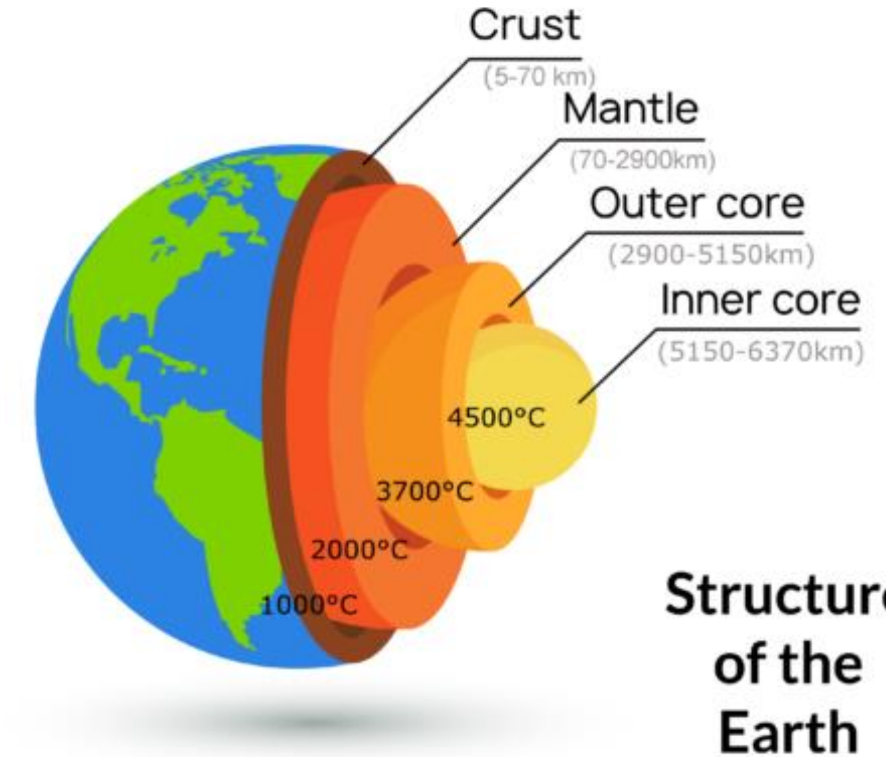
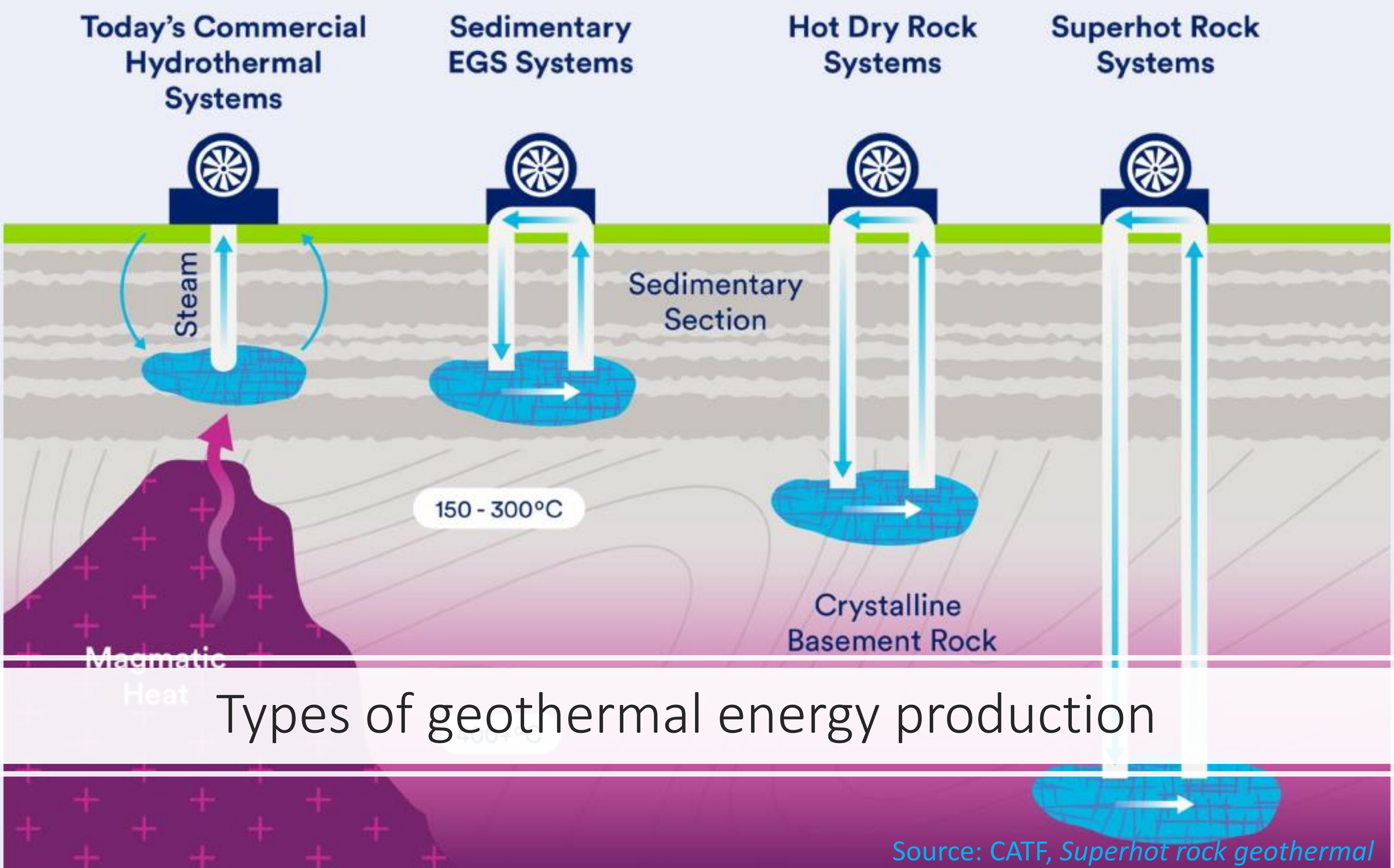
Matt Houde
February 2023

What is geothermal energy?



