

# TBM :The Birth ,Influences ....and the Future

Martin Knights FREng

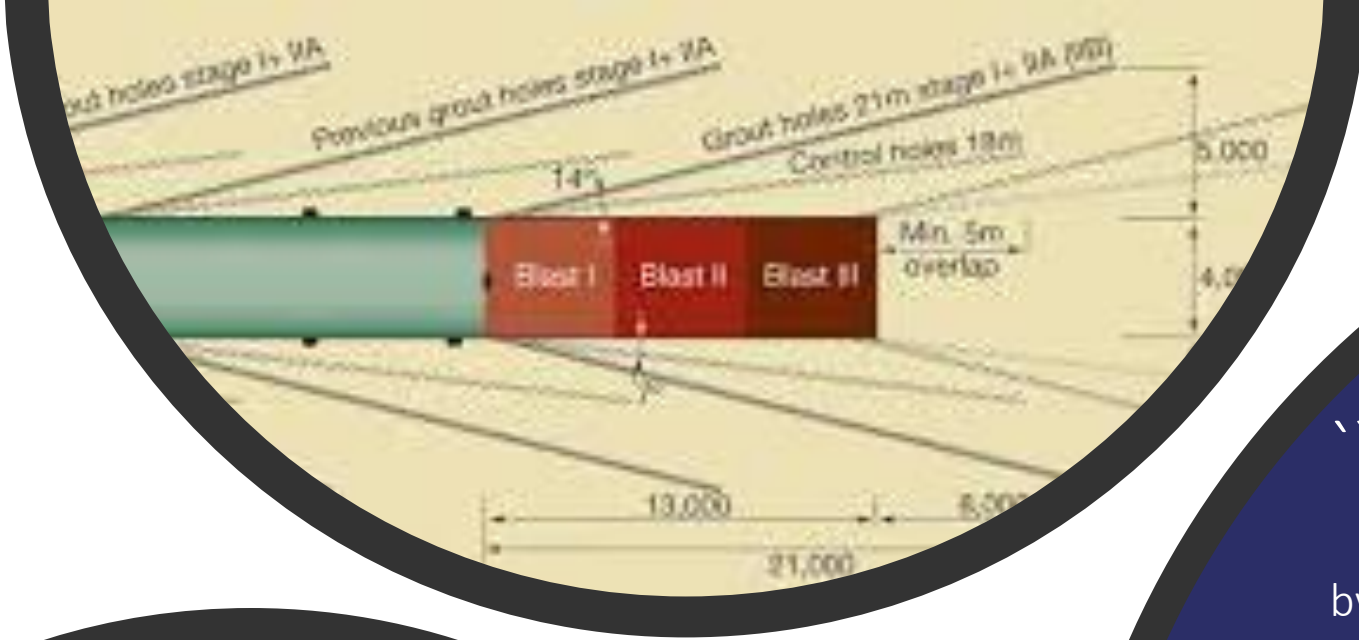
Chairman LBA Ltd UK

Former ITA President

Independent Consulting Engineer







``Norwegian tunnel builders are  
the world's best – a myth?``

by Arild Palmström, MSc, PhD., Rockmass AS 2014

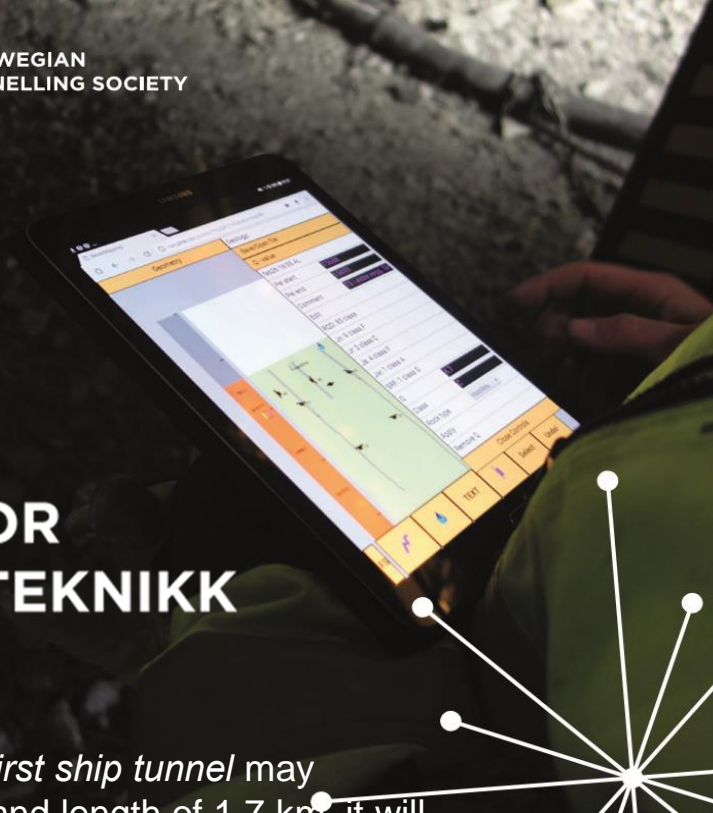


``Maybe in hard rock , but in soft or mixed soil...?``  
Martin Knights FREng 2019



# NORWEGIAN TUNNELLING TECHNOLOGY

Congratulations



## NORSK FORENING FOR FJELLSPRENGNINGSTEKNIKK

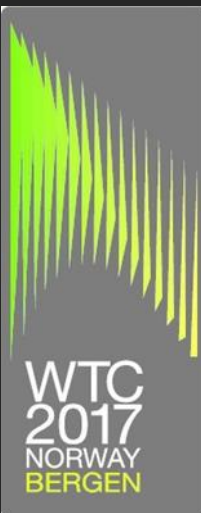
### Leading the world

**Stad Ship Tunnel** – construction of the *world's first ship tunnel* may commence in 2018. With a section of 1620 m<sup>2</sup> and length of 1.7 km, it will offer safe passage through a notoriously exposed piece of coast with many ship accidents

**Solbakk Tunnel** – as a part of the Ryfast connection- the *world's longest subsea road tunnel* will be 14.3 km long when completed in 2018 the *world's deepest road tunnel 2018*

**The Helgeland Tunnel**, the is being planned to descend 396 m below sea level – *more than 100 m below any other road tunnel in the world today* When it opens for traffic in 2023, **Rogfast Road Link** in Rogaland will become the *world's longest sub-sea road tunnel at 27 km*, and *among the world's deepest at 390 m*

The **Follo double-tube Railway tunnel** will be *Norway's longest rail tunnel* when completed in 2021. Most of the 20 km tunnels will be excavated by TBMs.







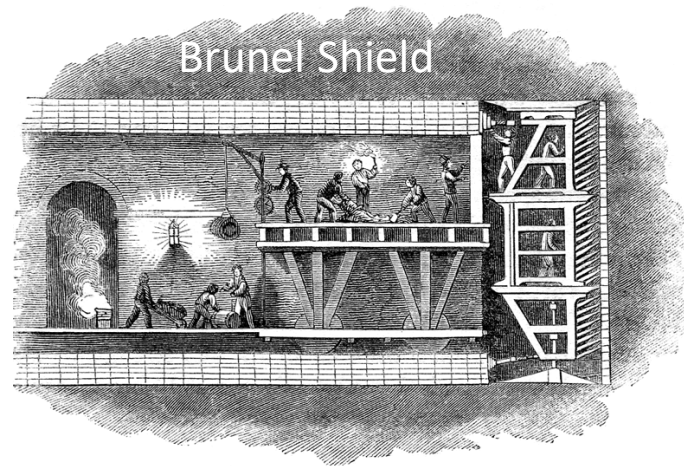
# Contents

- Introduction
- 1 Birth & evolution
- 2 Influences on the tunnel industry
- 3 Predictions
- 4 What can owners do ?



# TBM`s = Family`s and Dynasty`s

But what does TBM mean ?







The British Method ?





