Intelligent Tunnel Design (ITD)

Produce a satisfactory finished facility for no more money and in no more time than is required for the existing ground conditions.
Tunnels are Different than Above-Ground Structures

- Entirely within the ground.
- The ground cannot be specified.
- The ground can be changed.
- Serial Construction Schedule.
Tunnels are Different than Above-Ground Structures

✓ Work from inside/out.
✓ The ground requires temporary support.
✓ Lots of third party impacts.
✓ Land not owned by project.
Building a Tunnel

✓ **Excavate** the ground

✓ **Control** the ground during the process of excavation.

✓ **Support** the ground as the tunnel is advanced.

✓ **Install** the final lining.
What the Owner wants it the Final Structure!

The Owner views excavation, control, and support as necessary evils!

Unfortunately, excavation, control, and support represent 2/3’s of the cost of a tunnel and most of the risk!
Evaluating Tunneling Issues

- Project Layout
- Subsurface Conditions
  - Ground Behavior / Ground Control
    - Construction Methods
    - Third Party Impacts
    - Design Criteria
  - Contract Documents
Project Implementation

✓ Planning
✓ Design
  ▪ Finished Facility
  ▪ Underground Space
✓ Construction
  ▪ Underground Space
  ▪ Finished Facility
The Nine Elements of ITD

1. Project Layout
2. Subsurface Investigation
3. Ground behavior vs. Ground Control
4. Project Design
5. Construction Methods
6. Third Party Impacts
7. The Contract Document
8. Project Procurement
9. Construction Monitoring
Project Layout

✓ This may be one of the most difficult aspects of tunnel design.
✓ Trying to establish exactly what the finished facility will look like and how it will fit into an existing urban environment is difficult.
Subsurface Investigation

✓ As the Project Layout proceeds so does the subsurface investigation.

✓ Project Layout is highly dependent on the subsurface condition and this interface is also difficult to manage.

✓ Do your boings in phases and prepare your GDR and GBR for inclusion in the Contact Document.
Ground Behavior/Ground Control

✓ Ground Behavior/Ground Control is a massive brainstorming effort to determine both how the ground will behave (i.e. react) to the tunneling operation and what is the best way to control that behavior.

✓ Both tunneling methodologies and ground improvement techniques can be called upon to accomplish the above in the most reliable and cost effective manner.
For the purpose of this lecture we will concentrate on tunnel design issues associated with the temporary facilities.

What must the tunnel designer do in order to create an environment for success relative to tunnel construction.
Some items that fall into this category are:

- Tunnel Excavation and Support
- Shaft Excavation and Support
- Blasting
- Construction Dewatering
- Ground Improvement
- Muck and Water Handling and Disposal
- Third Party Impacts
Project Design

✓ I am a big believer in both KIS(S) and Goldilocks when it comes to project design for temporary facilities.

KISS - Keep It Simple (Stupid)!
Goldilocks - Don’t do too much!
Don’t do too little!

✓ Repetition is also a good thing.
Project Design

✓ The **best** way to know how to design the temporary facilities is to know how they will be constructed and this is where a lot of tunnel designers come up short.

✓ This is an extremely complicated and risky interface.

✓ No other form of construction has such a complex interface between design and construction.
Construction Methods

✓ What needs to be constructed in order to create the space needed for the finished facility?
✓ What is the best method for creating that space in a **safe** and **stable** manner?
  ▪ Safe for the worker
  ▪ Stable with respect to the third parties
Construction Methods

✓ Most of the cost, most of the time, and most of the risk for a tunneling project is related to this one item.

✓ What is more, while you are doing the design you do not know who will be doing the construction.
Construction Methods

✓ The Contractor will price what he is ordered to do under the contract; no more and no less.

✓ The Contractor will also carry contingencies and allowances for whatever residual risks he/she believes exists for any given project.

✓ Personally, I do not know why anyone would want to be a tunneling contractor.
Cooperative Effort

✓ The Owner, the Designer and the Contractor need to work together.
✓ The Contractor is an important part of the team.
✓ The Contractor is not the enemy.
Third Party Impacts

✓ Tunneling procedures need to provide protection for overlying and adjacent third party impacts.
✓ Most often you don’t have a contractual relationship with the third parties. Hence, you may be forced to show that you did not cause harm.
✓ Third party impacts also include community and environmental requirements.
A tunnel contract consists of five parts:

- The General Conditions
- The Plans
- The Specifications
- The GBR, and
- The GDR

The contract must paint a consistent picture of what the contractor must do in order to be successful.
The Contract Document

✓ Radically different as compared to an above-ground structure.

<table>
<thead>
<tr>
<th>Above Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% is in contract with the ground</td>
</tr>
<tr>
<td>90% is finished facility</td>
</tr>
</tbody>
</table>

Below Ground

100% is in contact with the ground
50% to 75% is temporary facilities

✓ The DSC clause is integral to everything you do when you go below the ground surface.
The Contractor has a right to rely on the subsurface information accumulated for an underground project.

The GDR provides “facts” and must be accurate and comprehensive.

The GBR provides “interpretations” and “baselines” and should be reasonable and helpful.
What About the GDR?

✓ The GDR must be comprehensive and accurate; just the facts.
✓ The GDR is the most important geotechnical report; not the GBR.
What About the GBR?

✓ What is the difference between a good and a bad GBR.
✓ A good GBR is positive and helpful.
✓ A bad GBR is nothing more than CYA.
Project Procurement

✓ Contractor Prequalification
✓ Partnering
✓ Escrow Documents
✓ Reasonable Cost and Schedule
✓ Measurement and Payment
✓ Sufficient Time to Prepare a Bid
✓ Dispute Resolution
✓ Is there a platform for fairness and cooperation?
Construction Monitoring

✓ The Owner must have experienced tunneling professionals in the field.

✓ Good project records are one of the most important parts of successful tunneling.
Tunnel Contractors

✓ Constructing tunnels is a hell of a way to make a living.

✓ How many people do you know who are addicted to taking risk and who are also eternal optimists?

✓ The low bidder for a tunneling project may be the guy who simply doesn’t realize what he is up against.
A Final Recommendation: THINK! THINK! THINK! THINK!