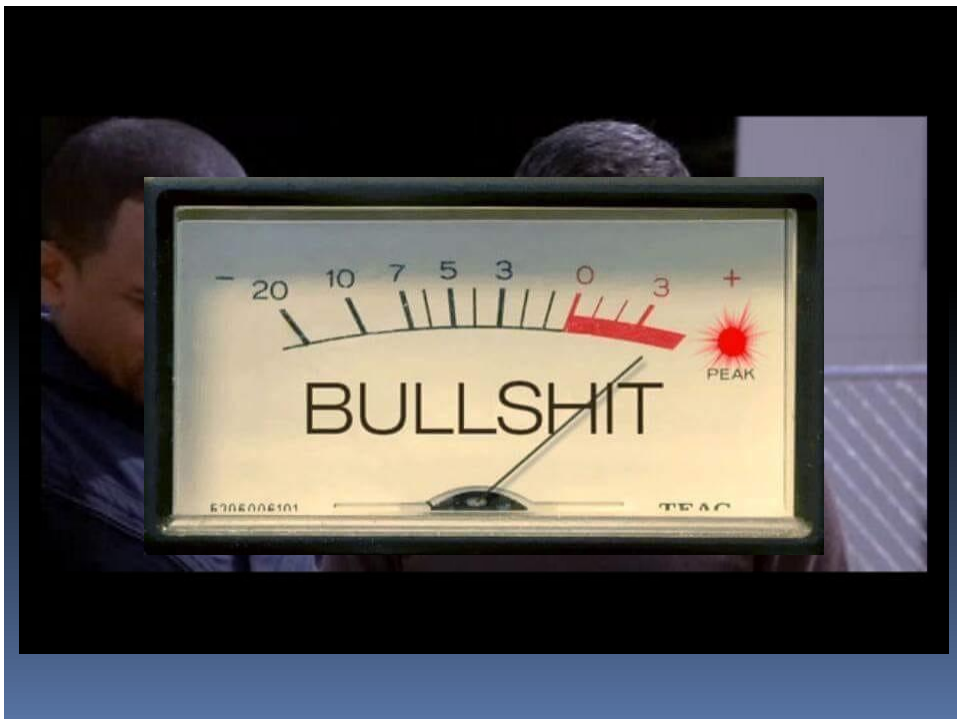
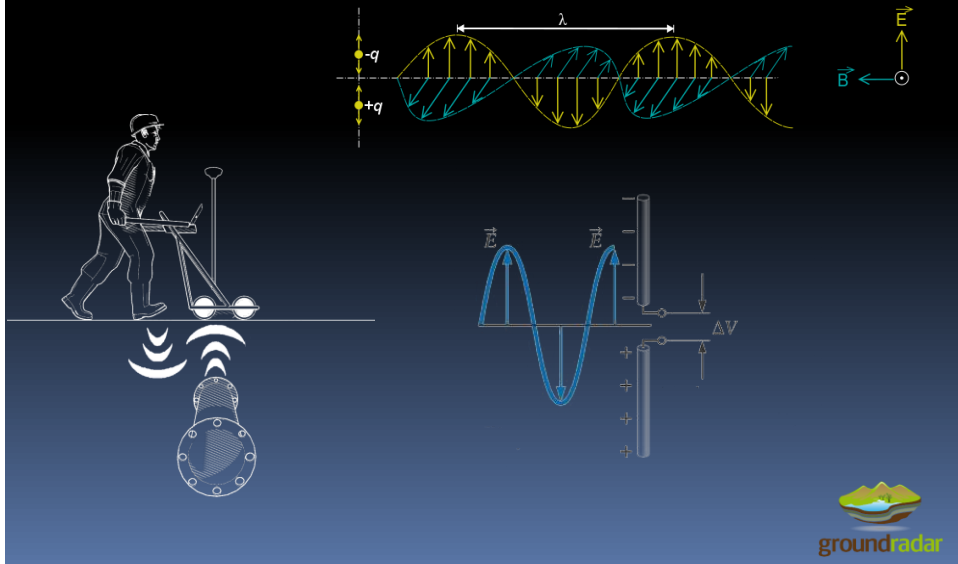


