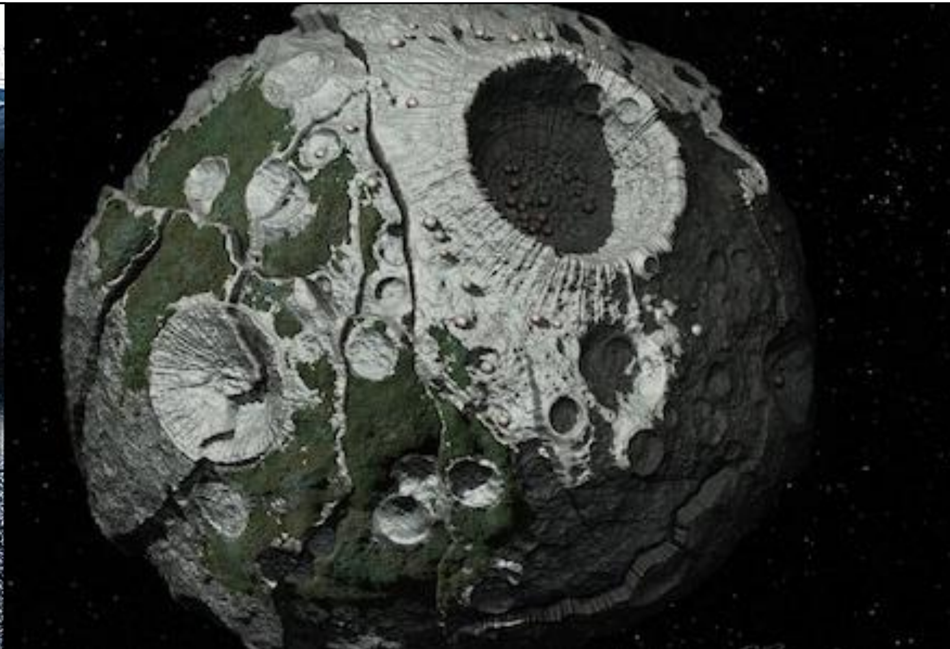
Digitally Transforming Mining

From Earth to Space

28 August 2017

Dr. Adriana Marais
Empie Strydom



Your Speakers

Dr. Adriana Marais
Head of Innovation, SAP Africa
Astronaut Candidate, MARS One

Empie Strydom
Vice President, Marketing
MineRP

What the Big 4 are telling CEOs

(Serving mining where it's going)

Deloitte *(Tracking the trends 2016)*	**EY** *(Top 10 business risks facing mining and metals 2016-2017)*	**KPMG** *(Global Metals and Mining Outlook 2016)*	**PWC** *(Mine 2016 Slower, lower, weaker... but not defeated)*
Operational Excellence	Cash Optimization	Focused on costs	Capital efficiency hits at an
China's Transition	Productivity	Invest in R&D	Asset sales as mines look to
Stakeholder & Community	Transparency	Portfolio Management -	GAP between miners and
Tax Issues	Access to Energy	Improve Visibility	Extreme volatility
Tax Issues	Cybersecurity	Productivity through Technology	
Safe, Secure & Healthy	Innovation		

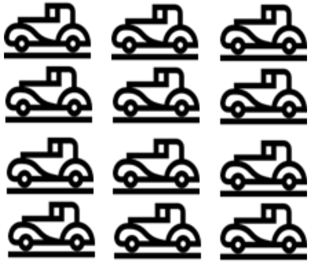
Keep the Promise – Stick to the Plan

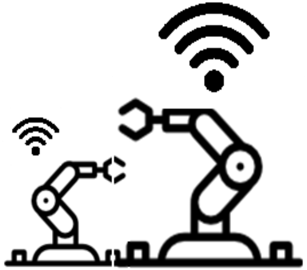
Innovate or die

Portfolios are liquid – but mines can't cope with the flexibility

Investors have lost patience – transparency is needed

Industry 4.0





1800
Industry 1.0

Mechanization,
Water power
Steam power

Physical Systems

1900
Industry 2.0

Mass production
Assembly lines
Electricity

Machine assisted Human

1970
Industry 3.0

Computers and
IT Automation

Human assisted Machine

2015+
Industry 4.0

Cyber-Physical
Systems

Cyber-Physical Systems

Mining 4.0 in the context of Industry 4.0

	Artisanal Mining	Most Mining Companies Today	MineRP	MineRP
	Mining 1.0	Mining 2.0	Mining 3.0	Mining 4.0
Plan	Paper	CAD	Enterprise	Real Time & Cognitive
Execute	Shovel	People & Machines	Sensors & Human Interactions	Instrument or People
Action	People	Radio	Workflow	Digital Instruct
Time	Never really know	Once a Month	Sensor on demand Human past shift	Millisecond mining & Cognitive

IMPACT HAZARD

SCIENTIFIC KNOWLEDGE

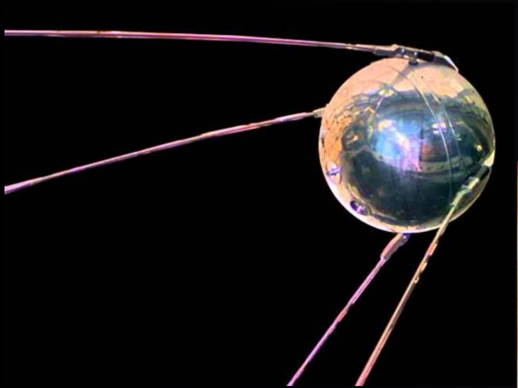
OSIRIS-Rex launched 2016,
sample return 2023

Bennu ~500m

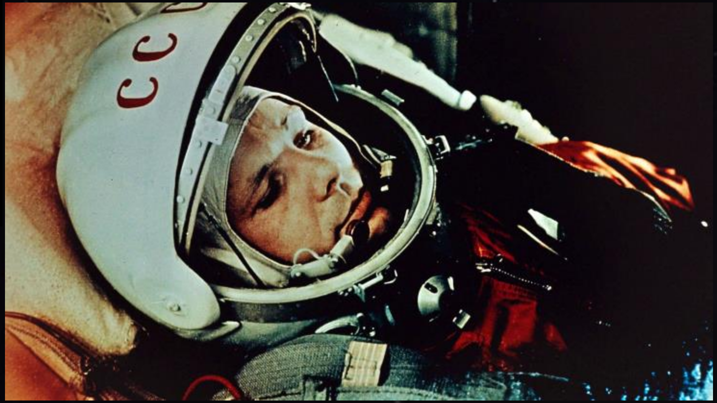
Hayabusa2 launched 2014,
sample return 2020