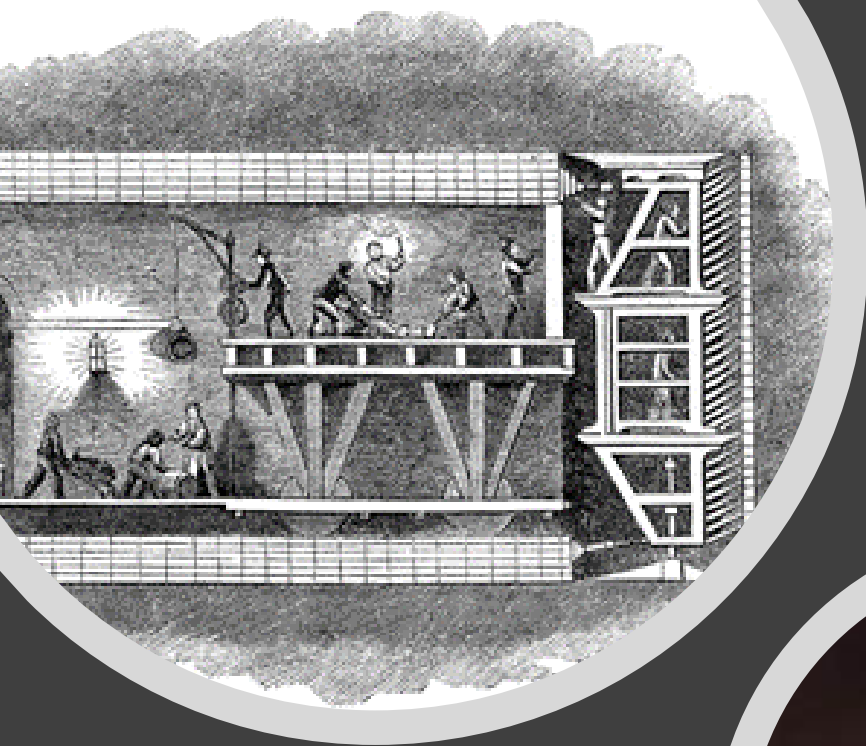
# The Boris (Johnson) Metho



Brexit negotiations enter the `tunnel`







# TBM

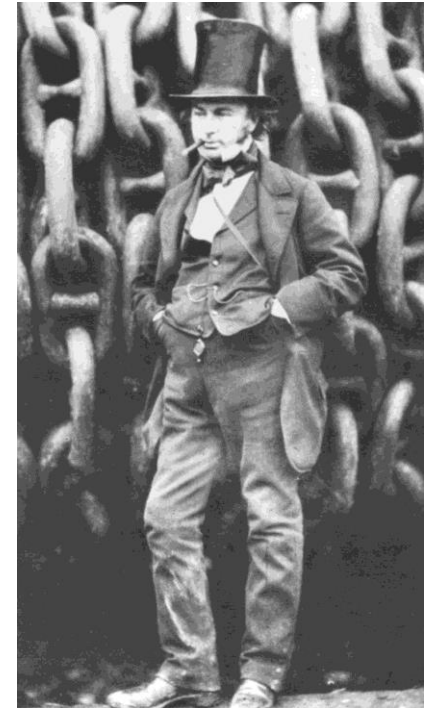
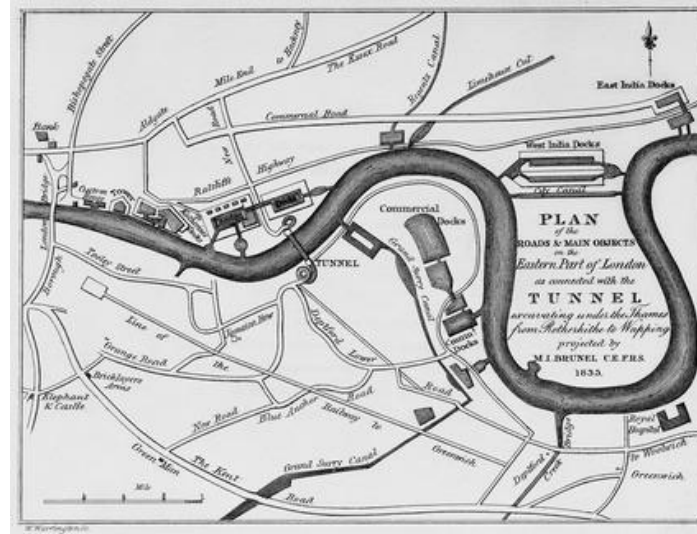
- The Brunel Method
- Innovation!!
- Mother nature



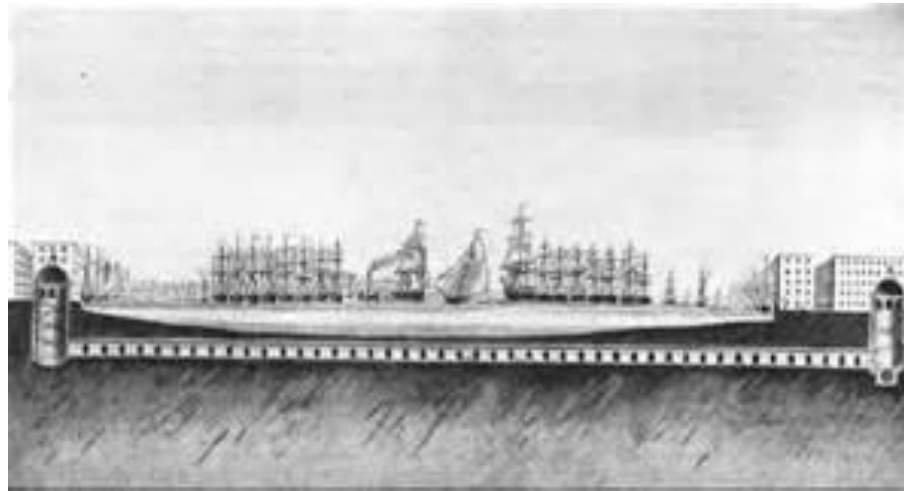
# TBM =The Brunel Method



Sir Marc Brunel -Father& Inventor of the first tunnel shield

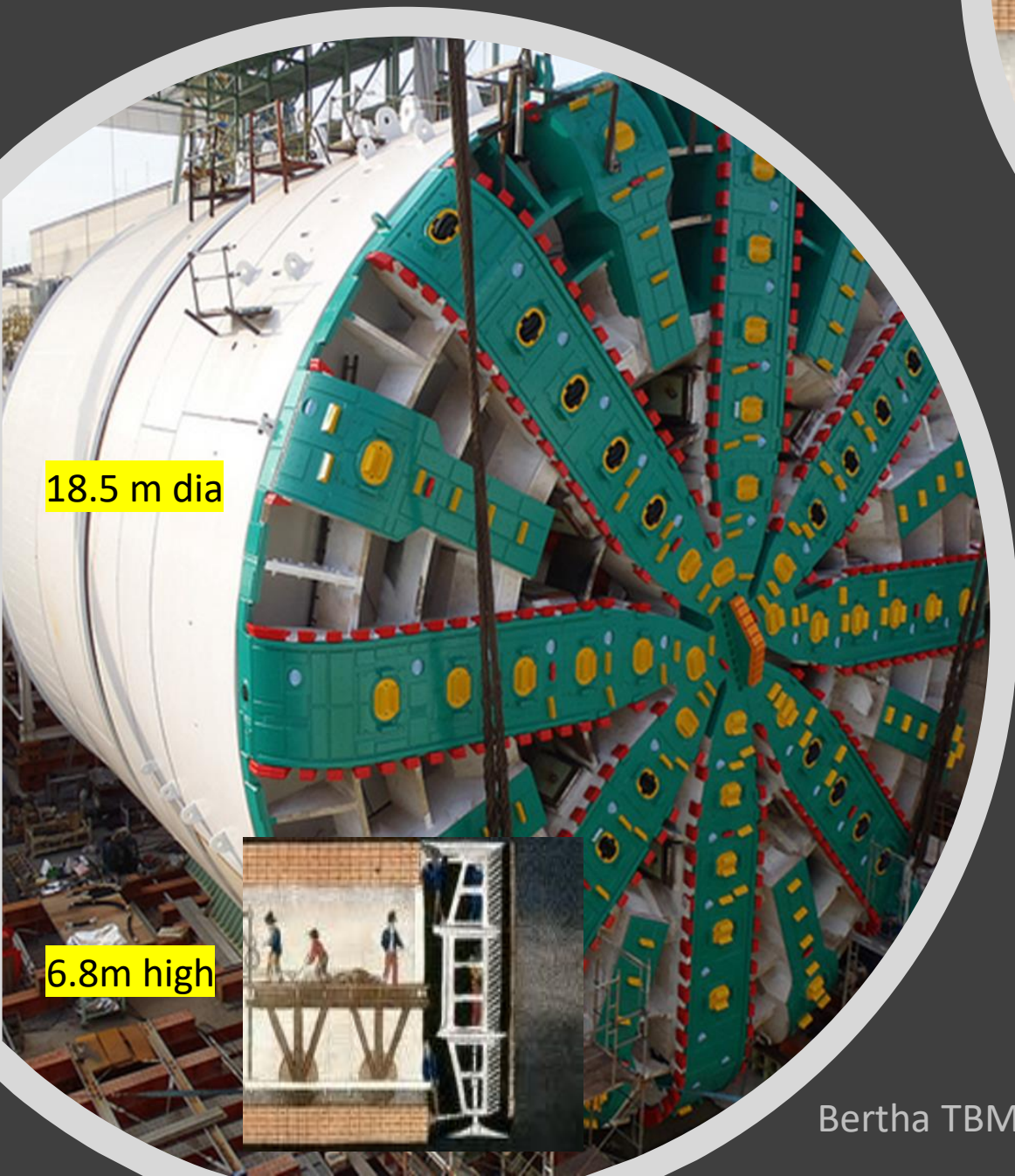


Isambard-son & his first job



The Thames Tunnel





18.5 m dia

6.8m high



London Thames Tunnel Shield 1825

# 1.0 The birth of the TBM & evolution

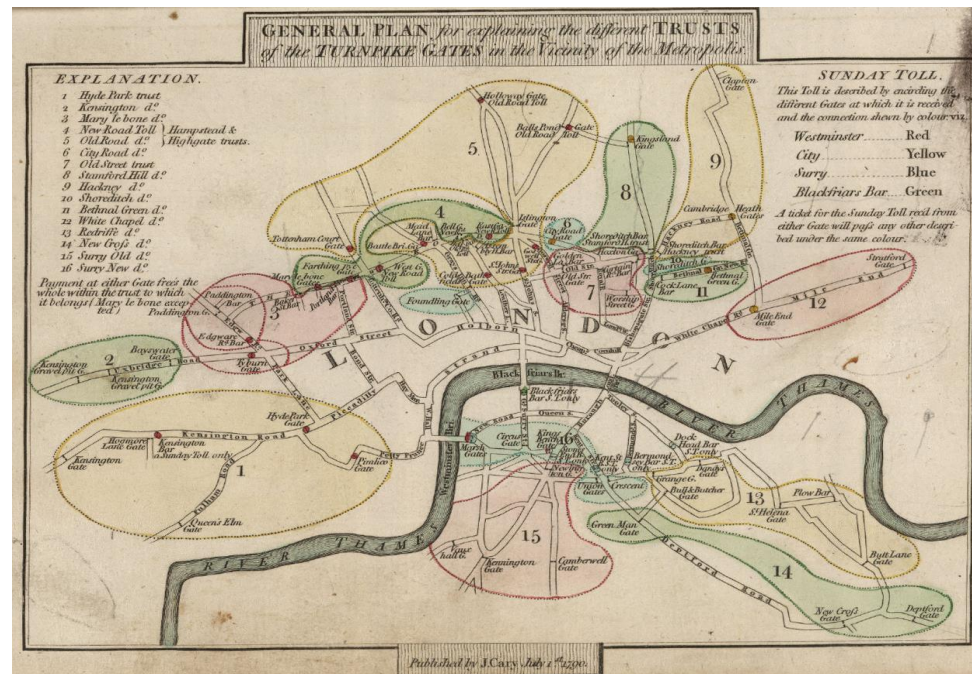
Bertha TBM Seattle 2015





History of The River Thames 50,000BC- 2019





# A River to Cross

Solution ?

