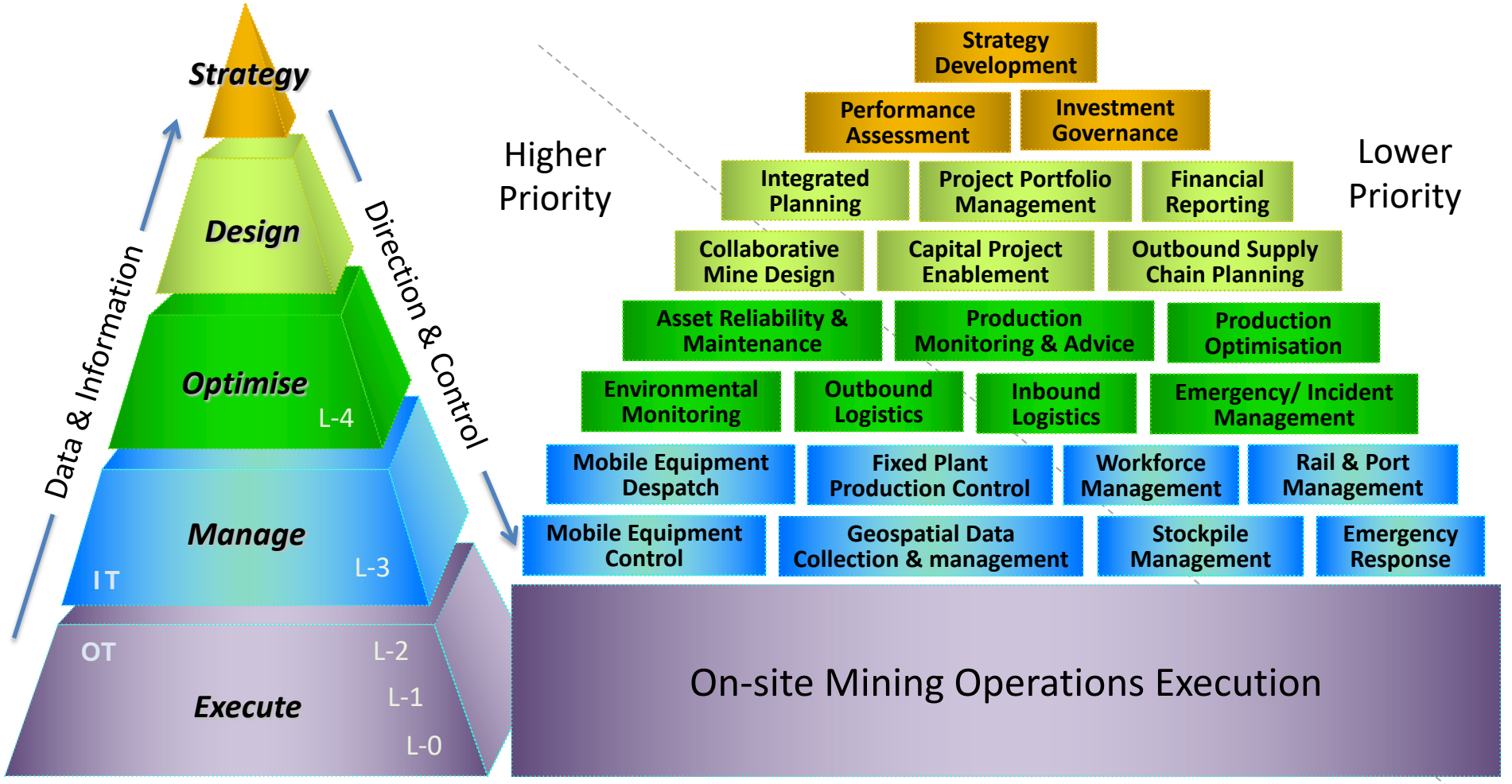
EPC View



EIS = "Environmental Impact Statement"
FID = "Final Investment Decision"
EPC = "Engineering Procurement & Construction Contractor"
FEED = "Front End Engineering Design"