Structure of the Earth

Types of geothermal energy production



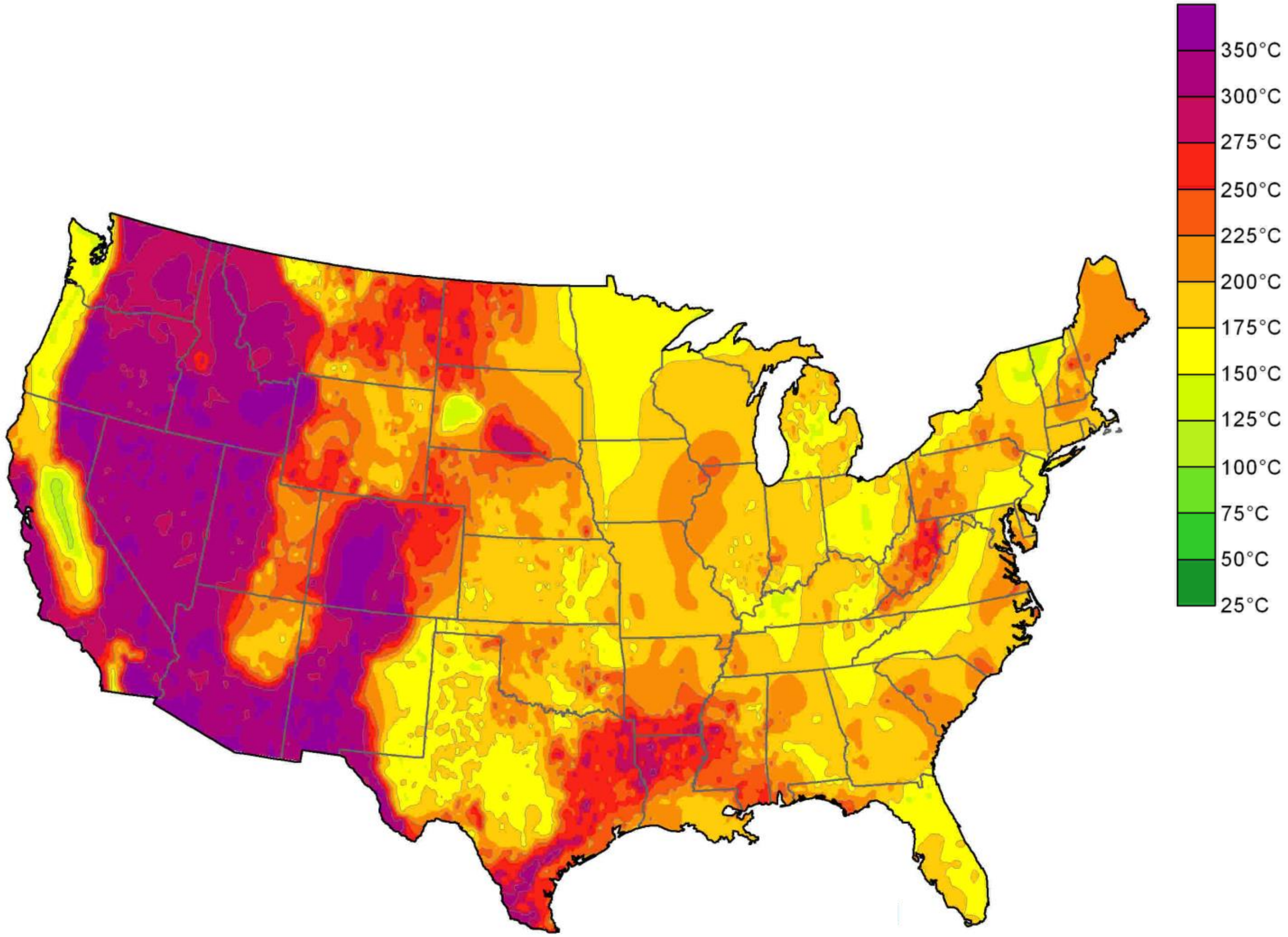
Source: CATF, *Superhot rock geothermal*

Quaise Mission Statement

Provide **universal access to supercritical geothermal** energy through **disruptive energy drilling technology**

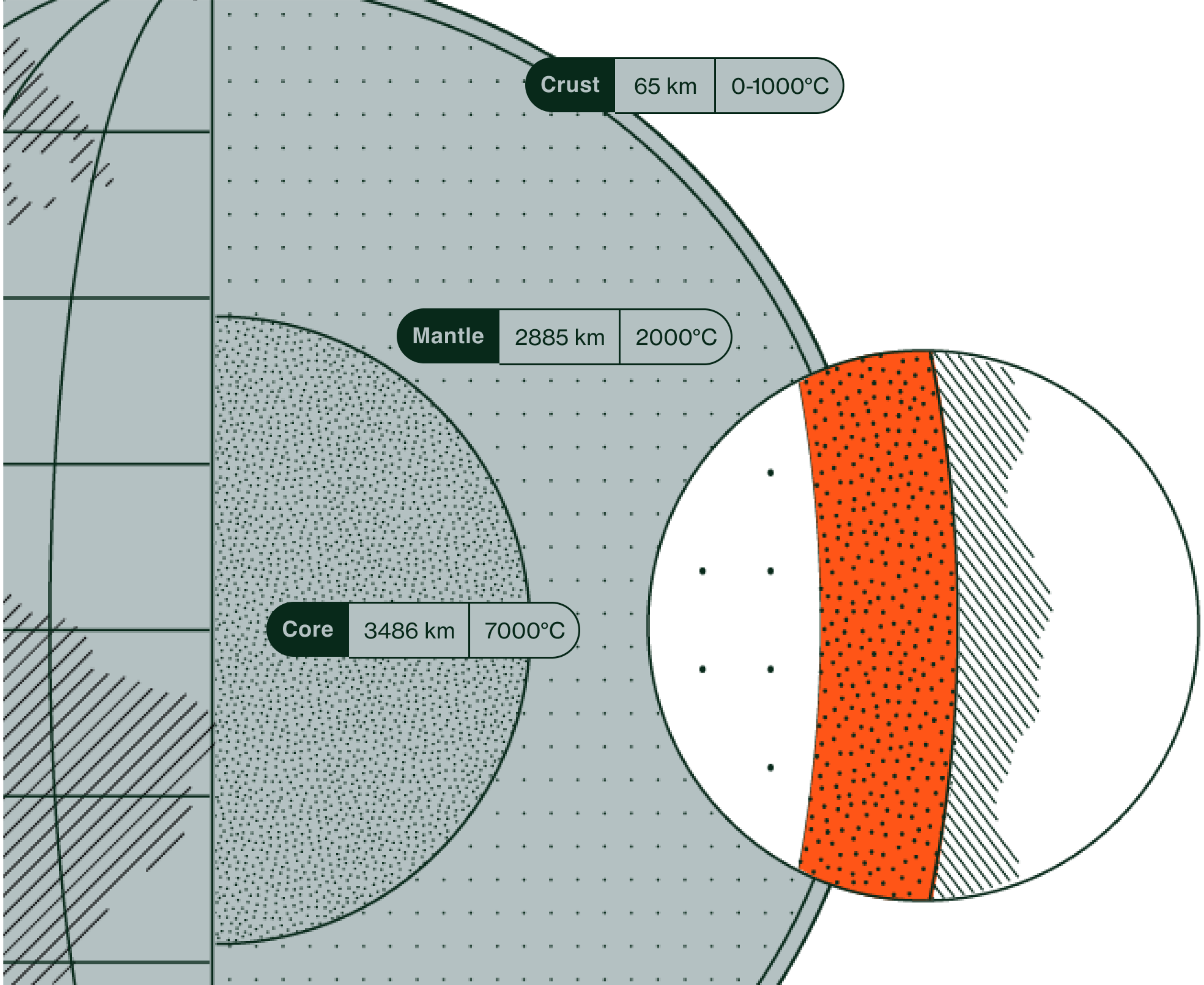
"Supercritical resources can be found everywhere on earth by drilling deep enough…Drilling to this depth is financially prohibitive with existing technology.. Economic production of supercritical resources will require the development of entirely new classes of drilling technologies and methods"