A tunnel was the only way to get cargo across the river without stopping the tall masted ships, but no-one had tunnelled under a river before.

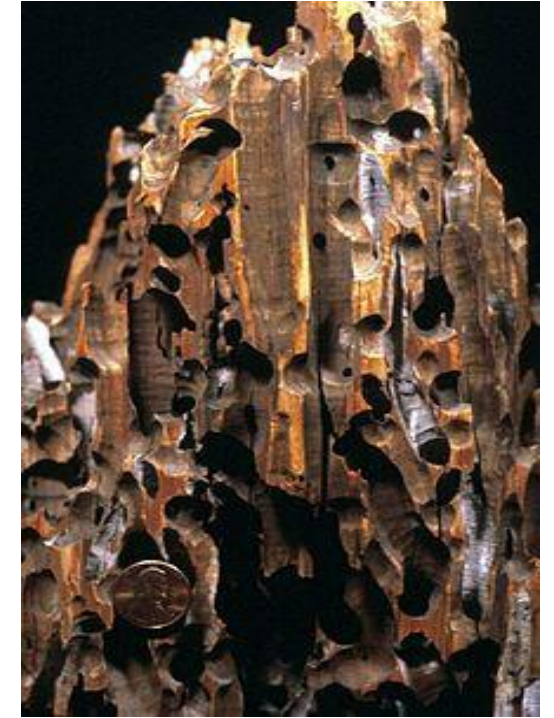




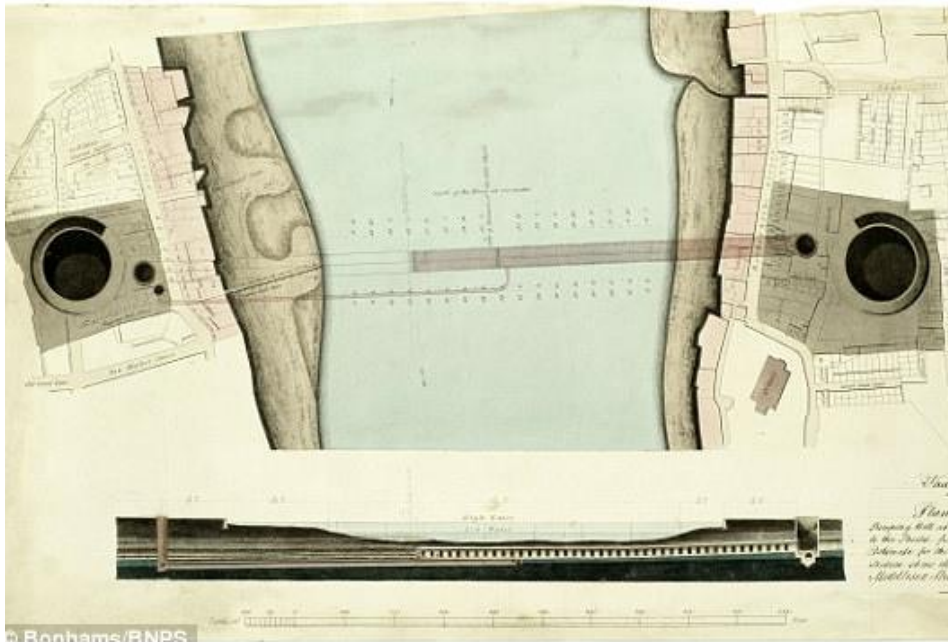
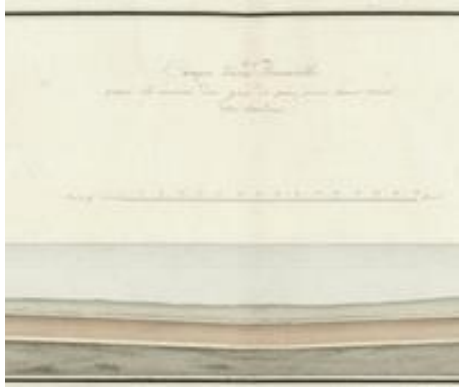
# `*Teredo navalis*`

or `ship worm`

Brunel found the inspiration for his tunnelling shield from *Teredo navalis* which has its head protected by a hard shell whilst it bores through ships' timbers. Brunel's invention and patent in 1818



The ship worm tunnel is circular in cross section and is lined with calcareous material extruded by the mollusc. It can be up to 60 cm (24 in) long and 1 cm (0.4 in) in diameter



© Bonhams/BNPS

## Client instructions for Marc Brunel !

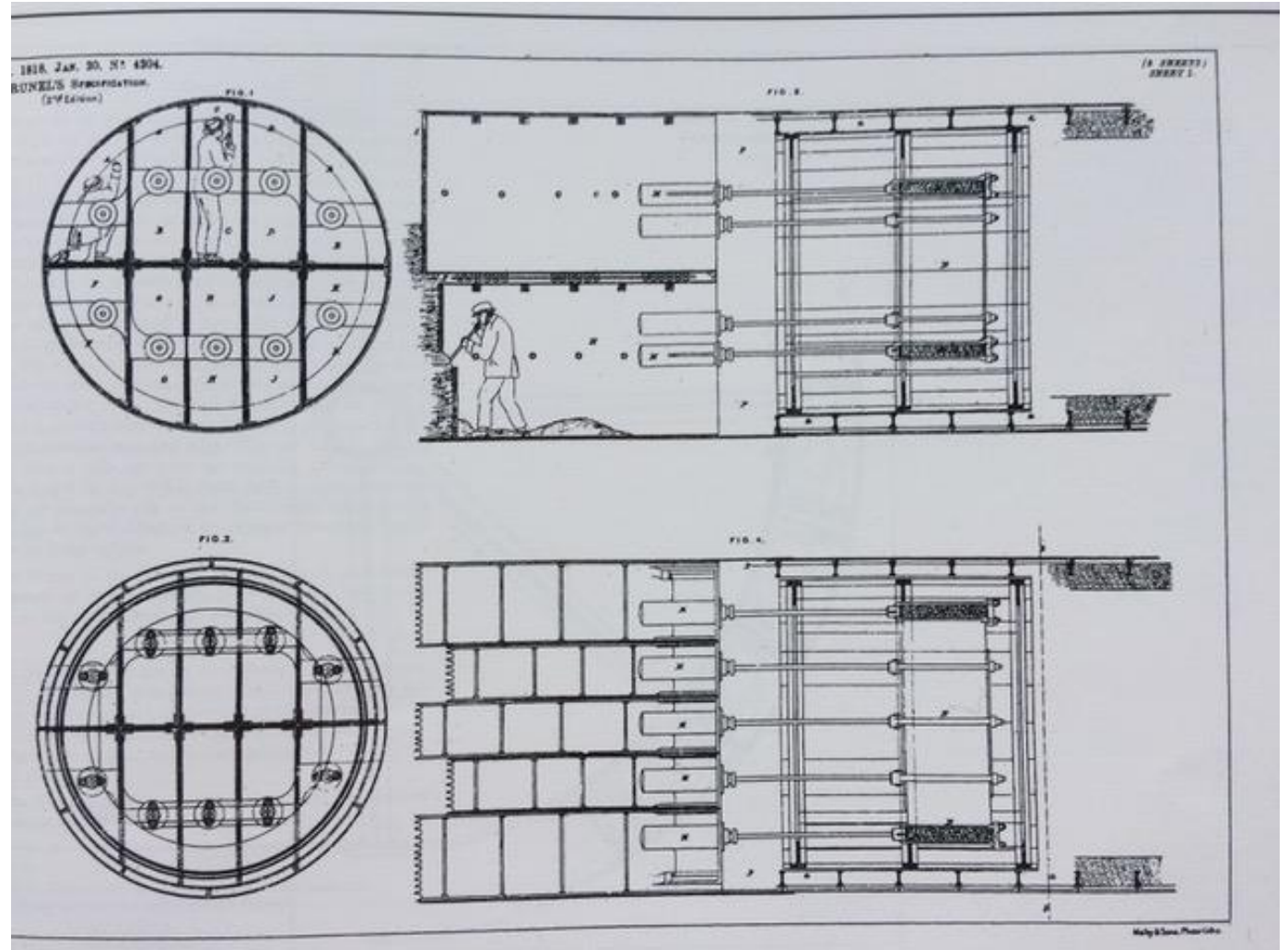
- Cross under the river
- Large enough for horse drawn carriages to pass
- Low cover to tunnel
- Soft gaseous ground
- River Thames was a toxic open sewer!
- Never been done before
- Investors had `tight budget`
- Do it ASAP!