Eating the Elephant

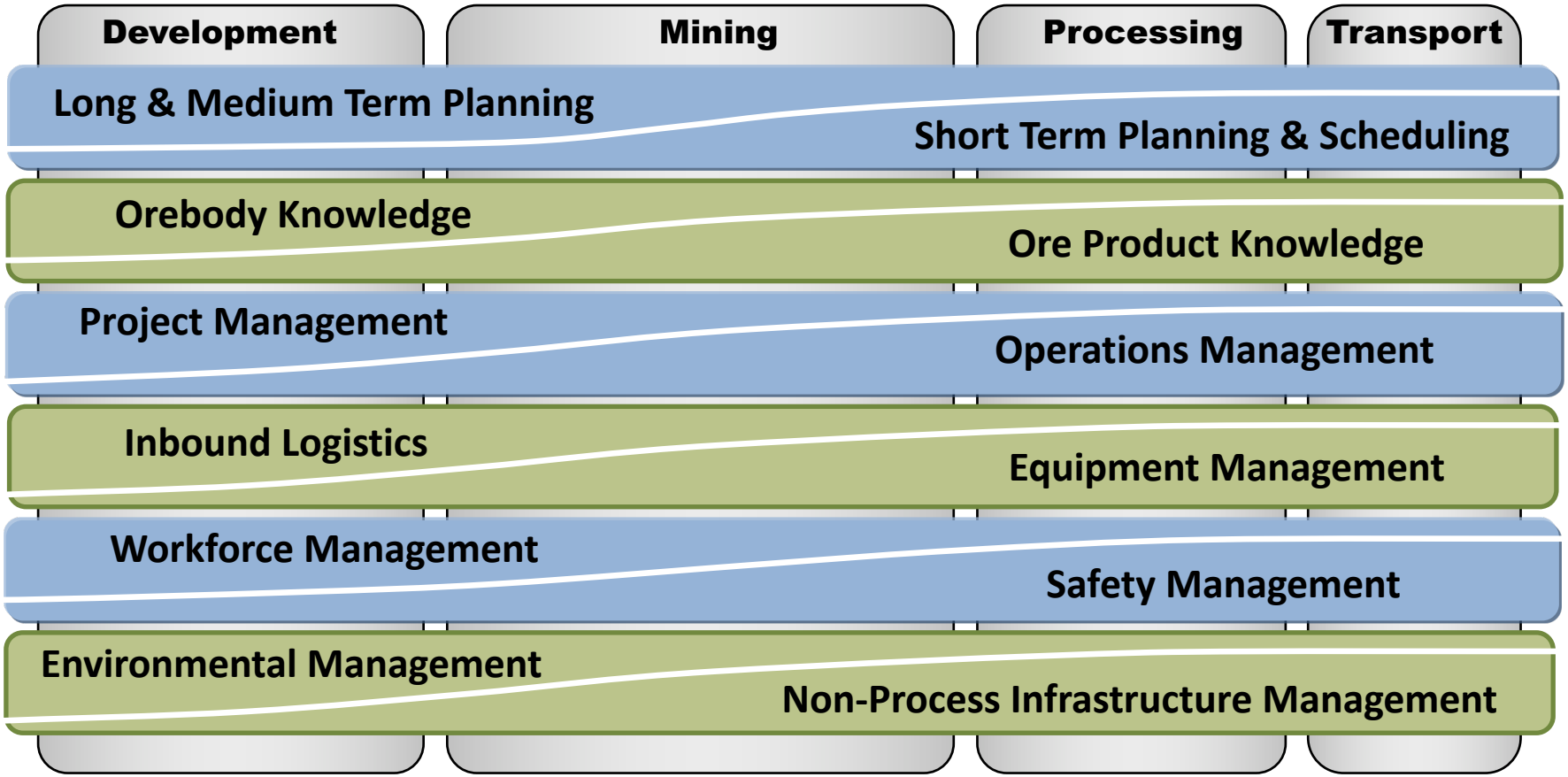
Select a combination of priority processes that are adjacent both along the value chain and at different decision levels