Ryugu ~900m

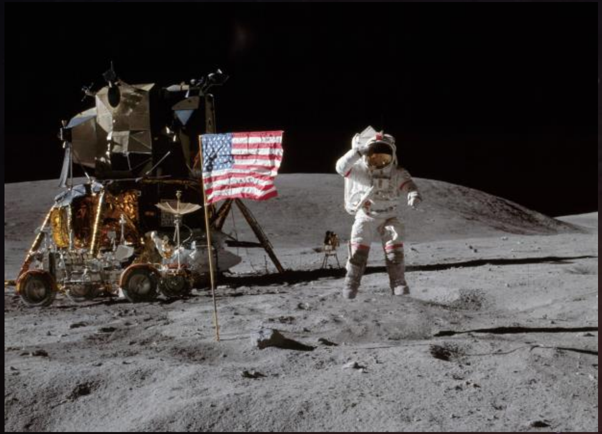
PROUD TRADITION IN SPACE



SPUTNIK 1957



GAGARIN 1961



ARMSTRONG 1969

100 ASTRONAUT CANDIDATES

Research opportunity of a lifetime!

RESOURCE UTILISATION

Table I. Abundances of ferrous and precious metals in asteroids

Metal	(1) Abundance in metal of average LL-chondrite asteroid	(2) Abundance in good" iron asteroid (90th percentile in Ir, Pt)	(3) Abundance in "best" iron asteroid (98th percentile in Ir, Pt)
Ferrous metals:			
Fe	63.7%	81-94%	82-94%
Co	1.57%	0.46-0.80%	0.43-0.75%
Ni	34.3%	5.6-18.0%	5.4-16.5%
Precious metals:			
Ge	1020 ppm	0.06-70 ppm	0.05-35 ppm
Re	1.1 ppm	1.1 ppm	2.4 ppm
Ru	22.2 ppm	20.7 ppm	45.9 ppm
Rh	4.2 ppm	3.9 ppm	8.6 ppm
Pd	17.5 ppm	2.6 ppm	1.2 ppm
Os	15.2 ppm	14.1 ppm	31.3 ppm
Ir	15.0 ppm	14.0 ppm	31.0 ppm
Pt	30.9 ppm	28.8 ppm	63.8 ppm
Au	4.4 ppm	0.16-0.70 ppm	0.06-0.6 ppm

Calculated from data given by Müller et al. 1971, Buchwald 1975, Malvin et al. 1984, Rasmussen et al. 1984, Hirata and Masuda 1992, and Morgan et al. 1992.

Asteroid mining for crewed space exploration

INFERENCE

Query: most cost effective ▾ Lookup: eg. 433 Eros or plot a custom orbit.

Name	Type	a (AU) ℹ	e ℹ	Value ($)	Est. Profit ($)	Δv (km/s)
Ryugu	Cg	1.190	0.190	82.76 billion	30.08 billion	4.663
Anteros	L	1.431	0.256	5.57 trillion	1.25 trillion	5.440