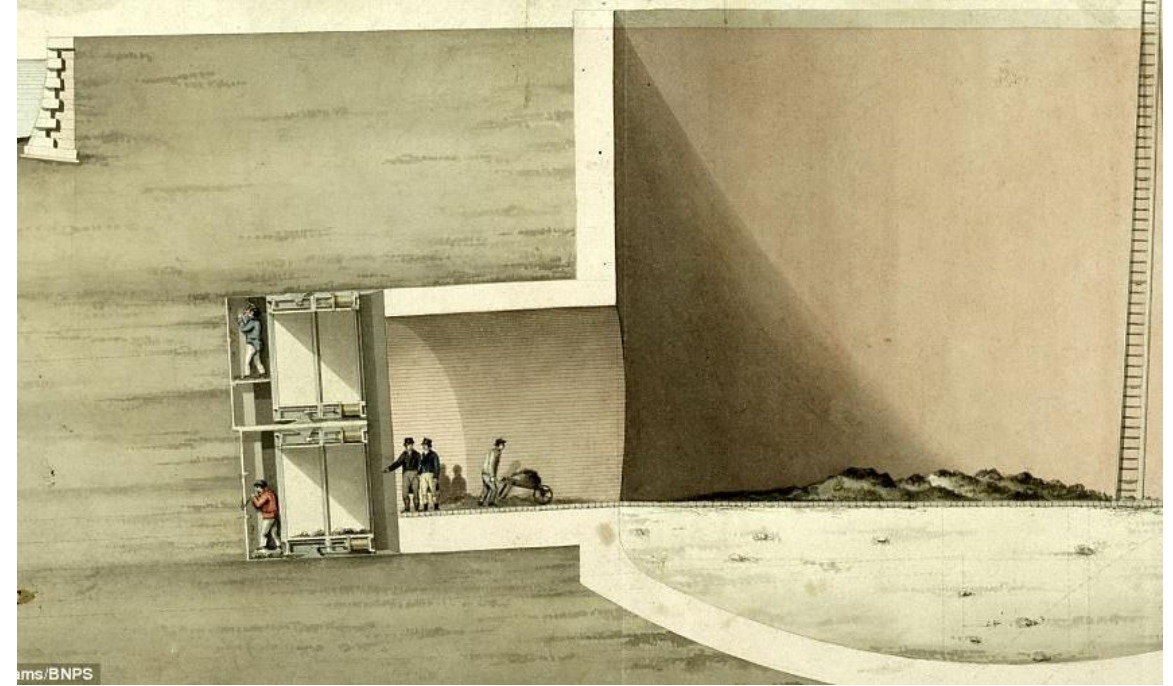
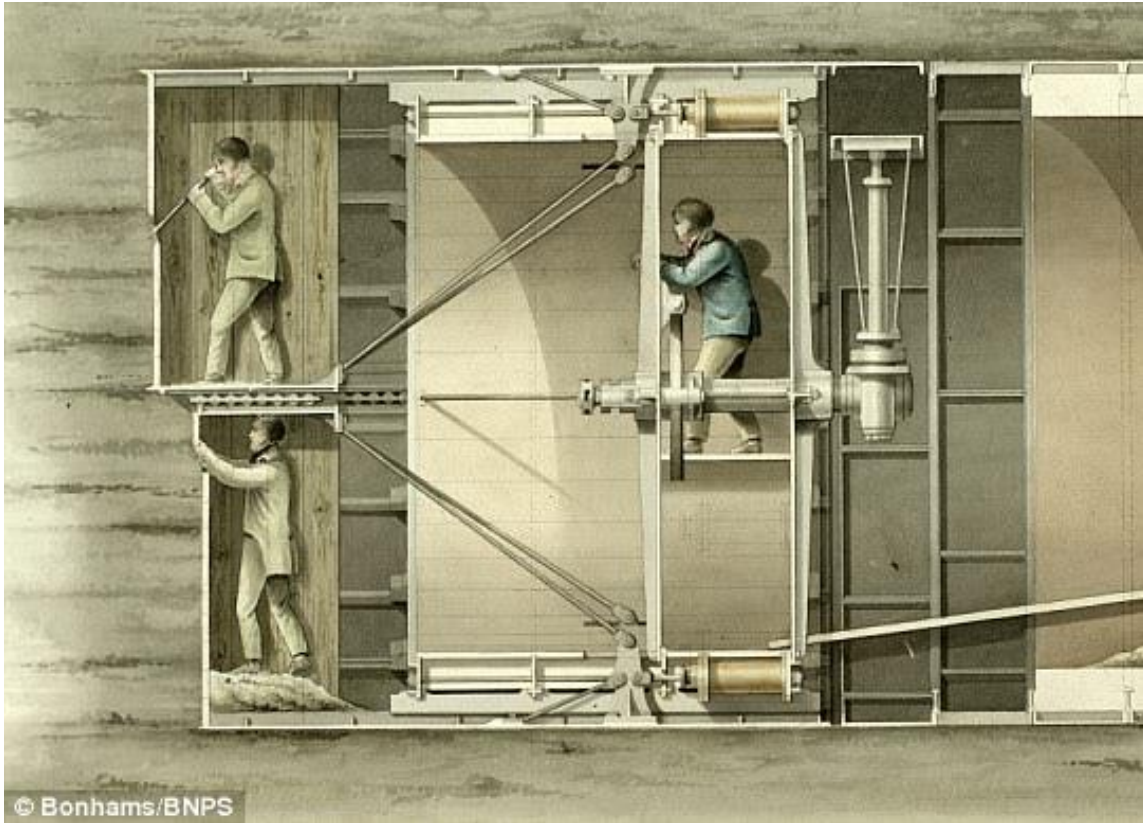
# Early idea's

Evolution of early innovative  
thoughts

Patent 1818





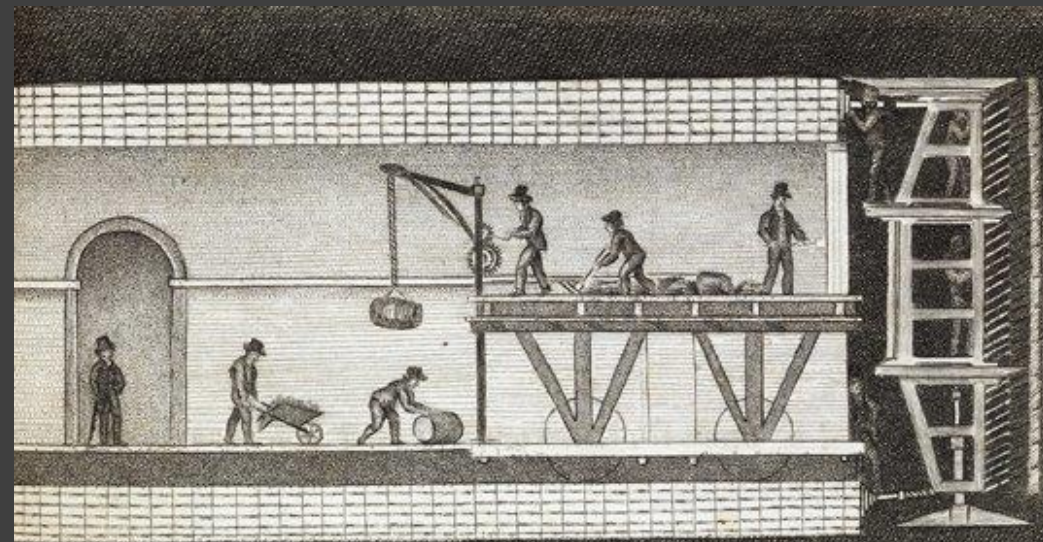
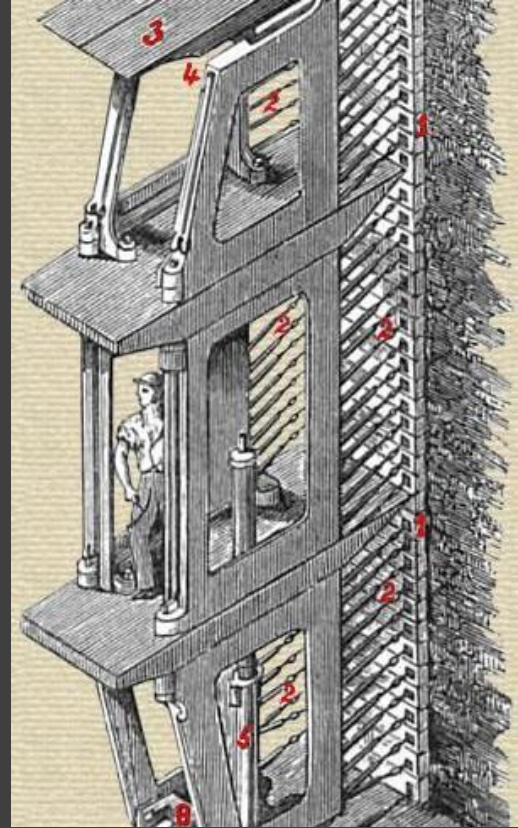
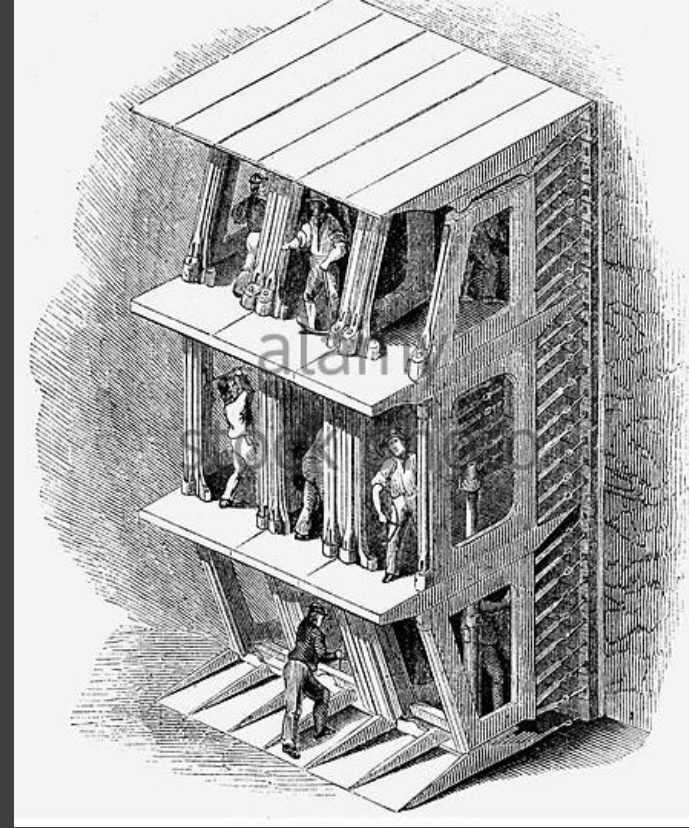
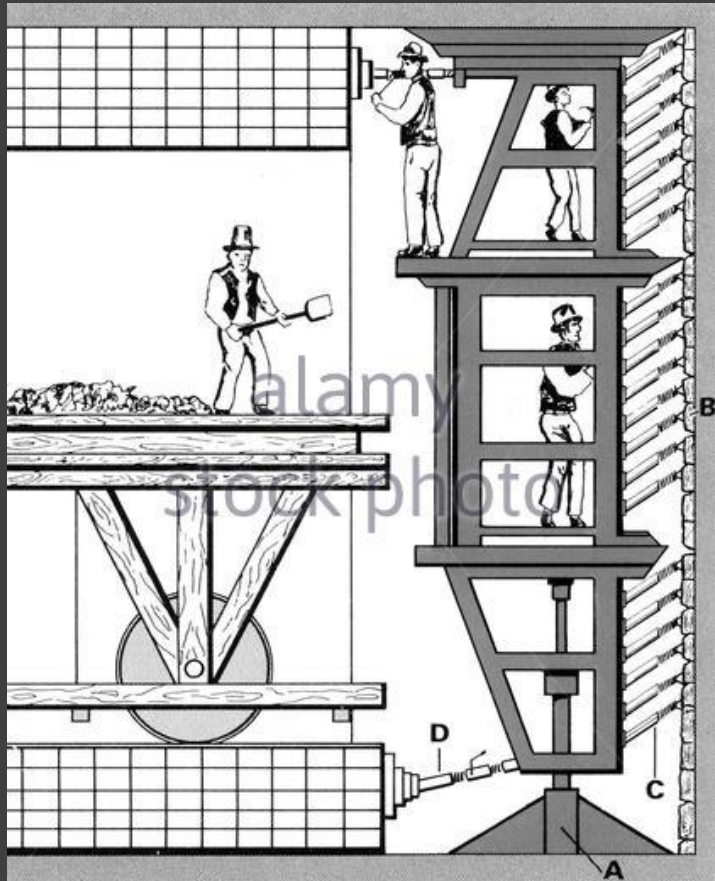