Source: GeoVision

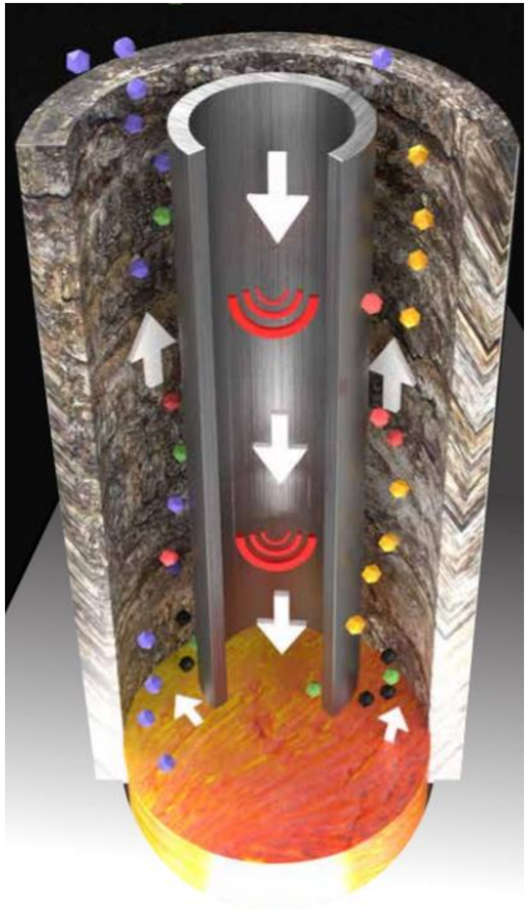


Temperature at 10 km depth

Source: SMU Geothermal Laboratory; Blackwell et al.,2011


Crust
65 km
0-1000°C
Mantle
2885 km
2000°C
Core
3486 km
7000°C

Solution: Millimeter-Wave Drilling Technology



Source: Quaise

Replace conventional drilling with **energy-matter interaction**

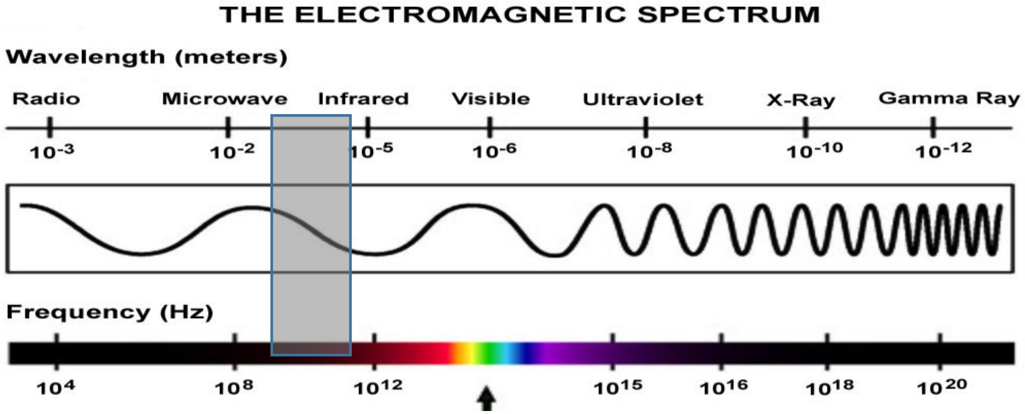
- High powered RF energy transmitted downhole via waveguide
- Dielectric material (rock) absorbs electromagnetic energy, converts to heat
  - Rapidly heated to melt, then vapor
- Condensed particulate conveyed up-hole by circulating purge gas
  - Alternative: melt displaced into formation by overpressure condition (ideal gas law)
- Borehole wall vitrified for borehole stabilization

Overcome limitations to current drilling technology

- Constant ROP w/ depth
- Reduce non-productive drilling time
- (optional) casing-while-drilling