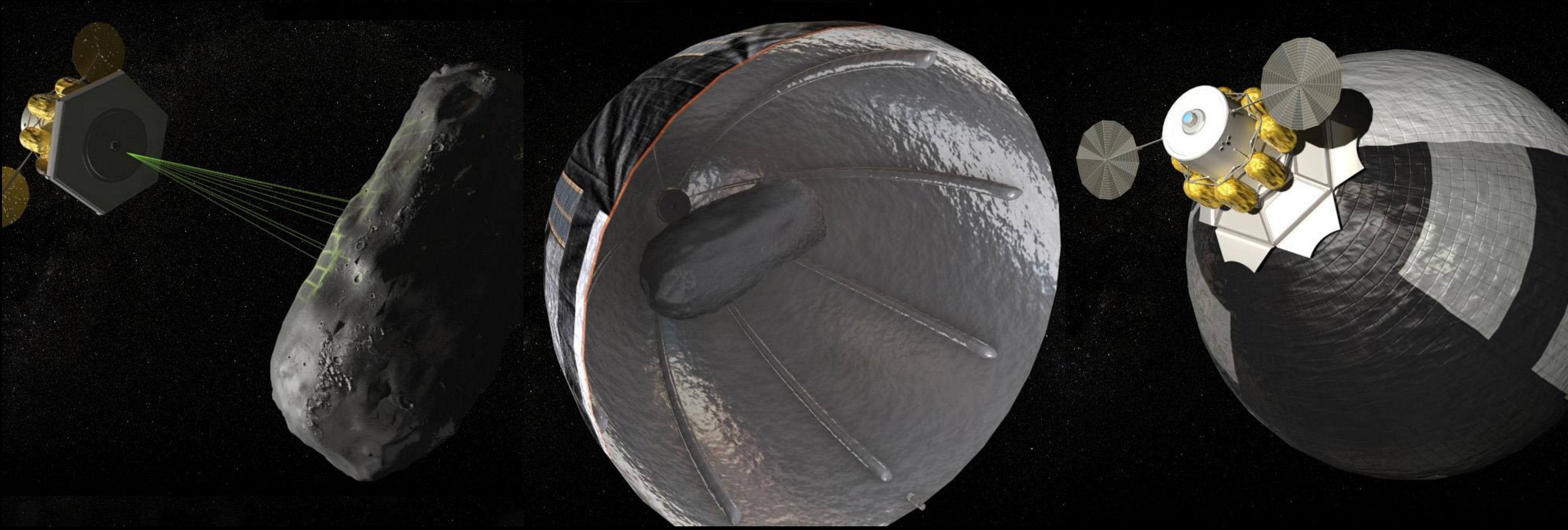
Asterank asteroid database

Estimation of size, composition & orbit

INDICATION

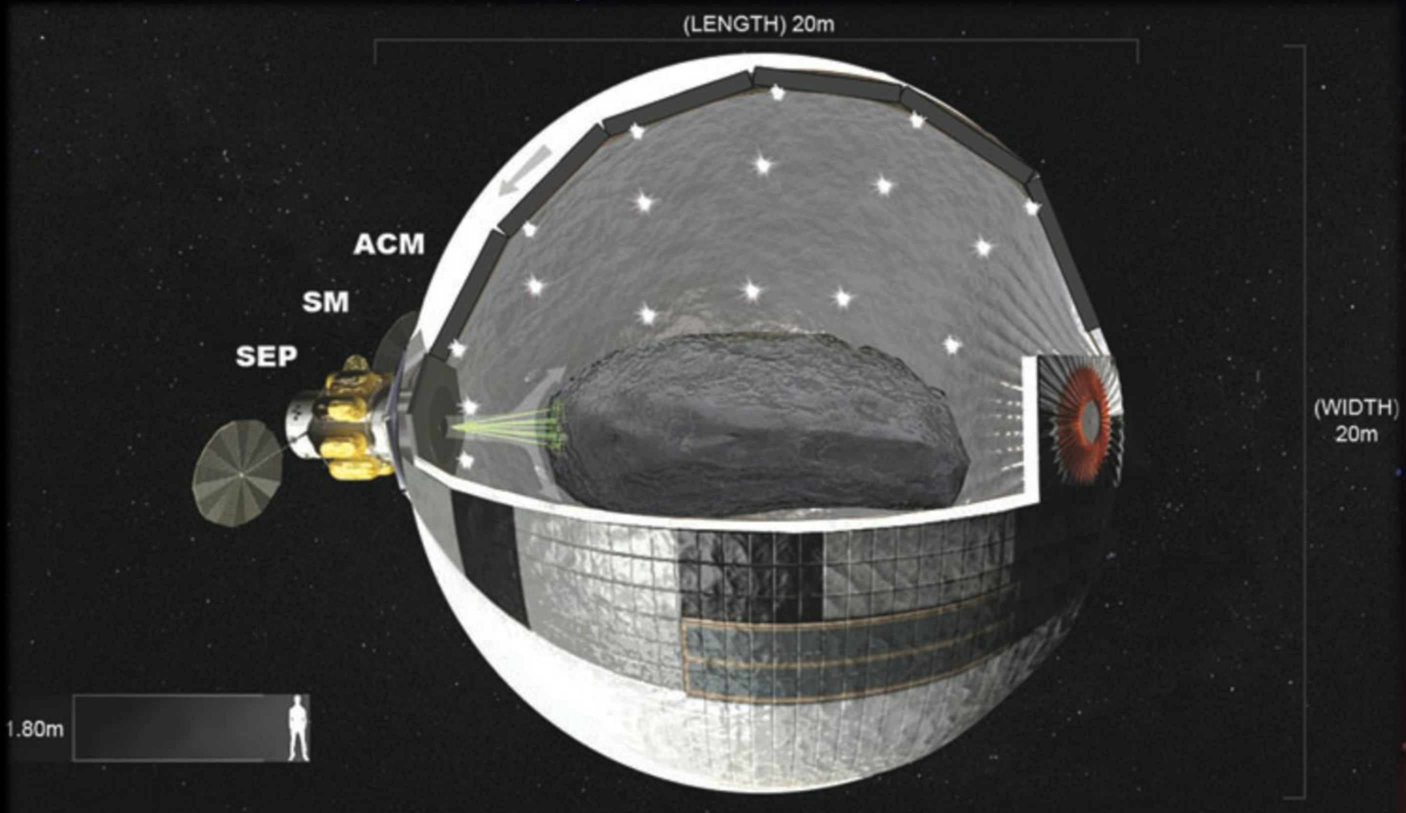
Fleets of solar-powered nanocraft probe asteroid belt

MEASUREMENT



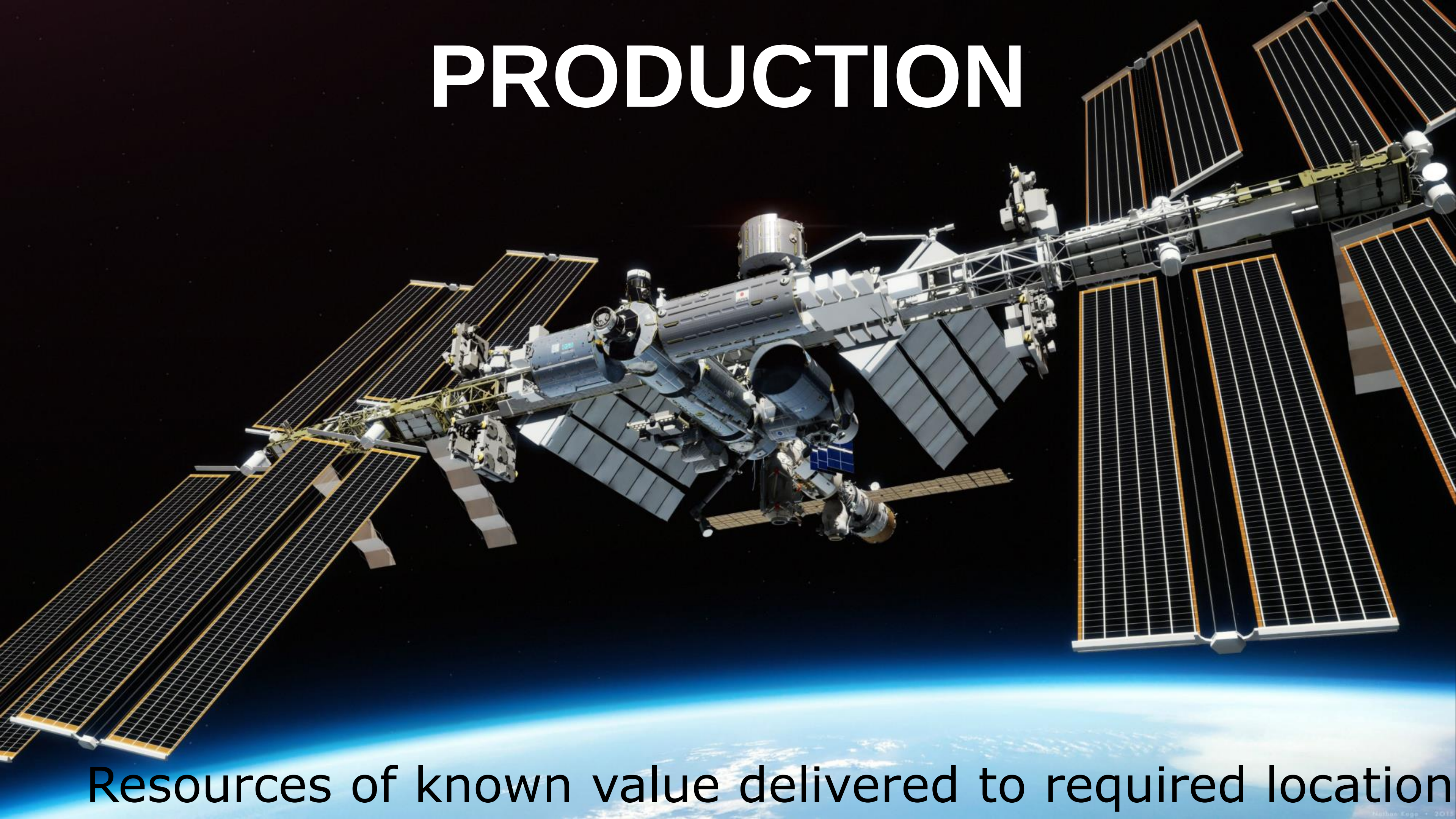
SHEPHERD: A Concept for Asteroid Retrieval with a Gas-Filled Enclosure