Brunel's proposals were illustrated using the 'Powerpoint' of the 19<sup>th</sup> Century !

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# Marc Brunel's solution The world's first tunnelling shield





St Clair Rail Tunnel    The first underwater rail tunnel in North America was opened by the St. Clair Tunnel Company in 1891.

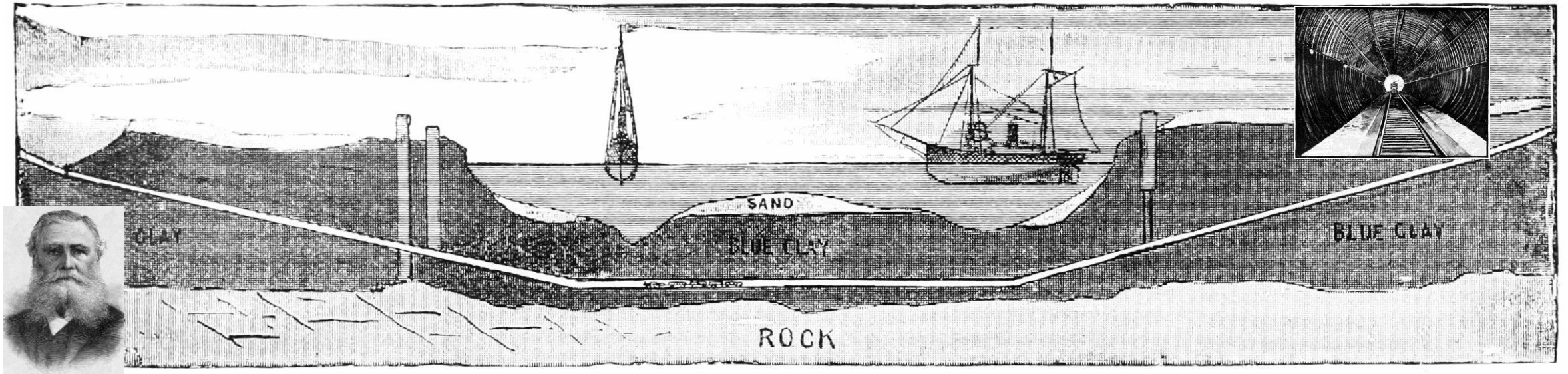
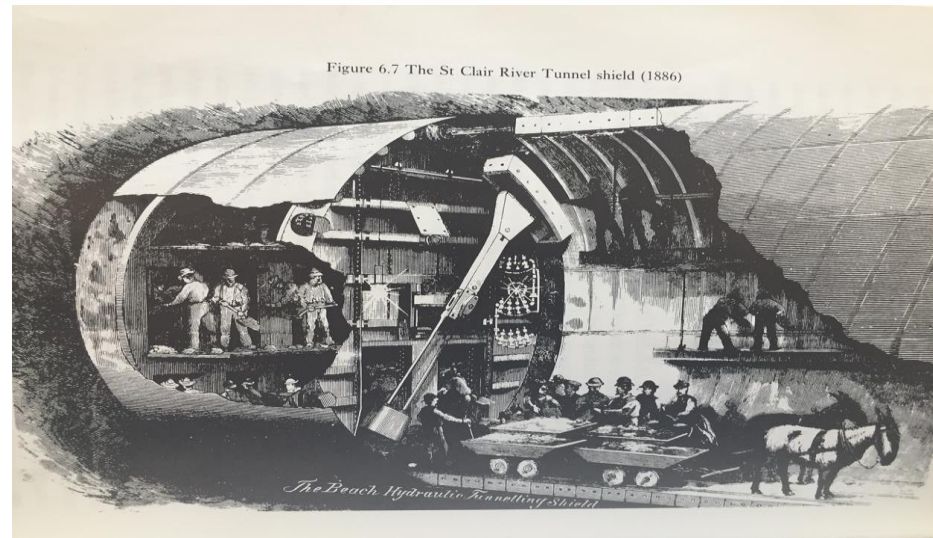


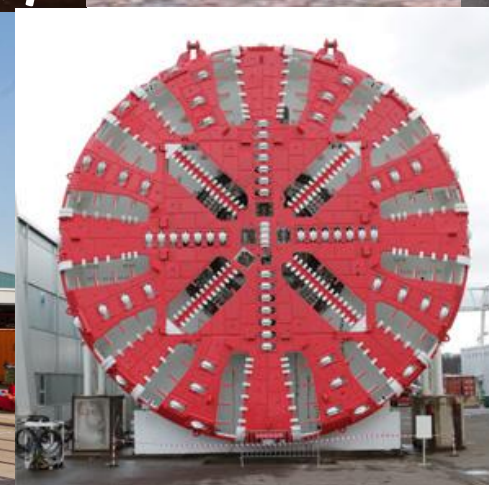
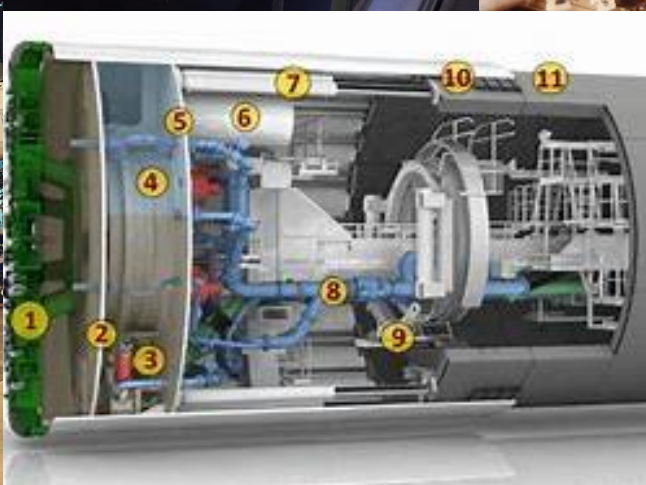
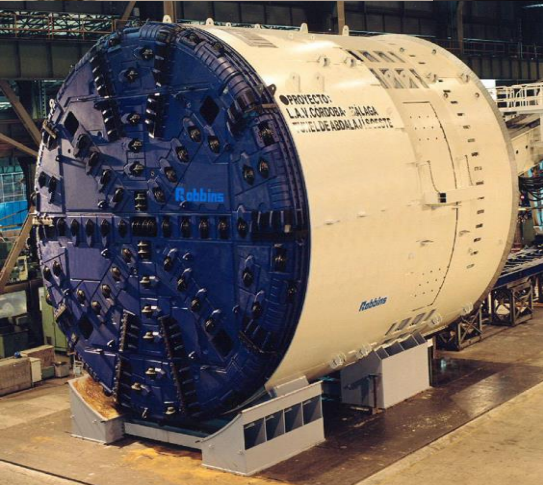
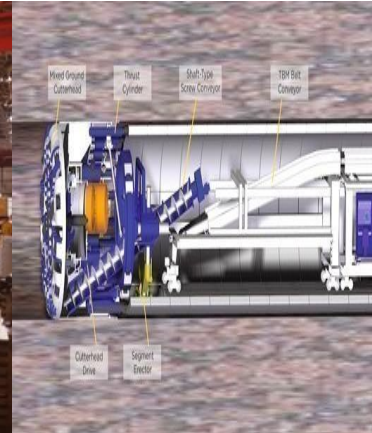
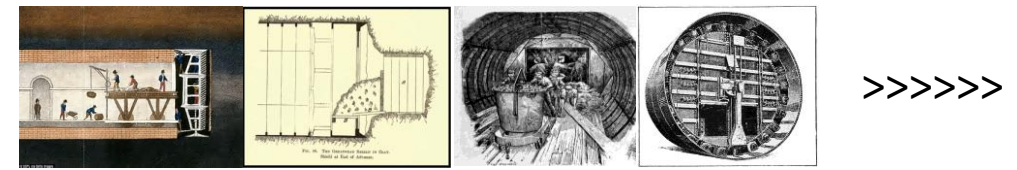
Figure 6.7 The St Clair River Tunnel shield (1886)