# Radar imaging of TSFs and the potential of 4D tomographic monitoring

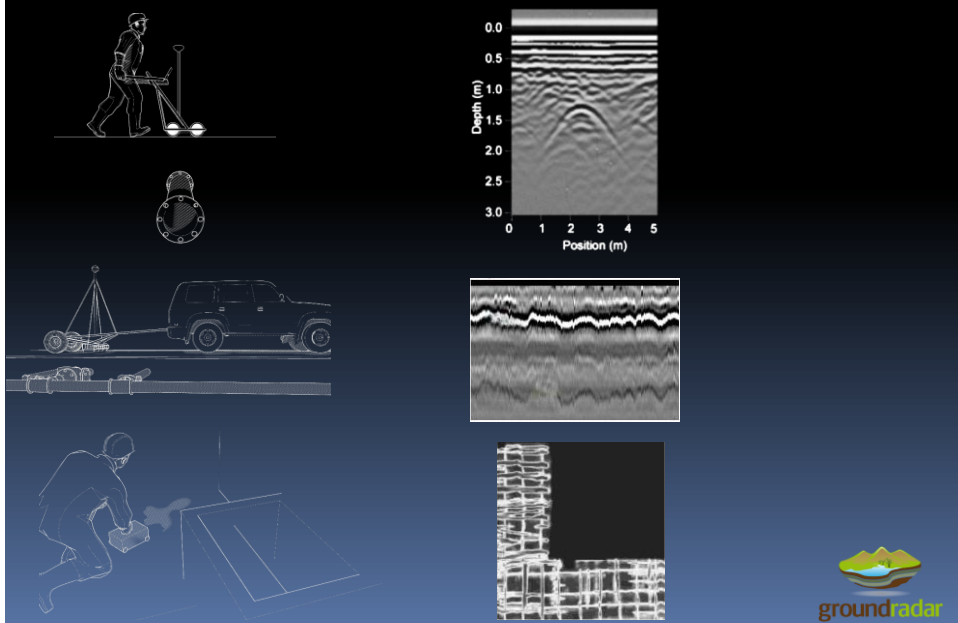
October 11, 2019



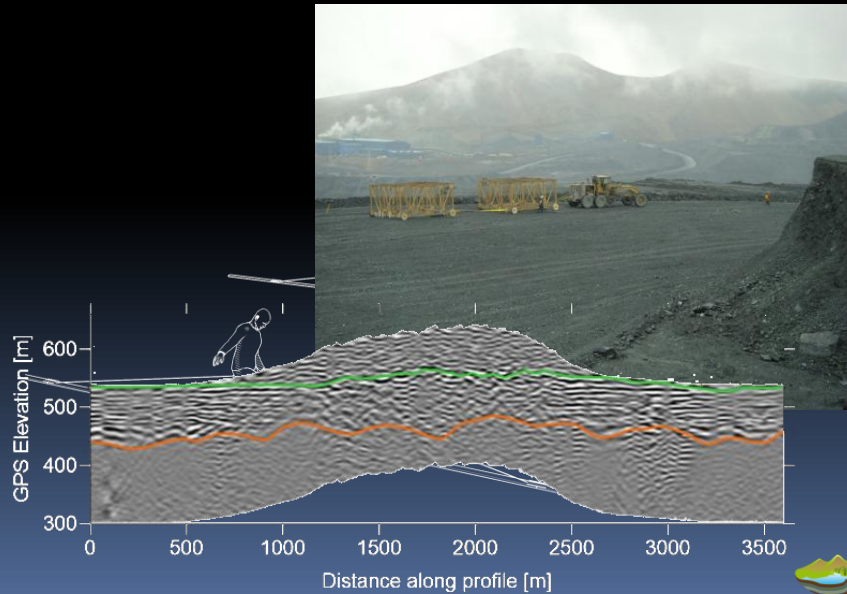
# GPR Concepts



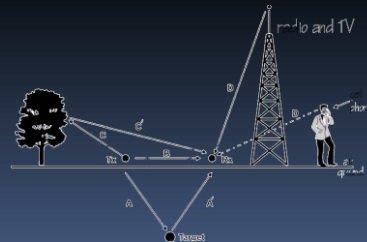
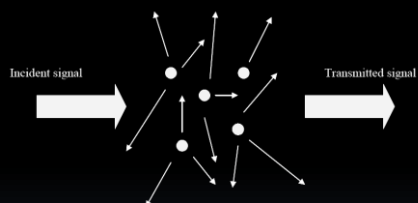
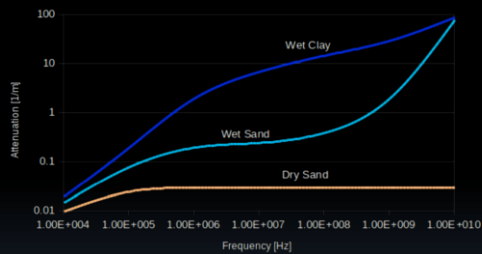