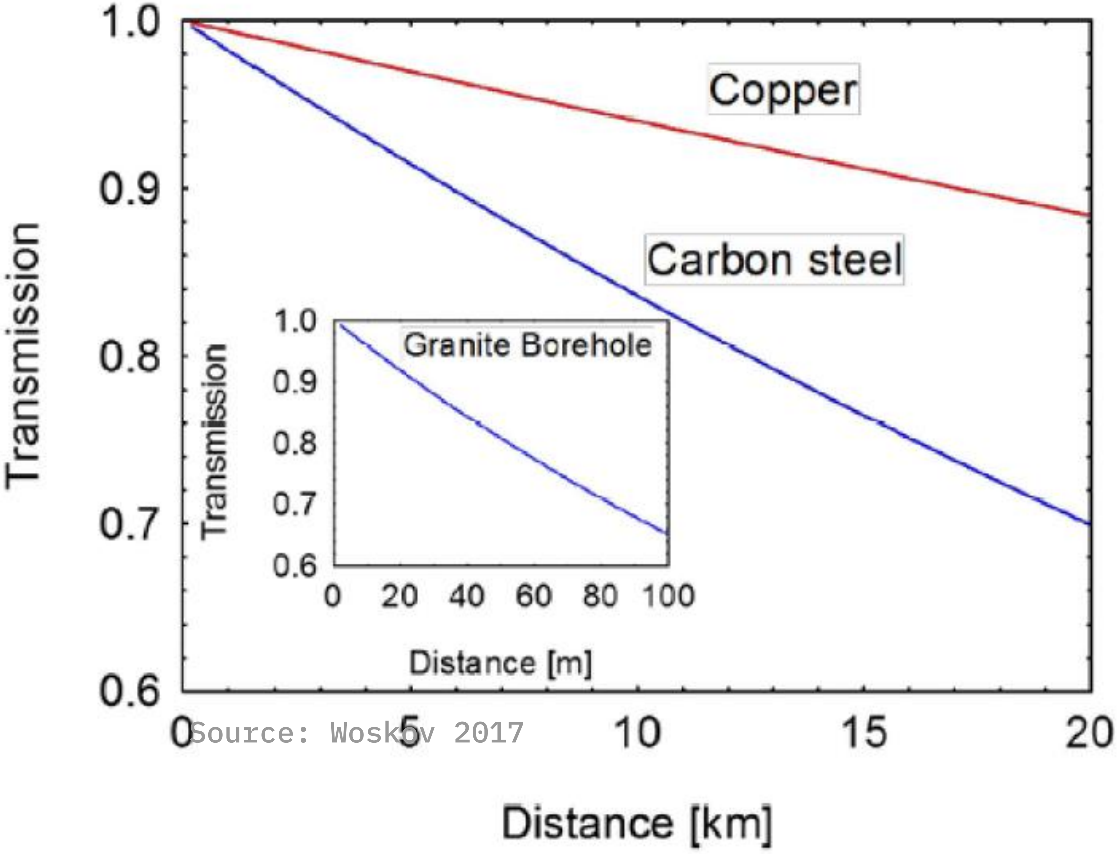
Millimeter-Wave (MMW) Physics

- 30 – 300 GHz (1-10 mm wavelength)
- Efficient absorption
  - Rock: 50% – 70%
- Avoid Rayleigh scattering in "dirty" environment
- Long-Distance Transmission
  - HE11, TE01 Modes