PROOF



Resources extracted, spectral analysis provides real-time profit estimate

PRODUCTION



Resources of known value delivered to required location

PROJECT OVERVIEW

10 year mission
3 bill USD

Asteroid Retrieval Feasibility Study (2012)

DID YOU KNOW?

Asteroids brought precious metals to early Earth’s mantle

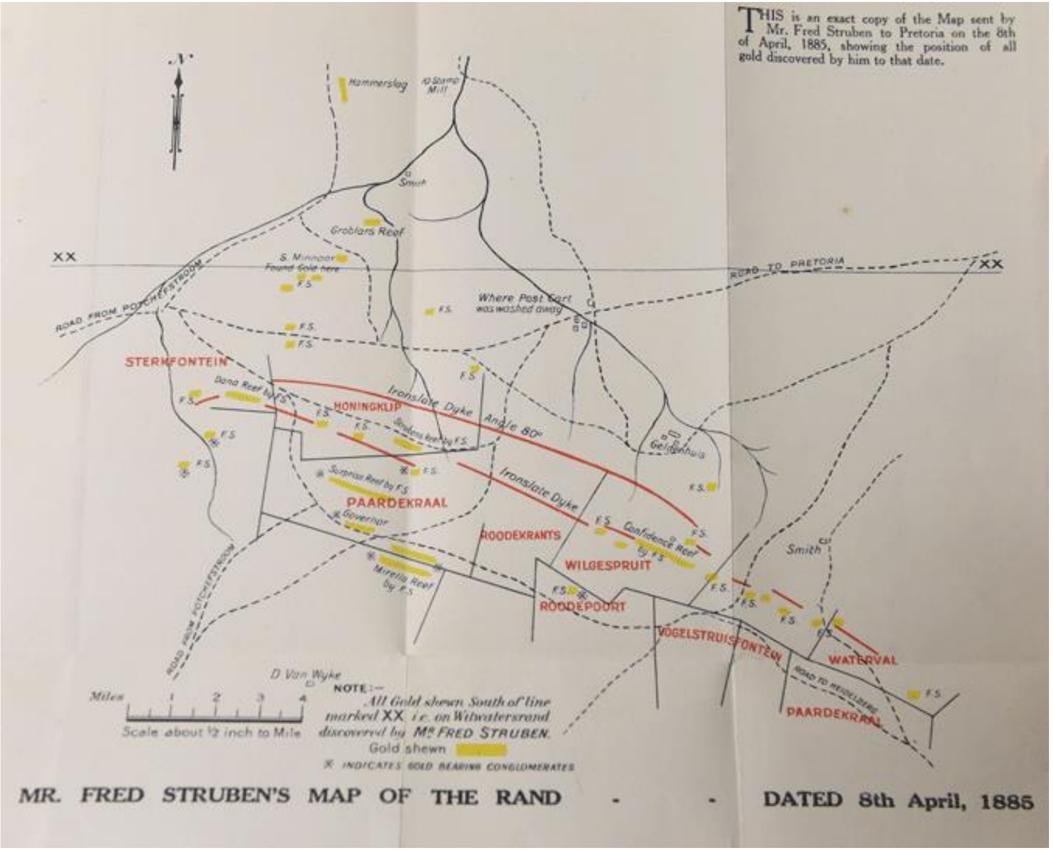
A lesson from History

History tells us that Gold was discovered at the Witwatersrand in South Africa by Mr George Harrison on the farm Langlaagte in 1886