# Common GPR Applications



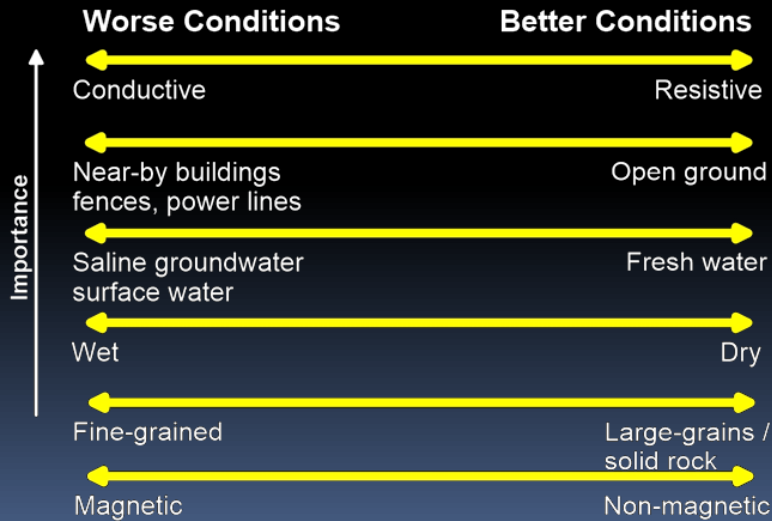
# Going Deeper



# Not that easy...

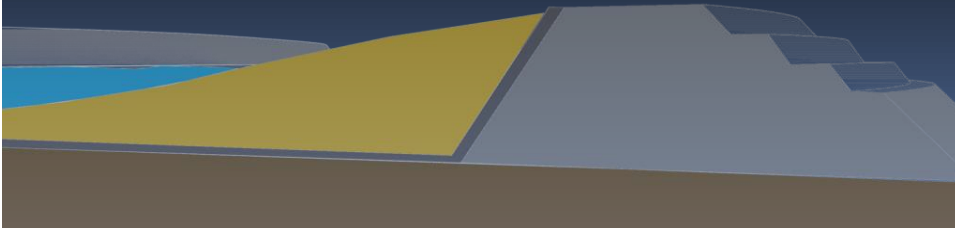
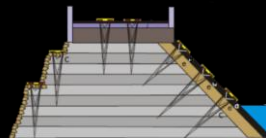


## Not that easy...



## TSF Applications

- Dams are made of fined-grained media
- Limited space
- Limited penetration from surface
- Technically difficult from walls