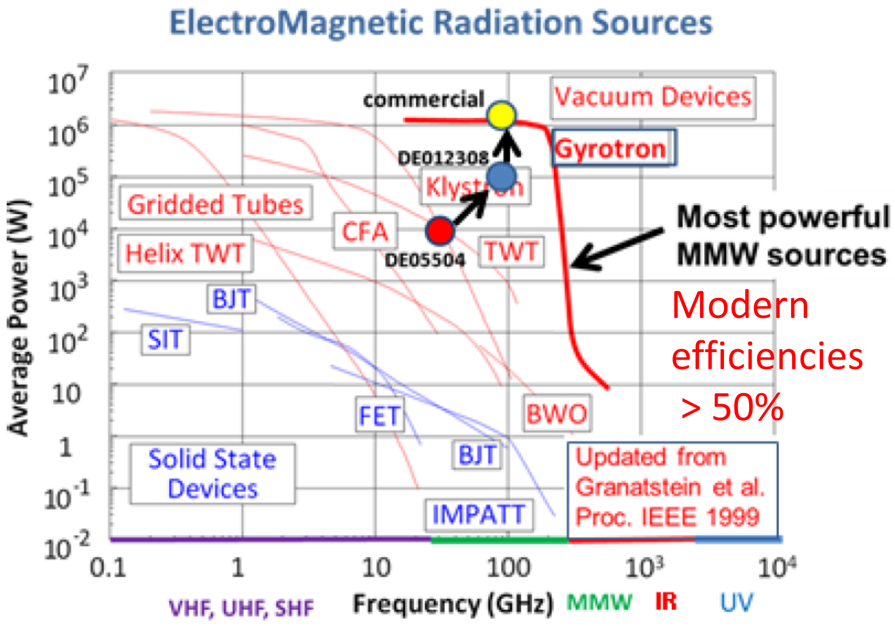


$Transmission\ loss \propto \frac{\lambda^2}{d^3}$

94 GHz, 5" ID, Corrugated (HE11)



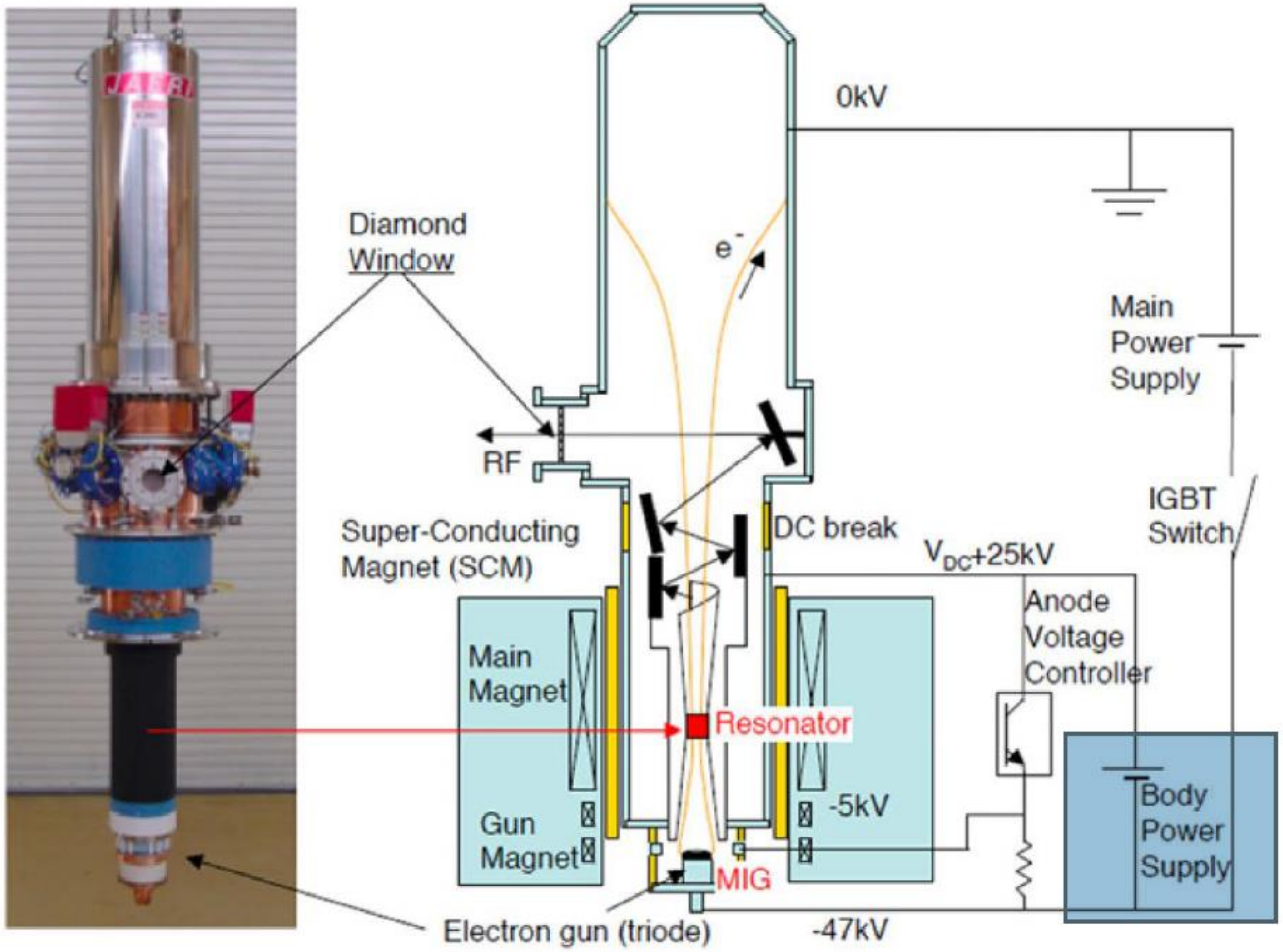
Gyrotron Device



1999

Source: DE-EE0005504 Final Report, U.S. DOE

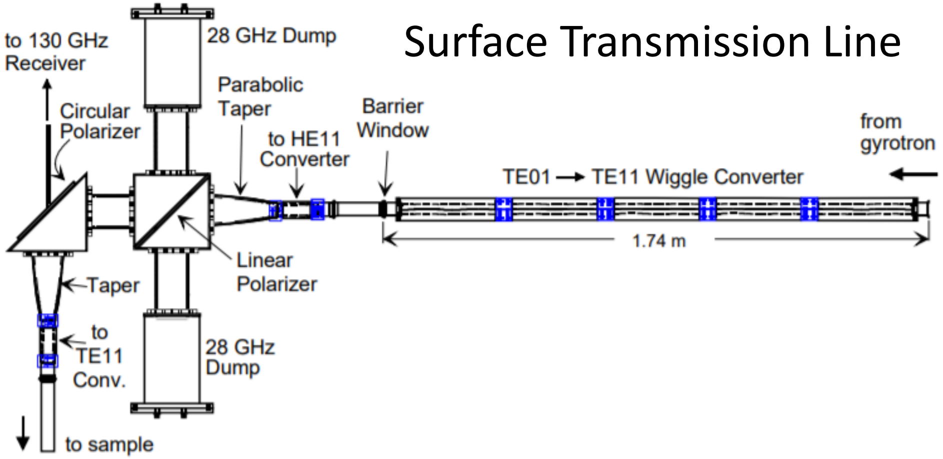
- Converts kinetic energy of electron beam into electromagnetic waves via strong magnetic fields
- Applications
  - Nuclear fusion
  - Manufacturing (ceramics, glass)
  - Active Denial System



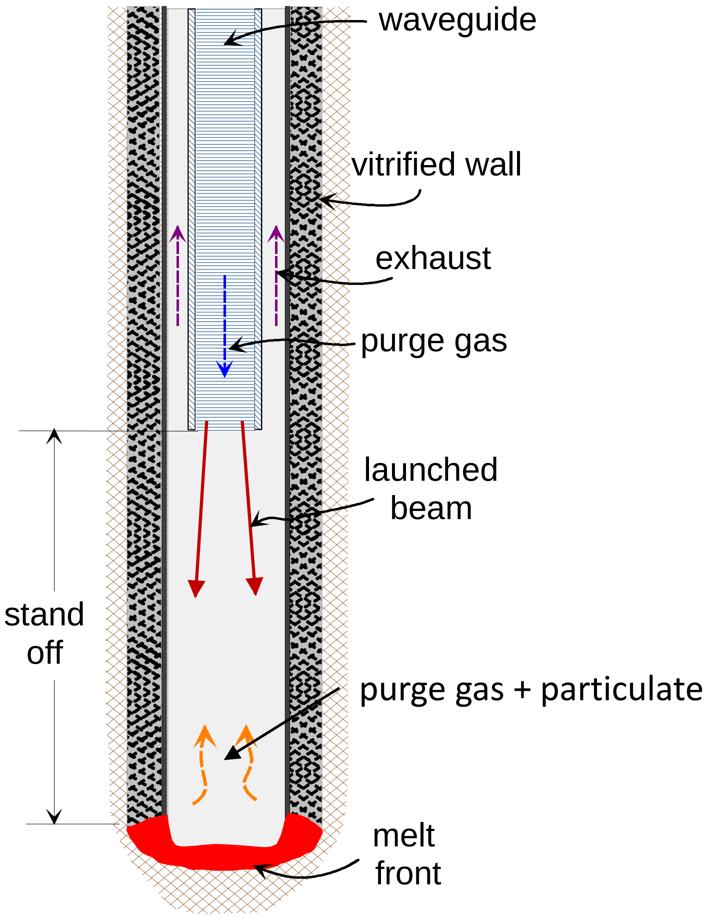
Source: K. Sakamoto et al., Nucl. Fus. (2009)

Downhole Assembly

- Waveguide: “Drill Pipe”
  - Transmit MMW beam downhole to borehole surface
- Purge Gas
  - Convey particulate up-hole
  - Maintain pressure
  - Downhole cooling
- 2 Approaches
  - (1) Full Bore Vaporization
  - (2) Melt Displacement