# Evolution of shields and TBMs

OVER 200 YEARS of Tunnelling under London





# 2.0 Rock TBM's

- Early attempts 19<sup>th</sup> Century
- The English French Channel Tunnel
- Beaumont TBM
- Chalk & Gault Clays

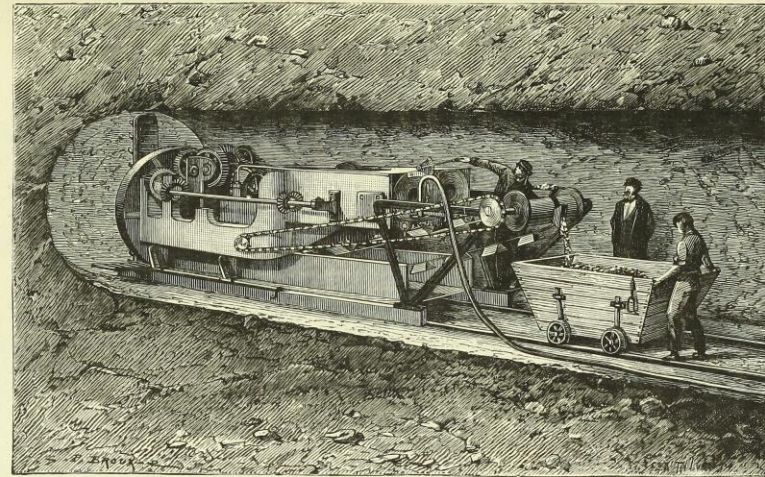
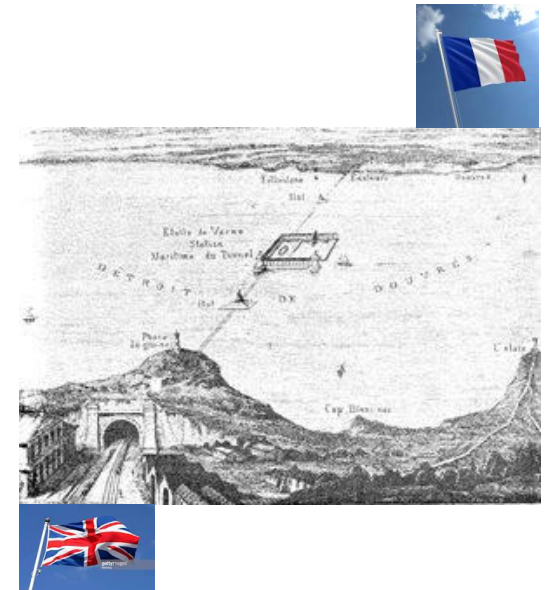
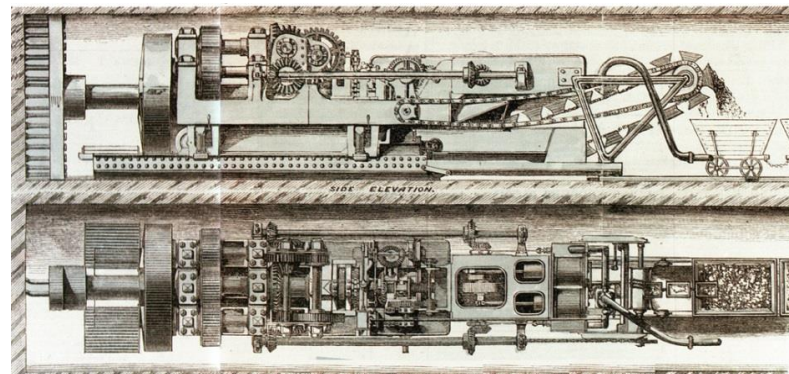
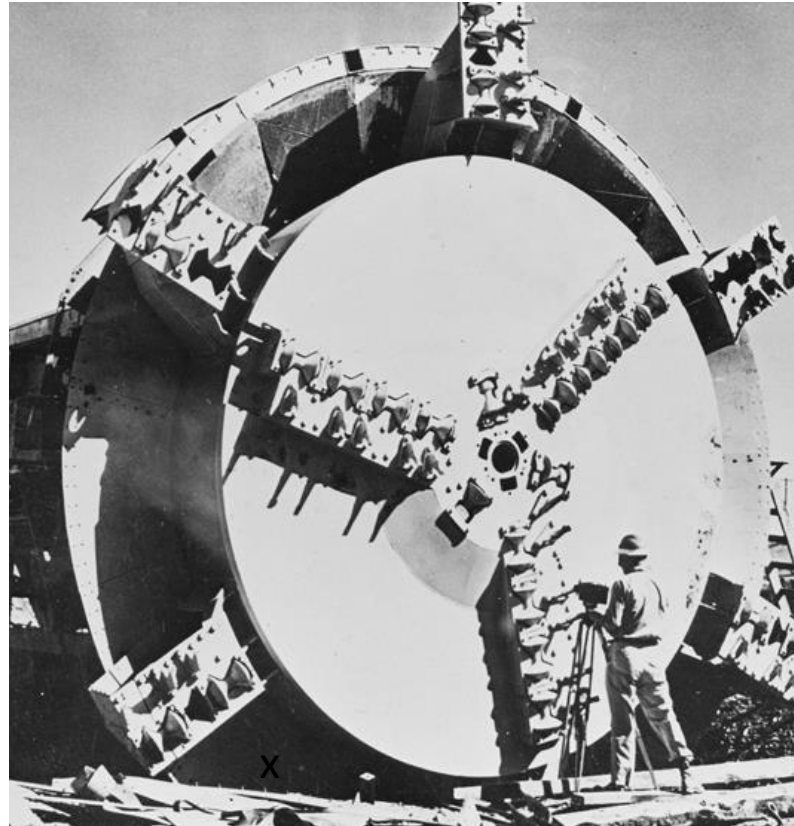


FIG. 150. — MACHINE BEAUMONT POUR LE CREUSEMENT DES TUNNELS DANS LES ROCHES TENDRES







Mangla Dam 1960's  
& 2<sup>nd</sup> Mersey Tunnel Liverpool 1970's  
*My first project*

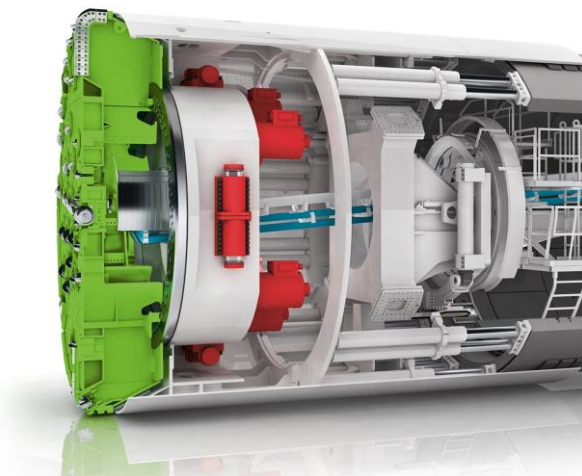
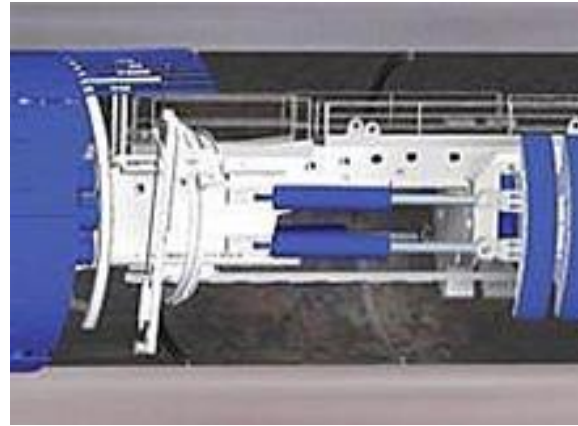
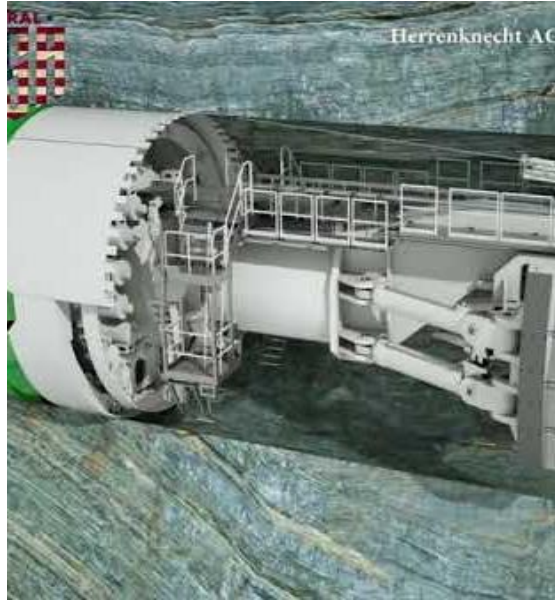
## Robbins Rock TBM's