Source: Africa Museum, Johannesburg

A lesson from History

And yet…

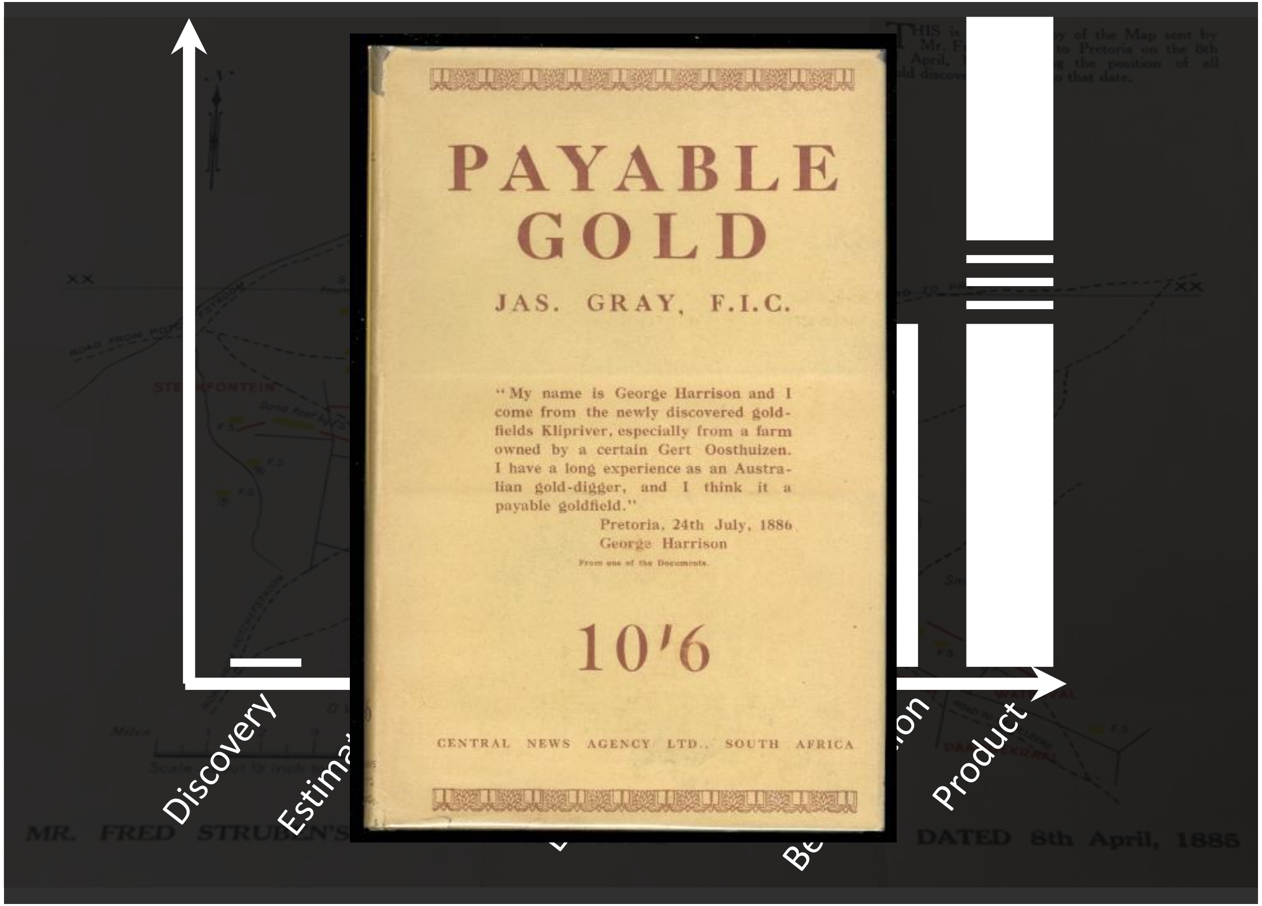


A lesson from History

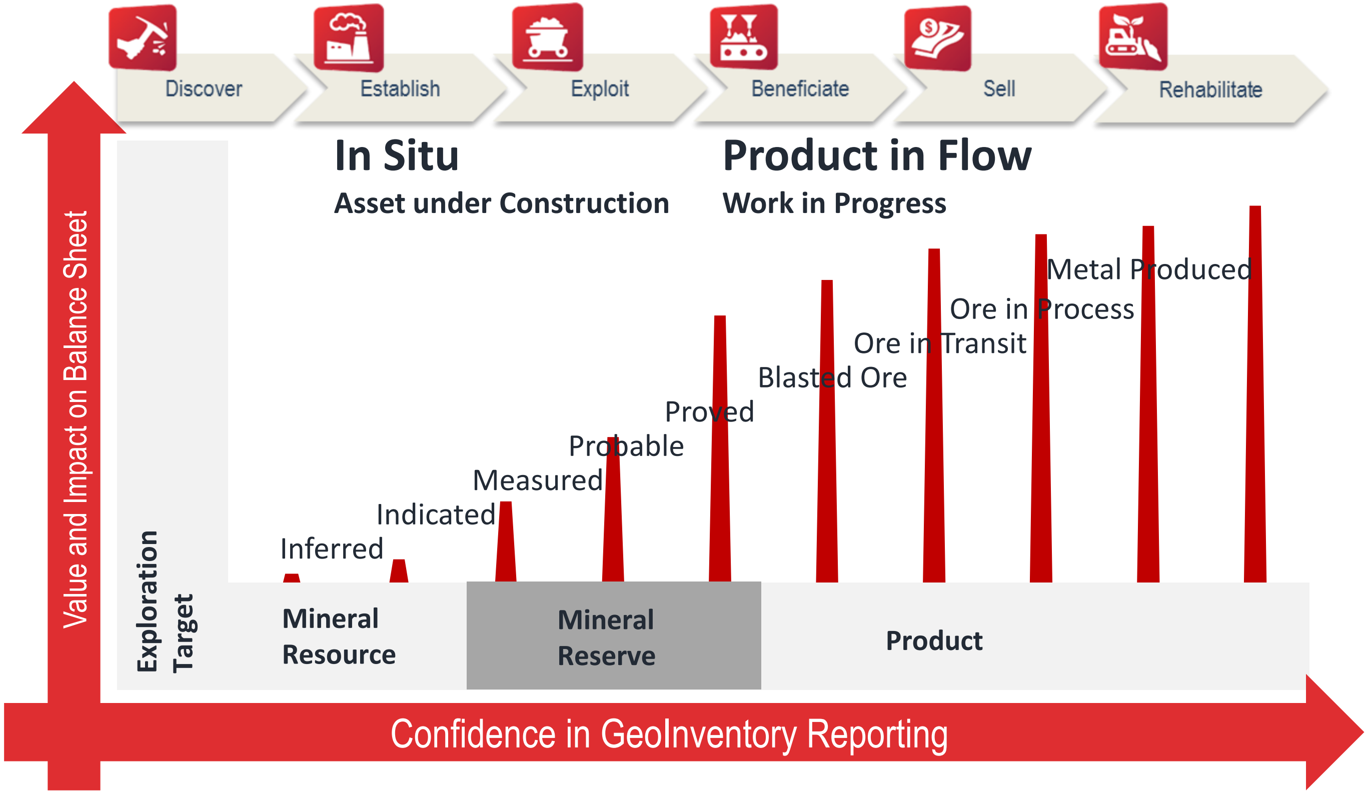
And yet...