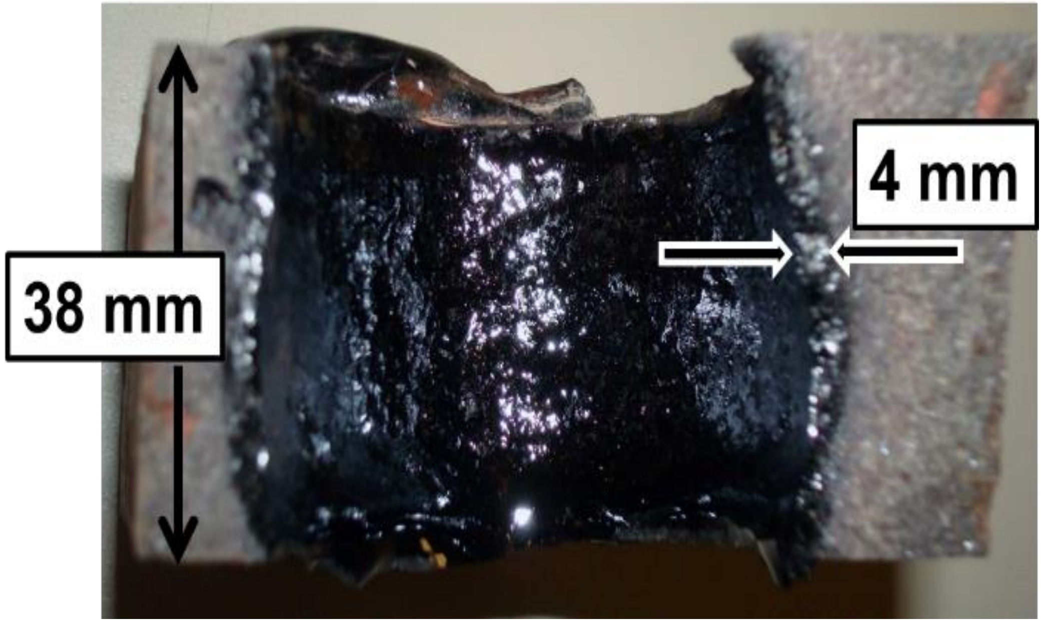
Source: Oglesby & Woskov 2014



Source: Woskov & Cohn 2009

Vitrified Borehole: “Casing-While-Drilling”

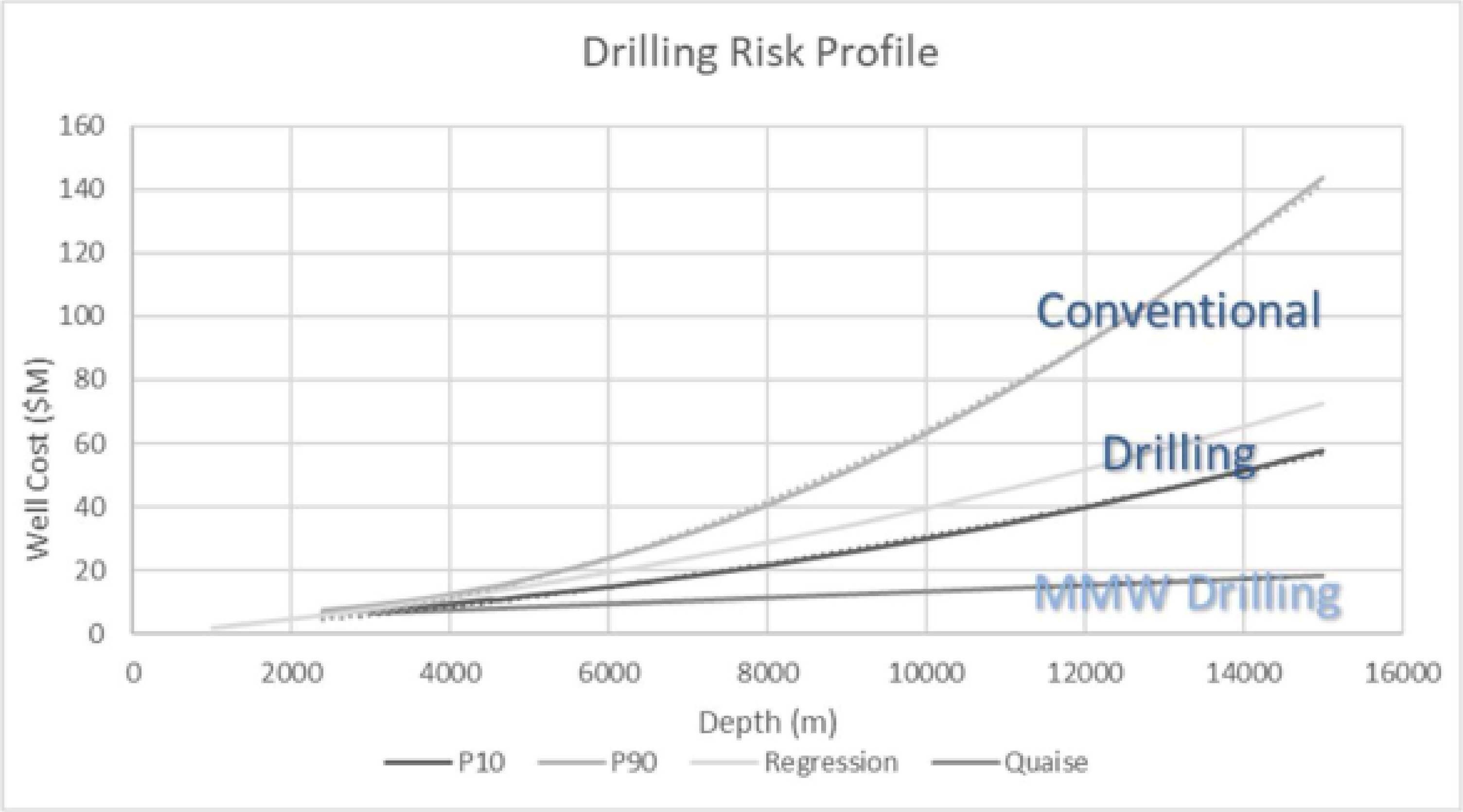
Source: DE-EE0005504 Final Report, U.S. DOE



MMW Drilling in action

MMW Drilling enables feasible drilling costs of $1,000/m for Deep SHR (10-20 km)

- Assumptions
  - Costs scale **linearly** with depth
  - ROP = 3.6 m/hr
  - 8.5" borehole
- Implications
  - $10M-$20M/well
  - **LCOE < $40/MWh**