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1950's 1960's 1970's

Based on ideas by Charles Wilson USA 1850





## Types of Rock tunnelling machine

Main Beam; Gripper; Single & Double Shield and VDM'S

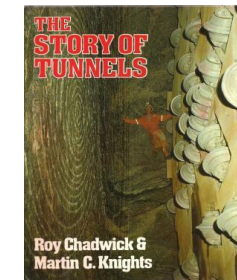
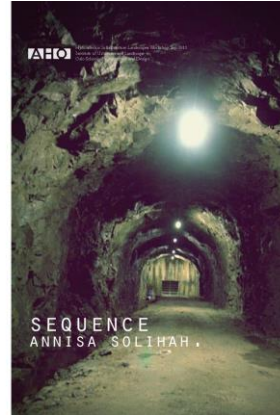
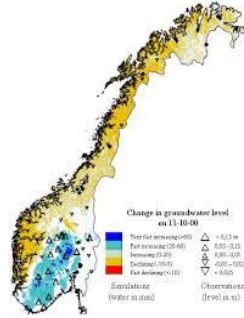
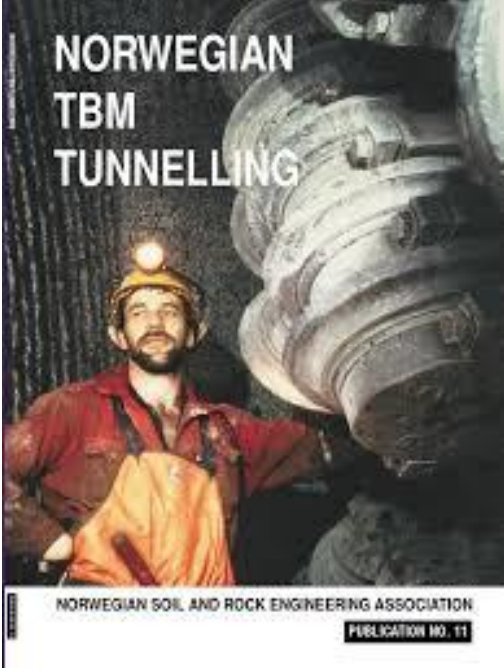




## My favourite TBM !

Seli Double Shield .First TBM to successfully tunnel under the Himalaya`s in squeezing , high water pressure ground-- 2015





Mr I Bohn Sorumsand laboratory 1922

Tokke Hydroelectric Project 1967 -1 m dia

Follo Line 2019

More to follow in future ..

``Norway to begin new TBM era`` TJ 2014

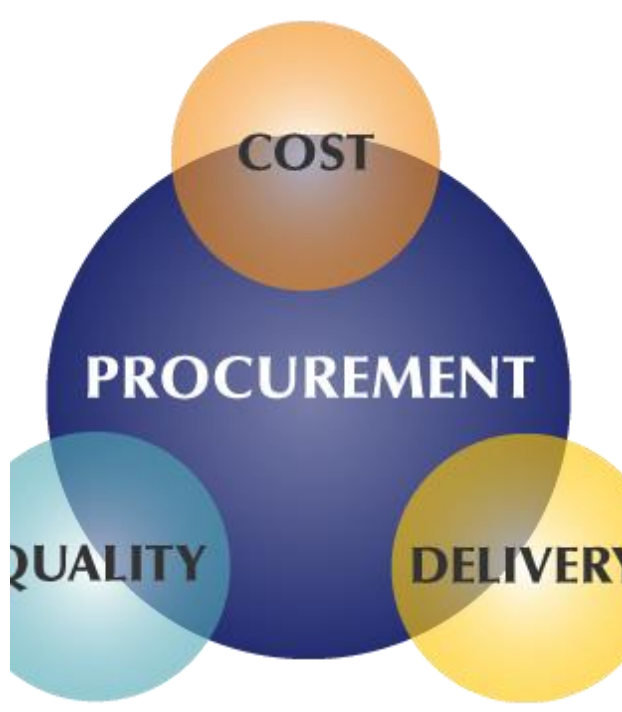


### 3.0 Recent Significant `soft` Influences`



- Pressure on cities –more urban `shallow tunnelling` eg metro`s
- More confidence ....therefore More work !!!
- More competition & ..
- Value for Money procurement
- As a result....*Better served by The Market*
- Better training & skills
- More research funding
- Attract talent & diversity
- Better risk management approaches
- Climate influenced design ..carbon reduction
- Resilience/ Sustainability /Mobility /Public Health
- More empathy with owners /public/media
- Urban tunnelling is more popular !
- Tunnelling is `sustainable` & effective





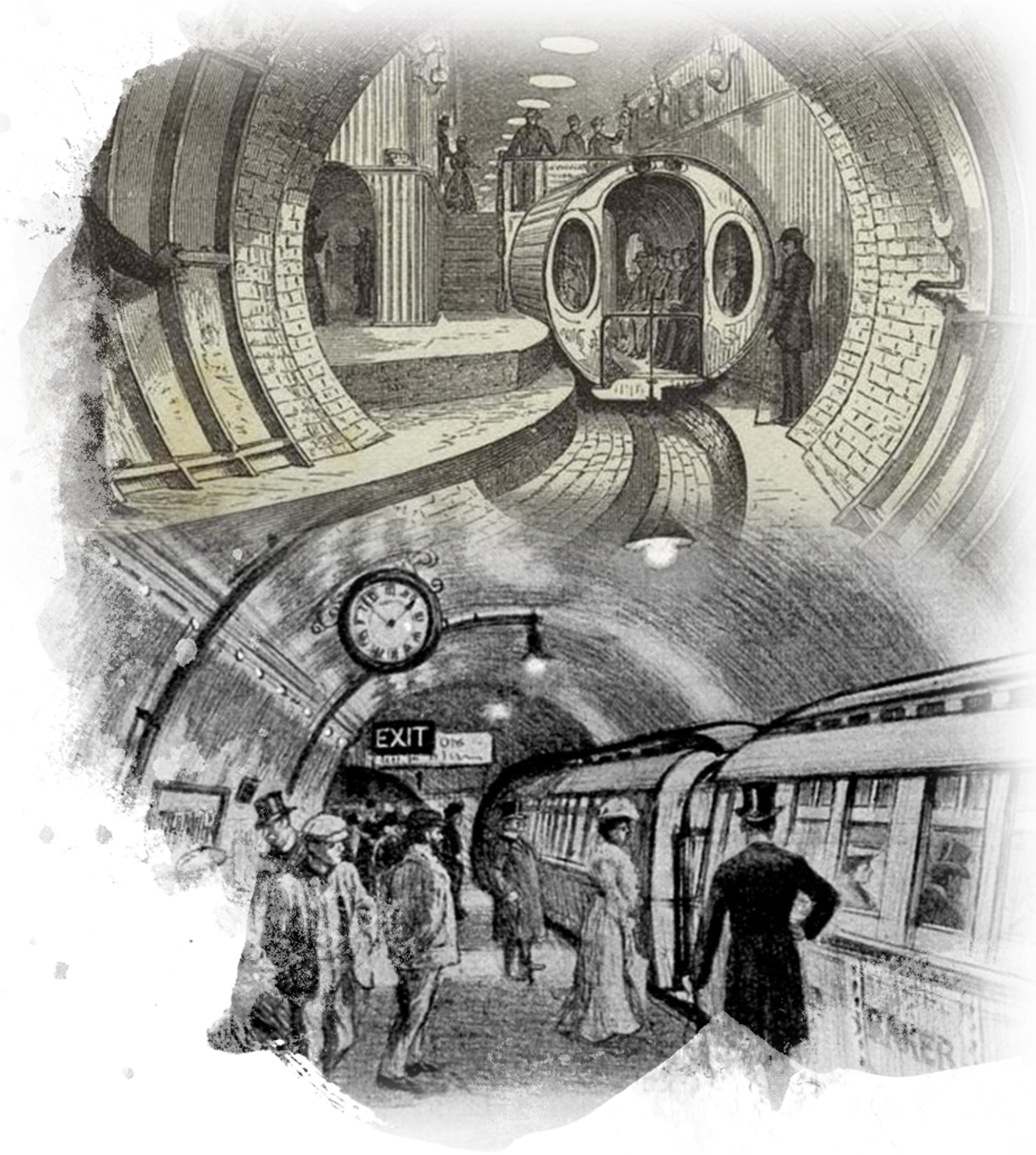
## Recent Key Advances

- Safety Culture/legislation
- Control and process
- Materials science
- Improved mechanisation
- Skills/talent /training
- Proactive Market
- Procurement & Contracts
- Computing power/ managing data
- Prediction /AI
- **What does this mean for the future?**



