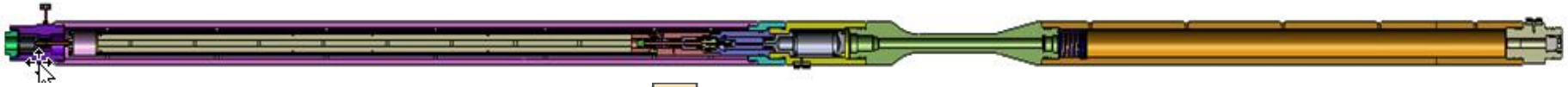
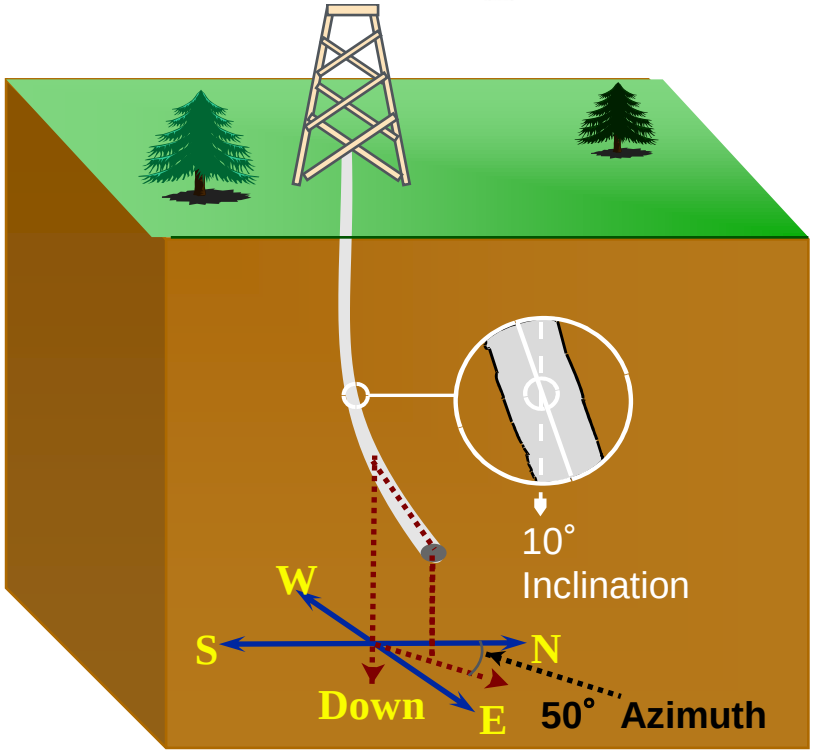