Quaise Summary

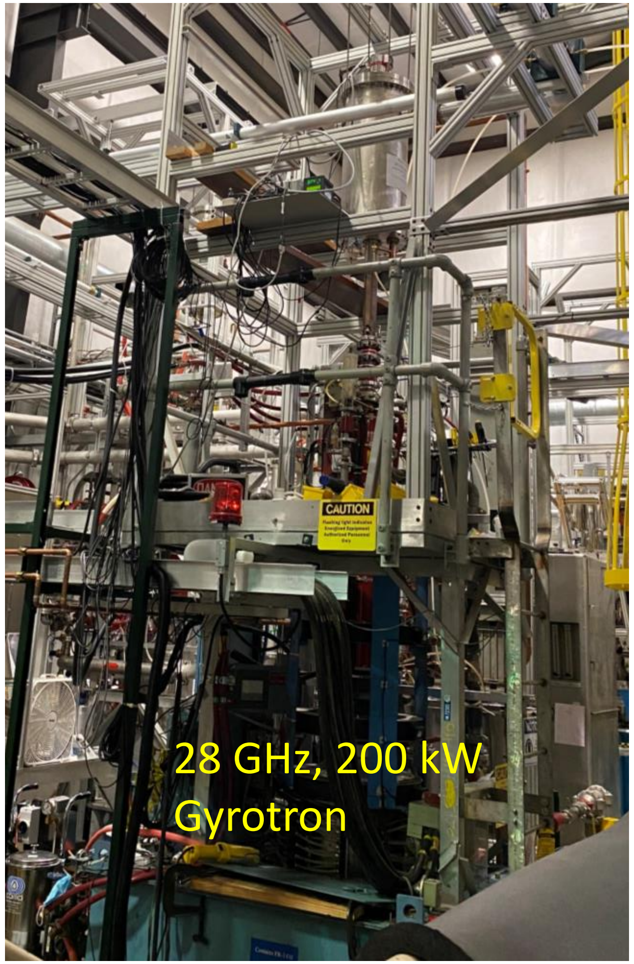
Funding

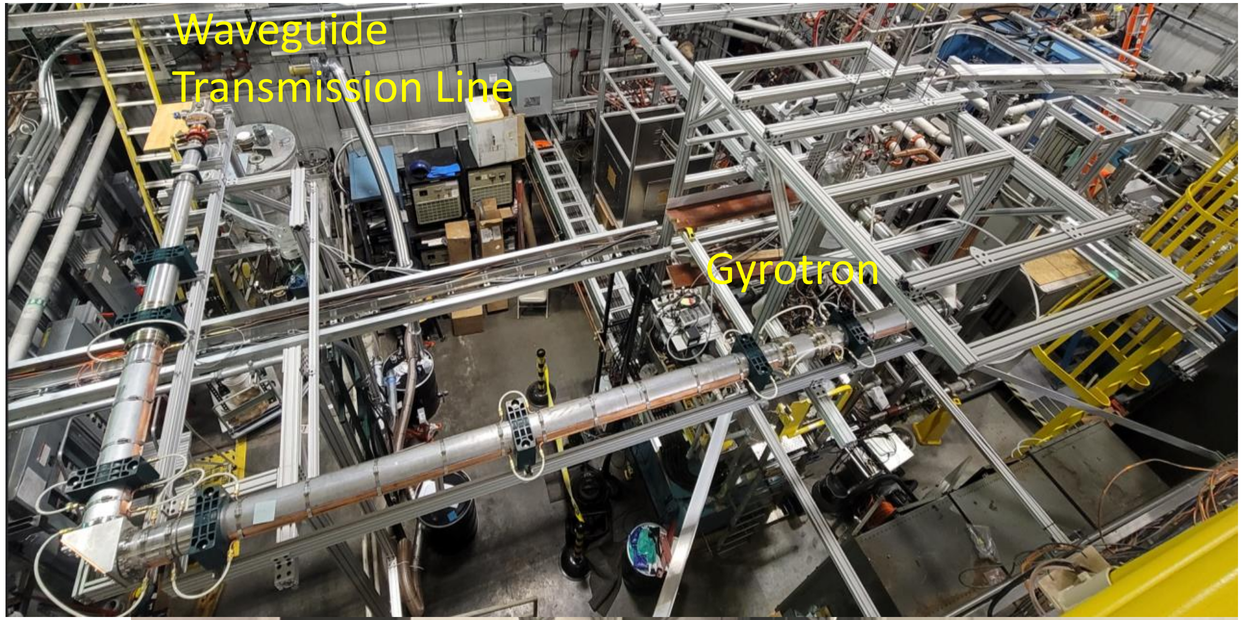
- **>$70M in private capital**
  - **$1M Angel investment (2018)**
  - **$6M Seed round (2020)**
  - **$12M investment from Nabors Industries (2021)**
  - **$50M Series A (2022)**
  - **$12M Series A extension (2022)**
- **Federal funding**
  - **$5M ARPA-e Award**

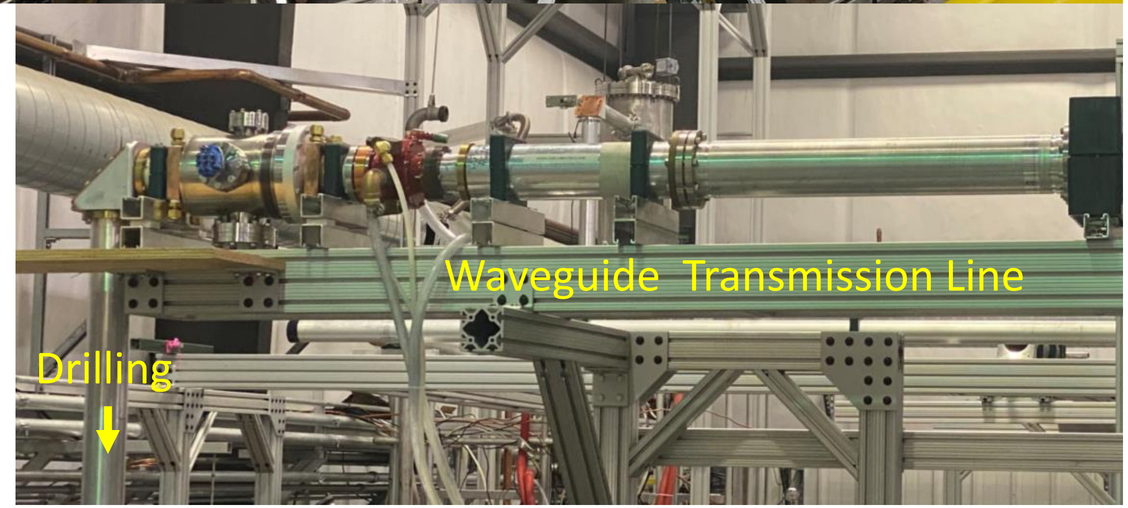
Team

- Carlos Araque – Cofounder and CEO
- Engineering team – Houston, TX
  - Henry Phan – VP Engineering
- Research and Simulation – Cambridge, UK
  - Franck Monmont – VP Research
- Business development – Boston, MA
  - Kevin Bonebrake – CFO and head of corporate development
- ARPA-e Test campaign (Oak Ridge, TN)
  - Matt Houde – Cofounder and project manager/co-PI

Lab testing at Oak Ridge National Laboratory (ORNL)