1886 1910

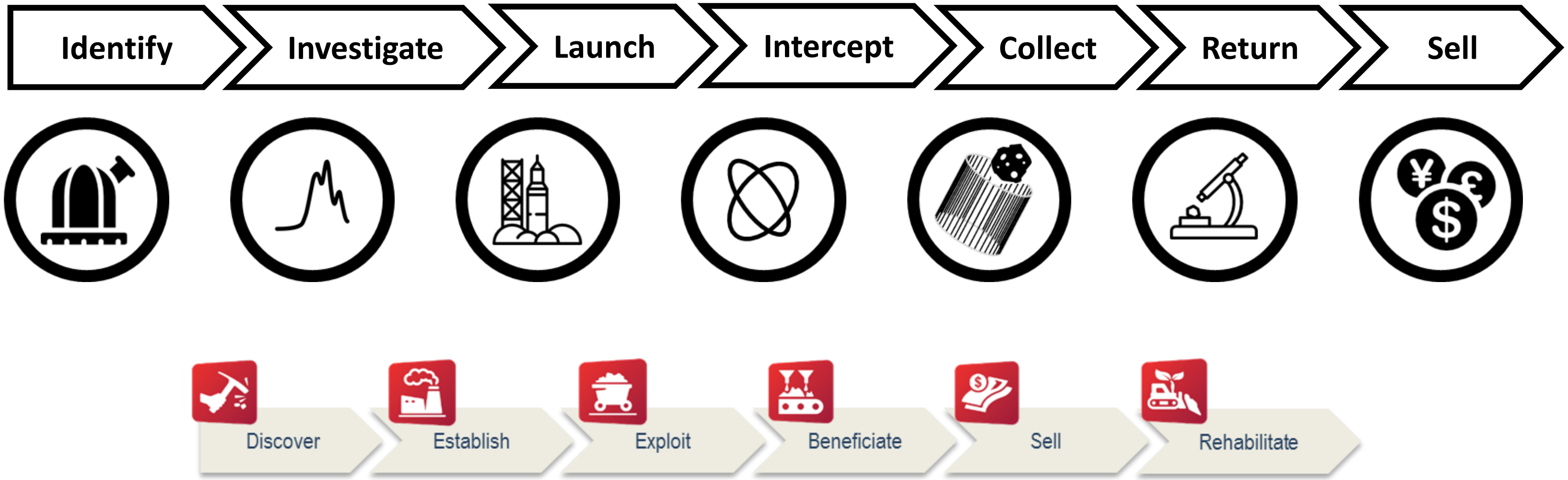
£ 3000 £ 94 809 000 000,00



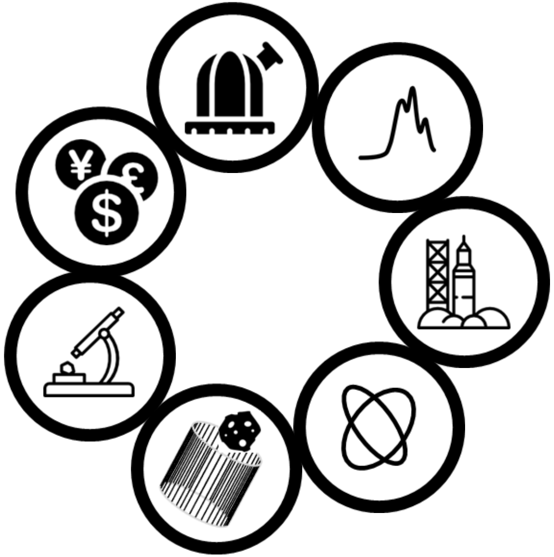
Value Accrual and Confidence



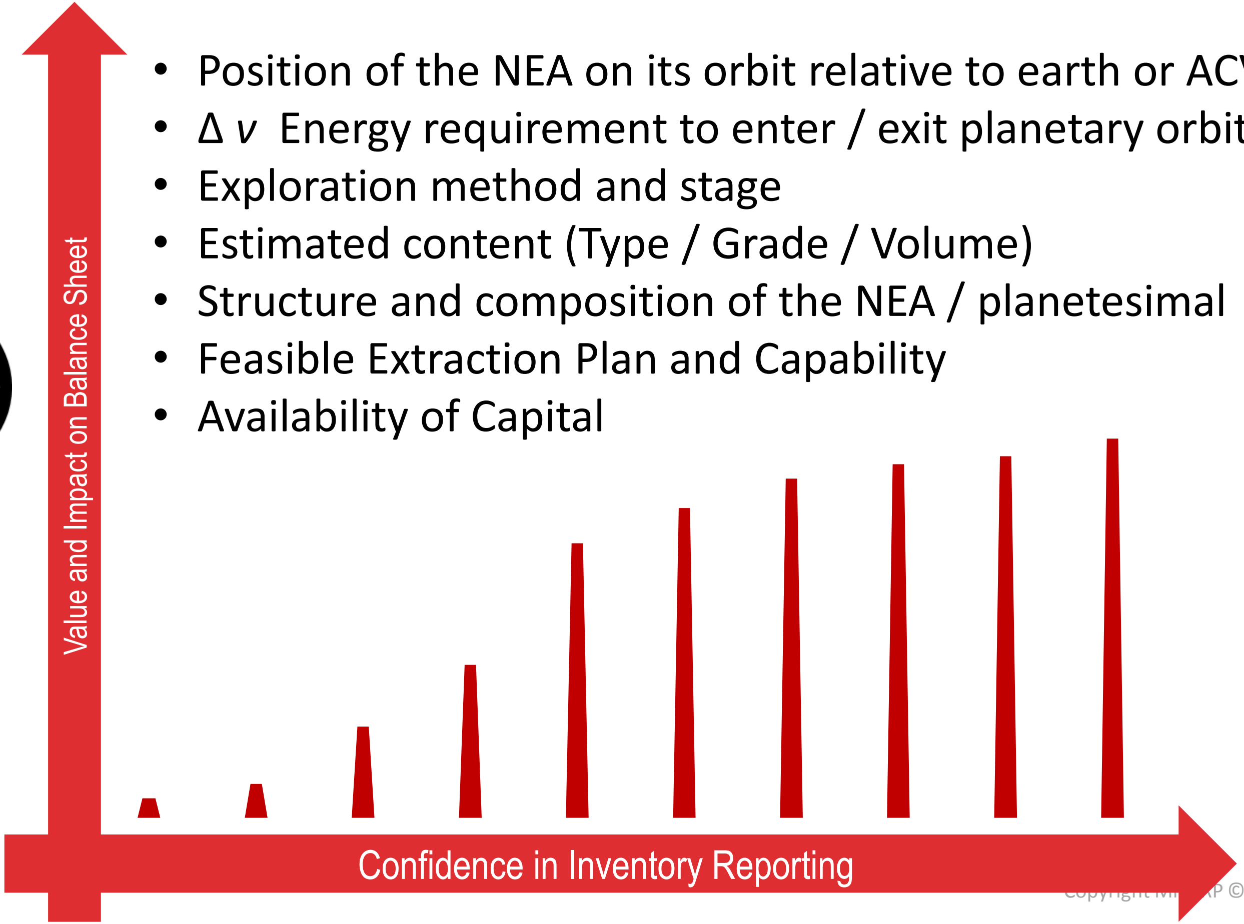
The Space Mining Value Chain



Valuation & Feasibility Criteria



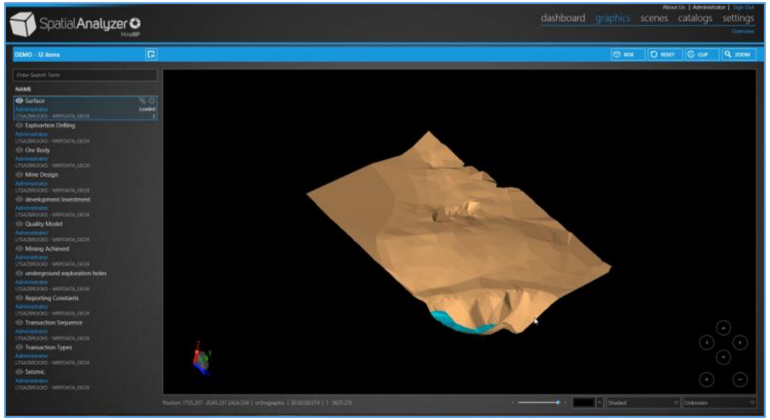
- Position of the NEA on its orbit relative to earth or ACV
- Δ *v* Energy requirement to enter / exit planetary orbits
- Exploration method and stage
- Estimated content (Type / Grade / Volume)
- Structure and composition of the NEA / planetesimal
- Feasible Extraction Plan and Capability
- Availability of Capital