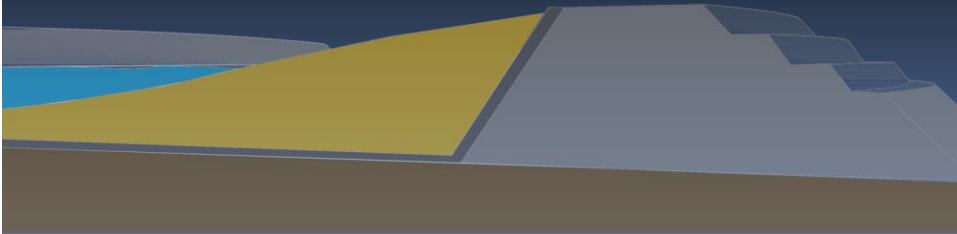
# TSF Applications

## Limitations

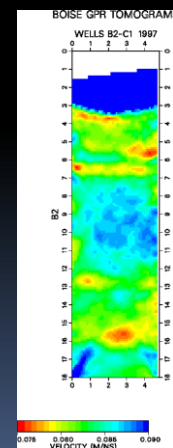
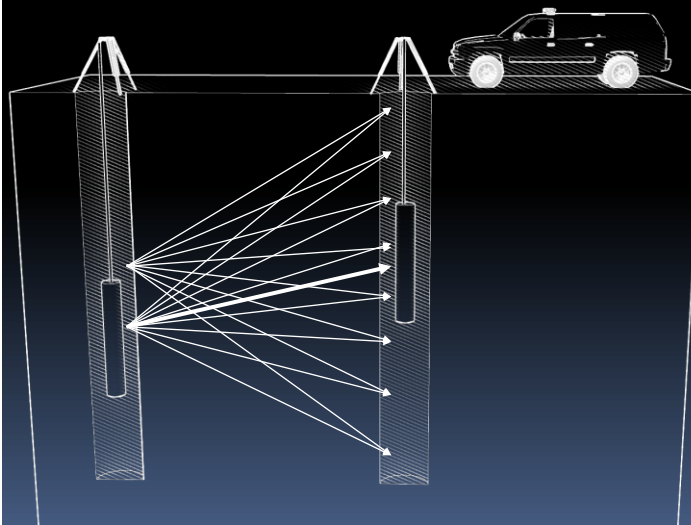
- Limited penetration
- Logistically difficult surveys
- Costly equipment
- Large antennas for deep penetration

## Benefits

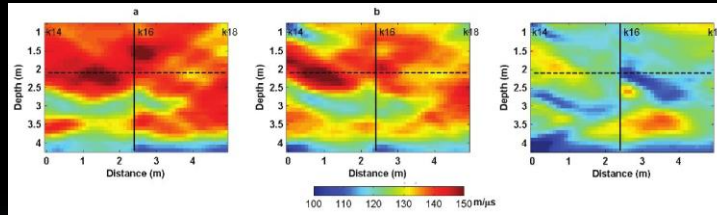
- Highest resolution geophysics
- Sensitive to changes in moisture (dielectrics)



# Radar Tomography



# Radar Tomography



Farmani et al, Vadose Zone Journal (2008) 7 (1): 272-283.

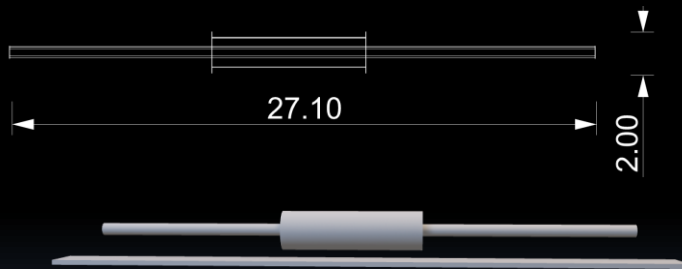
- Electronics on surface
- Long antennas
- Depth limited to 30 m
- Slow stacking
- Expensive instrumentation (>\$50,000)
- Laborious process



But...