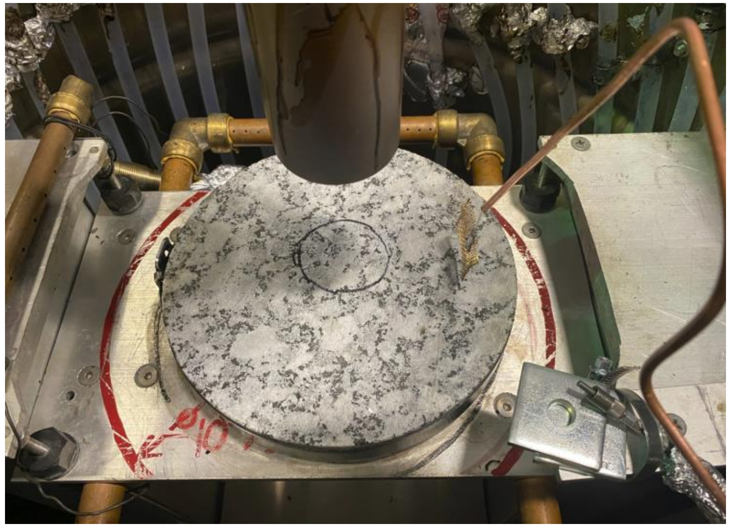


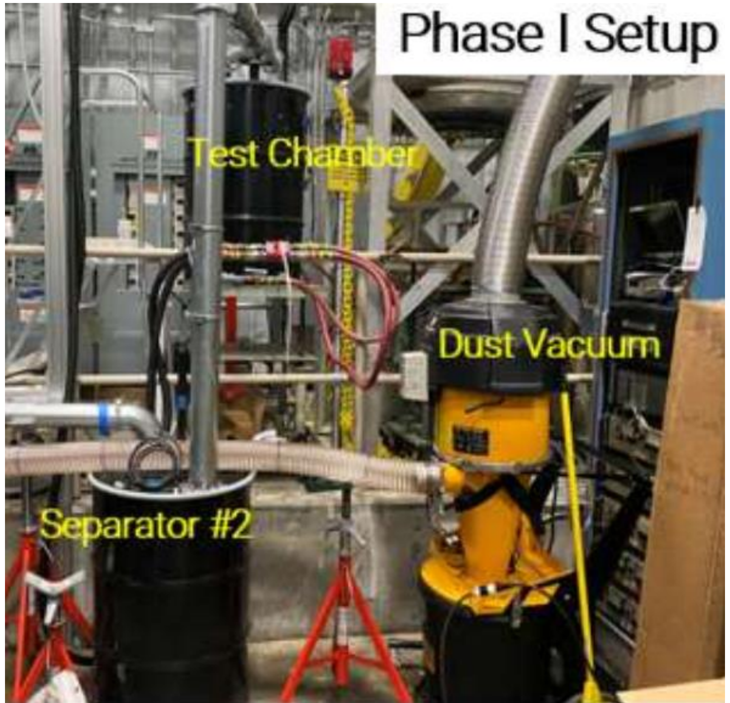
Lab testing at Oak Ridge National Laboratory

Funding - ~5M project
- **$3.2M – ARPA-e**
- **$730k – DOE (ORNL)**

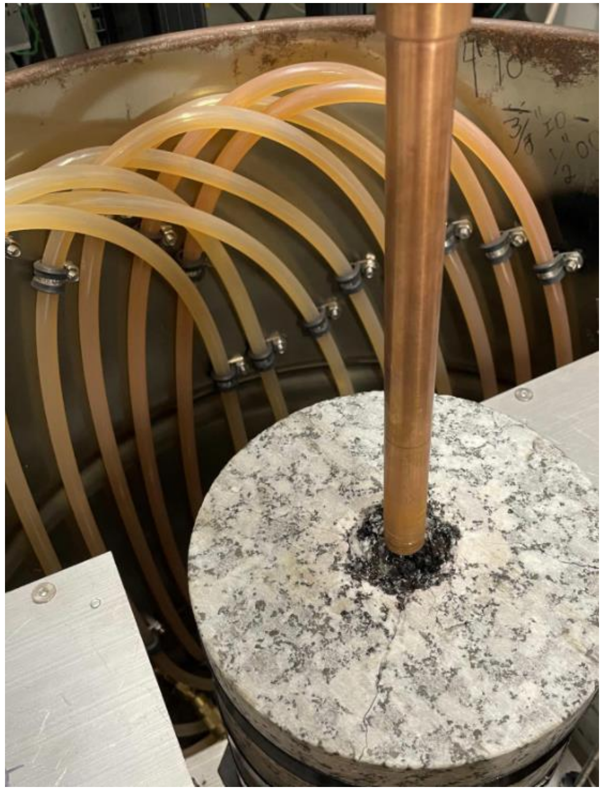
Equipment
- 28 GHz, 200 kW gyrotron
- Waveguide transmission line
- Rock chamber and test fixture

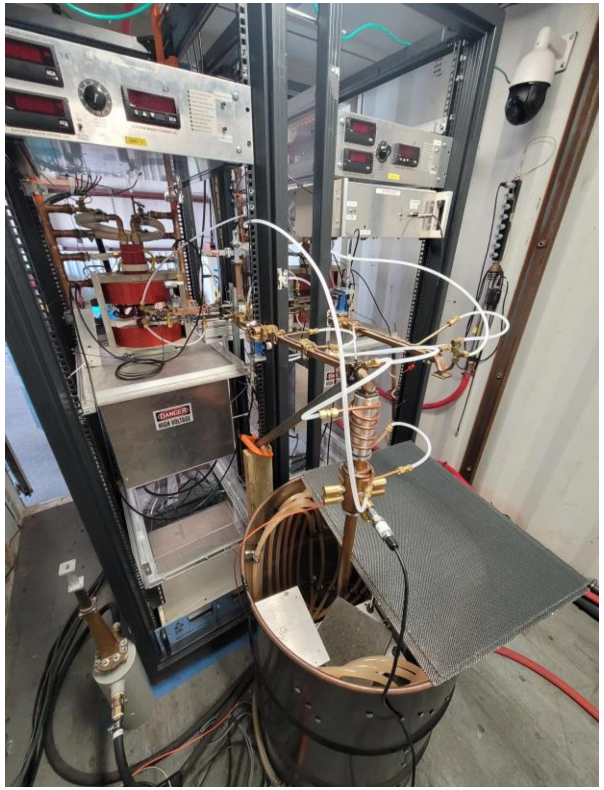
Milestones
- 2022 - **10:1** Borehole
- 2023 **100:1** Borehole





Lab Testing at Quaise-Houston Engineering Facility





EXP-G1 Land Rig (100:1 testing)

Questions?