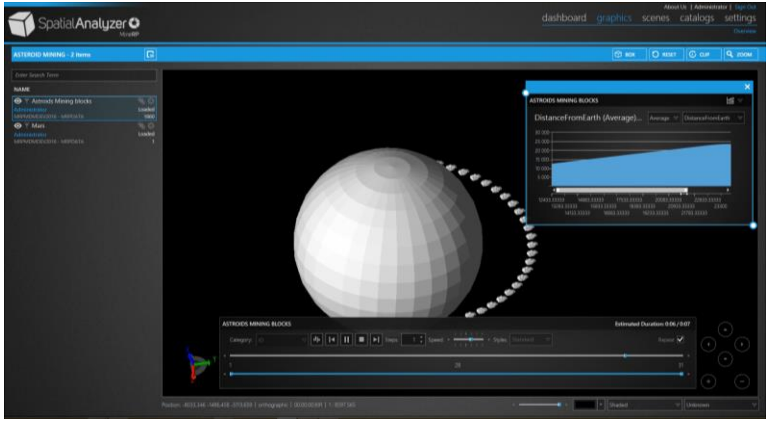


As in mining, the problems are technical and financial

SAP MineRP

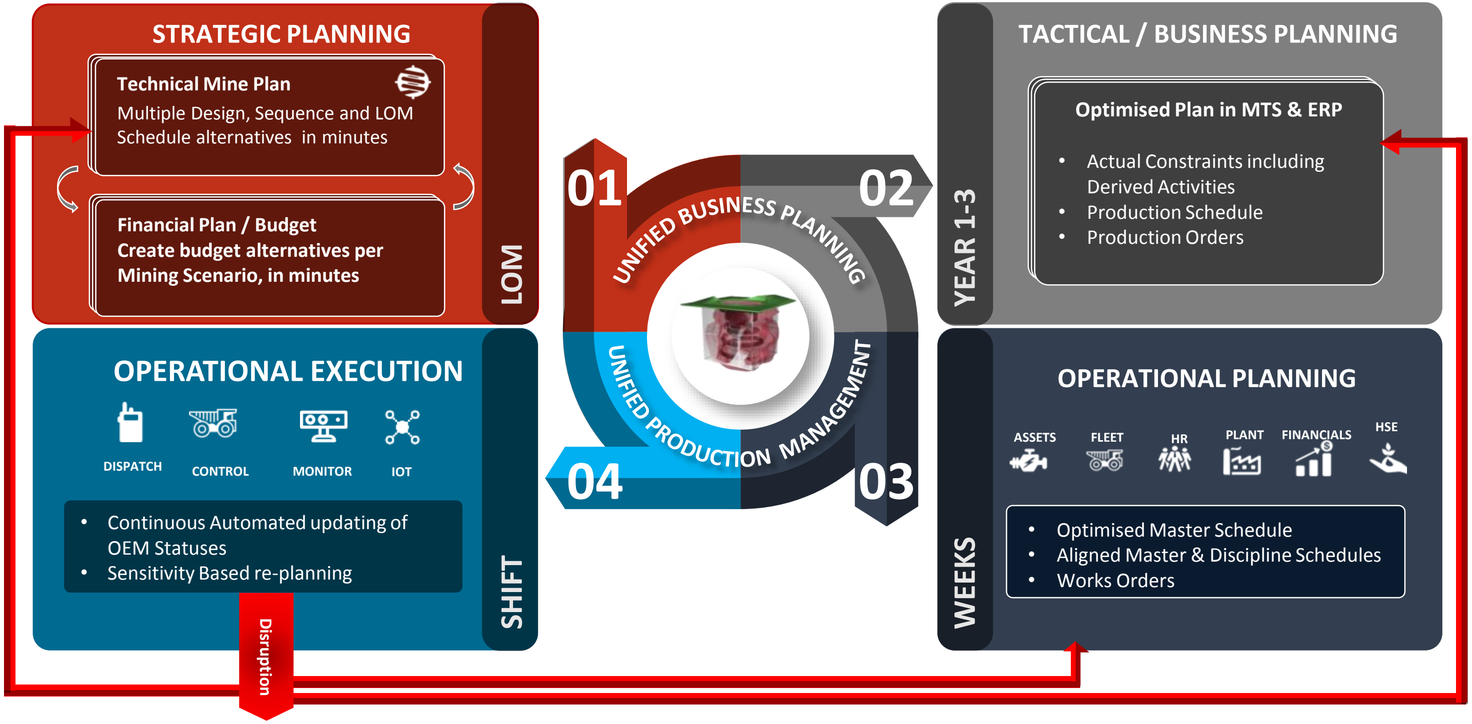
	Terrestrial	Space*
Metal Recovered over Life of Project	7.243Moz	
Initial Construction Capital Cost Estimate	US$759m	
Peak Funding	US$723.8m	
Total Capital Cost over Life of Project	US$1,090.4m	
Capital Efficiency	US$3,312/oz	
After-tax NPV at 5% Discount rate	US$1,550.5m	
After-Tax IRR	20.3%	
Life of Mine	24 years	6-10 years
Payback	6.9 years	6-10 years
Cash Operating Costs	US$343/oz	
Profit Margin	57.97%	
All In Sustaining Costs (“AISC”)	US$ 2839m	
All In Costs (“AIC”) US$542/oz	US$ 3925m	USD 2,6bn