Problem	Solution
Electronics on surface	Data logging on radar
Long antennas	3D printed magnetic antenna
Depth limited to 30 m	All electronics in hole
Slow stacking	64,000 stacks (real-time)
Expensive instrumentation	<\$400
Laborious process	Permanent installation
Conductive environment	One-way ray path and real-time sampling for max. SNR

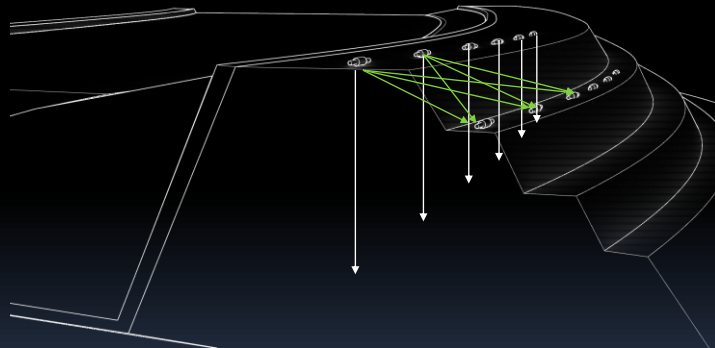




- Radar transceiver (can act as Rx or Tx or both)
- 30 MHz
- Real-time sampling (64,000 stacks)
- 150 kHz PRF Tx
- 64 GB on-board storage
- Fiber optic to surface



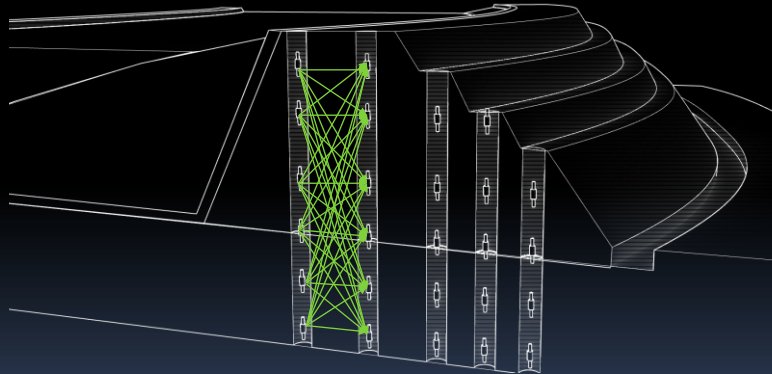
## Applications within TSFs



- Radar sensors embedded on benches
- Reflection and tomographic modes
- Each sensor has surface solar power/LTE



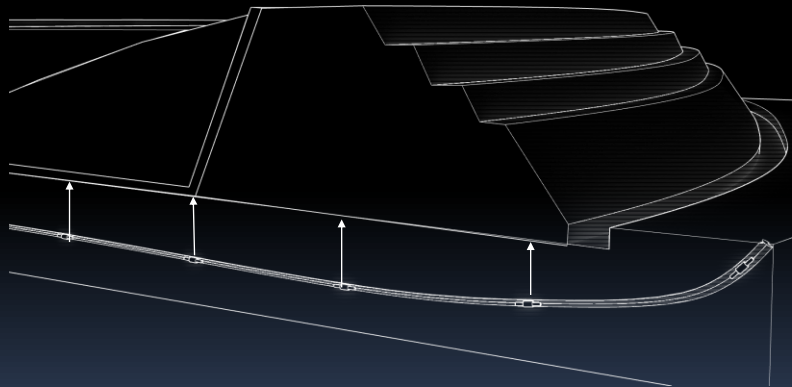
## Applications within TSFs



- Radar sensors embedded in monitoring holes
- Tomographic modes
- Each string of sensors has surface box with power, LTE and control
- Phased array/beam forming?



## Applications within TSFs



- Radar sensors embedded in HDD hole
- Reflection mode and tomographic to surface
- One control/power box at surface





## Not that easy...

Problem	Solution
Natural changes in moisture (e.g. rain)	Long term monitoring to build database of rain events
Power and data to surface	Shielded cables or wireless power
Accuracy	Does not need to be accurate, just precise
Noise	Can stack for hours for excellent SNR
Data from network	LTE or hard-wired to mine network
Live processing and monitoring	Cloud processing with <b>change detection</b> algorithm



## Project Status

- Radar receiver and controllers electronics ready now
- Transmitter ready in 3 months
- Cloud parallel processing ready now
- Surface boxes ready in 4 months
- First testing early in 2020

## Questions?