Eating the Elephant

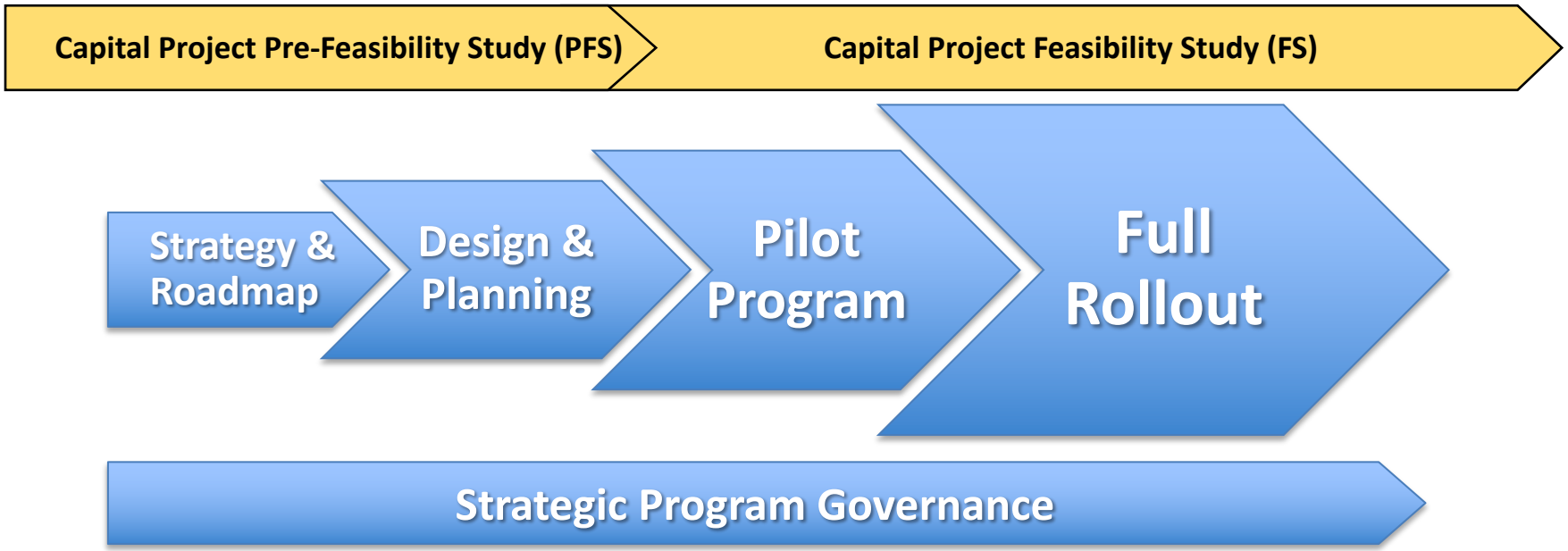
Focus integration on horizontals that work across the Value Chain

Some business process areas are already “linked integrators” across the value chain so could be focus areas for initial integration and digital twin efforts

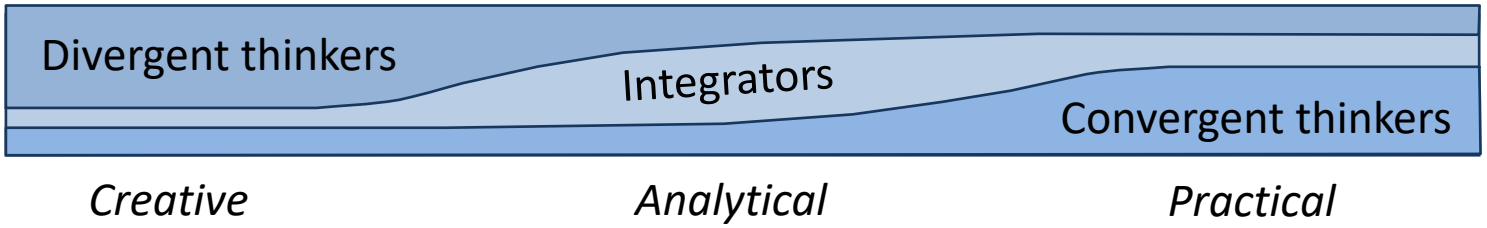


Eating the Elephant

Design and implement the Digital Twin in stages that are aligned to the appropriate capital project phases



Get the right people involved at each stage



Eating the Elephant

Start the journey with a clear understanding of your current capabilities and the emerging technology options

Phase 1 aims to understand the internal and external technology and business capabilities in order to define a set of valid strategic options for progressing the strategy

Phase 2 aims to evaluate each strategic option and set the priority for further detailed planning & development

Phases 1a and 2b can be largely carried out by consultants, but **Phases 1b and 2a** must be carried out by the key client stakeholders

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