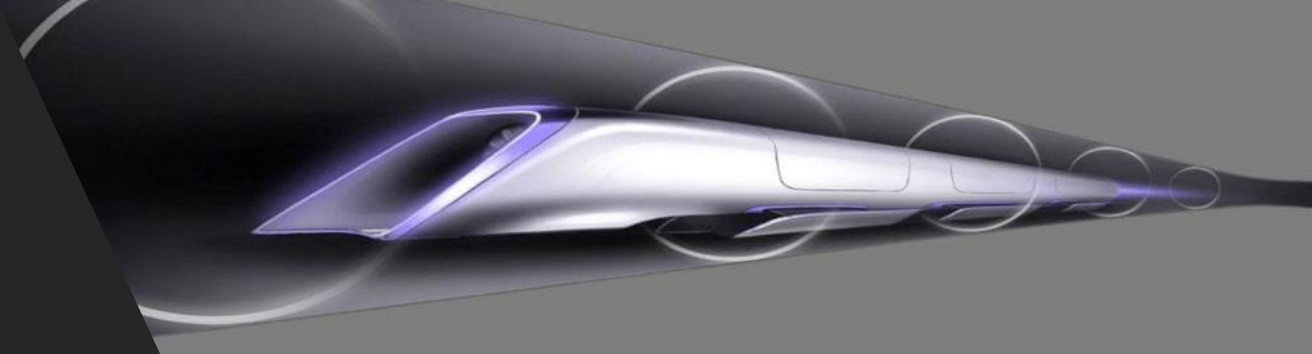
## 4.0 Back to the Future!

This used to be the future!





Is this the future?





# This is **Elon**

He thinks this is the future!

**Elon** wanted a safe payment method,  
so he created **PayPal**.

**Elon** wanted to drive an electric car,  
so he founded **Tesla Motors**.

**Elon** wanted to go to space,  
so he created **SpaceX**.

**Elon** wanted faster transportation,  
so he is developing the **Hyperloop**.

**Elon's** now into tunnelling –OMG!

**Elon** does not complain how bad the  
world is.

He is changing the world.

**Be like Elon.**







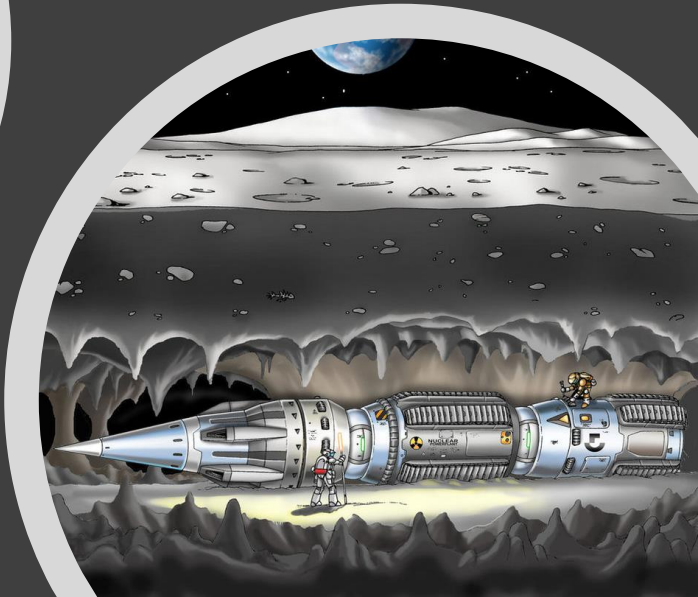
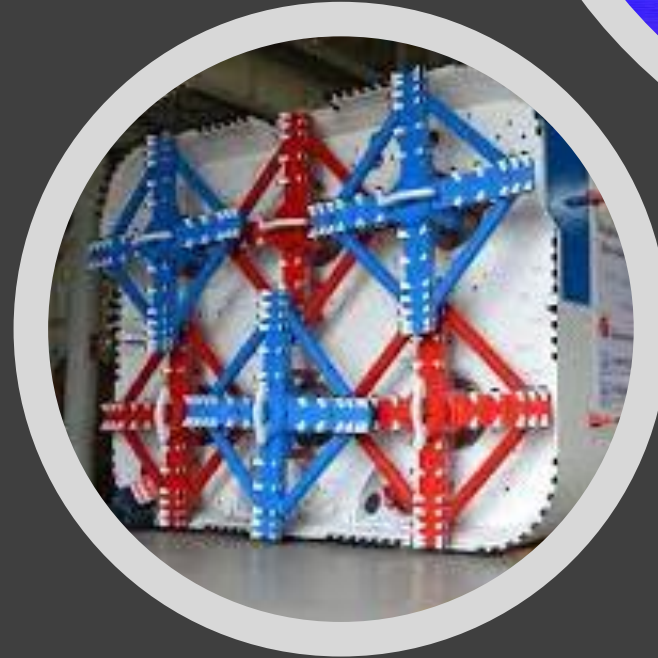
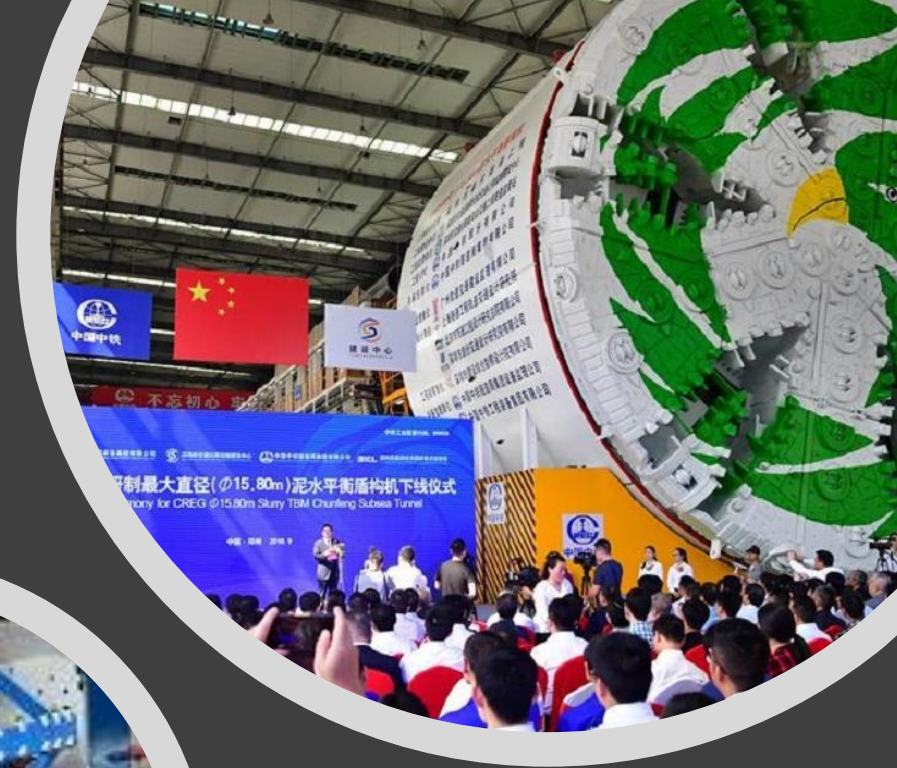
“Las Vegas bets \$48m on  
Elon Musk's tunnel vision”  
Elon `thinks` The Boring  
Company can complete the  
tunnel by the *end of 2019*.

Dated May 24, 2019 -- 10:45 GMT (11:45 BST) | Topic: [Innovation](#)



# The future will include ...

- *Effective data management*
- *Big and Bigger Data; Digital Platforms; BIM level 7 & beyond!*
- AI Computing, algorithms, intuitive `machine`s & improved analysis
- Better controls
- Improved control of ground movement
- Efficiencies in logistics—segment & materials handling, productivity
- Safety ,health and welfare
- `Social value`
- Less underground labour ,more automation & mechanisation( carbon efficient too)
- Next generation materials— grouts, additives, fibres, , graphene, recyclable plastics, self healing materials
- Need to improve to make tunnelling affordable & effective
- China will want to sell you a TBM
- *Knowing what we don`t know now!*





# TBM future --- areas for improvement, development..?

**Business model**

**More automation**

**Automatic ring build**

**Logistics –a critical area!**

**Face mapping**

**Soil conditioning**

**Skills & training**

**Continuous tunnelling**

**Supply chain**

**Service as a `value`**

**Long term relationships & collaboration contracts**

**Early --Earlier involvement**

**Gasket design**

**Segment design and handling**

**Tail seal**

**Muck disposal**

**Cutter wear improvements**

**Re use & Rennovation of TBMs**

**Safety and welfare**

*More Carbon Reduction -we just have to do it!*





# 5.0 What can owner`s do re the use of TBMs?!

*Our wonderful clients!*



Owner /Client !!



Negotiations !



# What can owners do ?

*9 helpful hints re TBMs*

- ~Proactive Carbon Reduction - no`freeride` on this planet
- ~Share lesson`s learned –*not just the good news*
- ~Promote automation- *to reduce labour*
- ~Don`t buy just on price- *value and service /TBM is not a commodity*

~Less client prescription – *over prescription is not clever or helpful ! Performance specification -- not detailed Specification*

~Procurement of TBM is a key influence in Metro, Water Tunnel projects -*get tbm supplier in early*

~Improve Risk Sharing – *client has to manage some risks*

~Ensure Fair Financial Practices—*reward value*

~Responsible` capitalism- *R&D eg Tideway lining idea*



# OUR CLIENTS



# NORWEGIAN TUNNELLING TECHNOLOGY

- Have a good conference
- ..and thank you Norway for being a proactive global influence in tunnelling

•Takk!

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Chairman LBA Ltd UK

Former ITA President

Independent Consulting Engineer

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