* Asteroid Retrieval Feasibility Study, KECK Institute for Space Studies, 2012

The Art of the Possible



Millisecond Mining: Disruptively rethinking the way mine planning and execution should be working to enable real-time planning, execution and operational control

MineRP's Art of the Possible

SAP MineRP

STRATEGIC PLANNING

Technical Mine Plan
Multiple Design, Sequence and LOM Schedule alternatives in minutes

Financial Plan / Budget
Create budget alternatives per Mining Scenario, in minutes

LOM

TACTICAL / BUSINESS PLANNING

YEAR 1-3

Optimised Plan in MTS & ERP

- Actual Constraints including Derived Activities
- Production Schedule
- Production Orders

OPERATIONAL EXECUTION

DISPATCH CONTROL MONITOR IOT

- Continuous Automated updating of OEM Statuses
- Sensitivity Based re-planning

SHIFT

OPERATIONAL PLANNING

ASSETS FLEET HR PLANT FINANCIALS HSE

- Optimised Master Schedule
- Aligned Master & Discipline Schedules
- Works Orders

WEEKS

Unified Strategic Business Planning

SANDVIK MineRP

STRATEGIC PLANNING

MineRP

Technical Mine Plan
Multiple Design, Sequence and LOM Schedule alternatives in minutes

SAP

Financial Plan / Budget
Create budget alternatives per Mining Scenario, in minutes

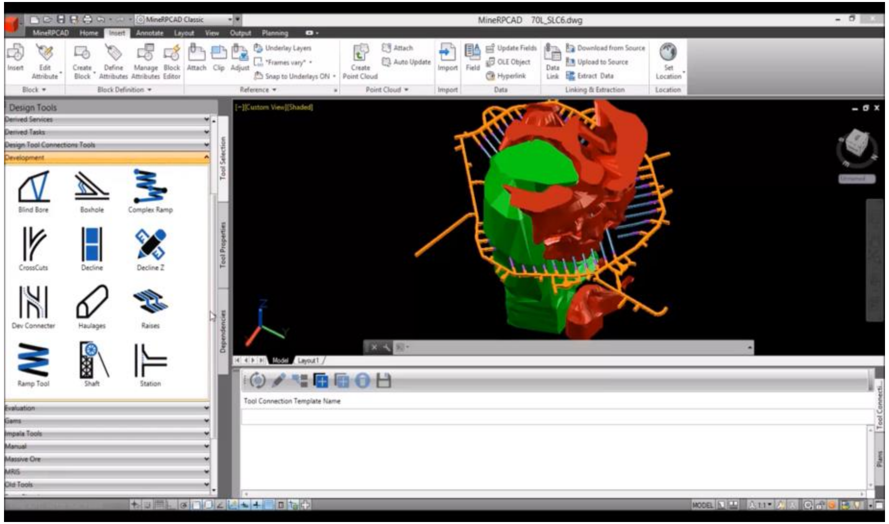
TRADITIONALLY

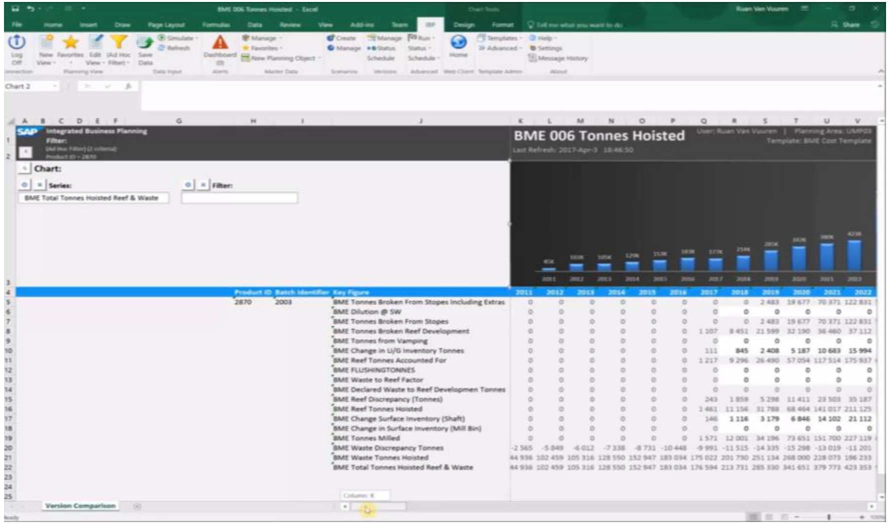
- Design Alternatives take **weeks or months**
- **No Integration** between technical plan and financial plan
- Planned using **average costs & aggregate grades**

WITH MINERP UBP

- **Real-time, parametrically generated** Design Alternatives
- **Fully Integrated** technical and financial scenario plans
- Planned using **Actual / Contracted costs & live Geometallurgical Models**

Unified Strategic Business Planning





MineRP

Technical Mine Plan

Multiple Design, Sequence and LOM Schedule alternatives in minutes

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SAP

SANDVIK MineRP

The MineRP Unified Business Planning Solution

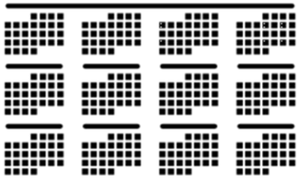
Fully Integrated Mining Technical Systems

Multiple Mine Planning Scenarios

Multiple Financial Planning Scenarios

Digitally Transforming Mine Planning

Year



Reduce Planning Cycle from Months to Minutes

Days

MineRP's Art of the Possible

SAP MineRP

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HR
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HSE

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WEEKS

Real-time Execution Control and Management

OPERATIONAL EXECUTION

DISPATCH CONTROL MONITOR IOT

- Continuous Automated updating of OEM Statuses
- Sensitivity Based re-planning

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OPERATIONAL PLANNING

ASSETS FLEET HR PLANT FINANCIALS HSE

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WEEKS

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