# Directional Measurement-While-Drilling System for Geothermal Applications

Project Officer: Bill Vandermeer

Total Project Funding: $ 5 M

May 11, 2015

Kamalesh Chatterjee

EE0005505

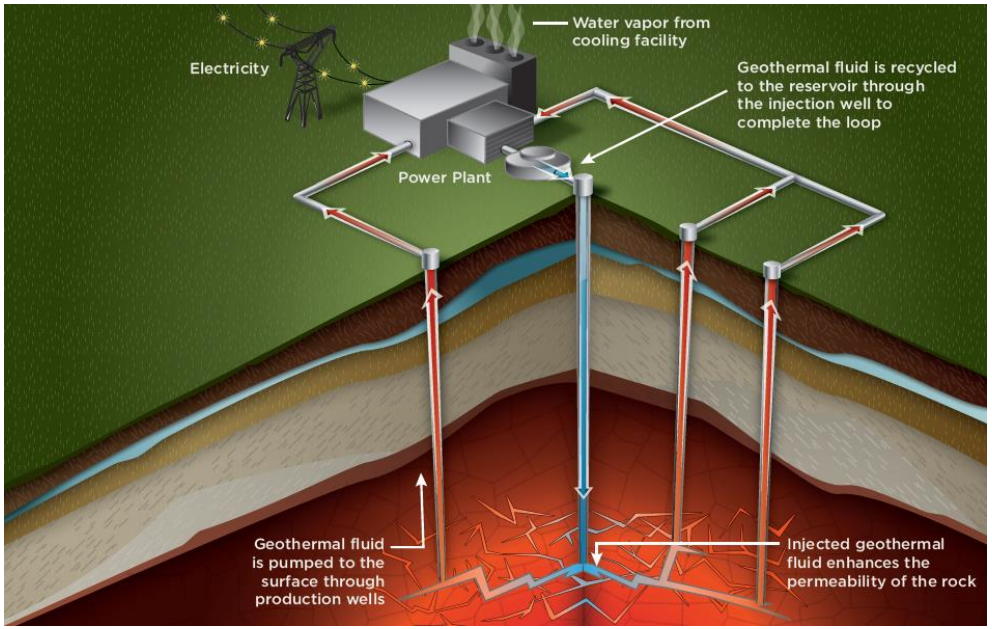
Baker Hughes

Track 3 EGS1 - High Temp Tools, Drilling Systems

# Relevance/Impact of Research



A Directional Drilling System (DDS, EE0002782) and directional Measurement-While-Drilling system (MWD, EE0005505) for geothermal applications will operate in hard rock at depths as great as 10,000 meters and temperatures as high as 300ºC.




- Commercial DDS tools are functional up to 175ºC/200ºC
- Aligned with GTO R & D goals
  - Directional Drilling of EGS wells at high temperature.
  - Drilling cost a significant part of total budget in geothermal wells.
  - MWD information needed for precise well placement.

# Relevance/Impact of Research

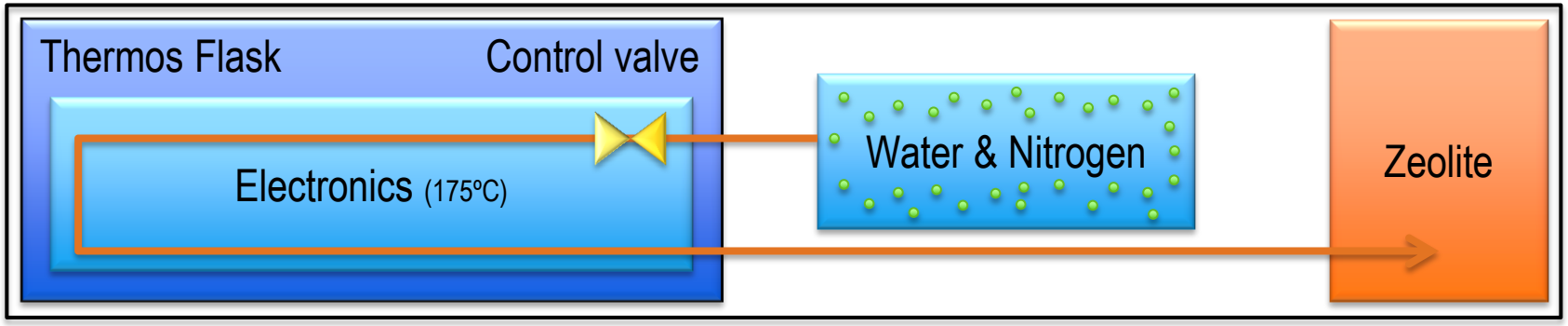


- Prototype directional MWD system for geothermal
  - Deliverables: 3 prototype tools
  - Temperature up to 300ºC for 50 hours
  - Hard rock, depths to 10 km (pressure 20 kpsi)
  - 6 ¾ inch tool for 8.5 inch diameter hole

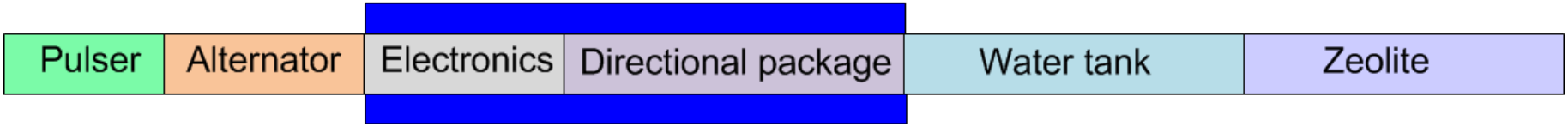
- Major technology modules:
  - 175ºC Directional navigation package (electronics and sensors)
  - Telemetry module (pulser)
  - Power module (alternator)
  - Active cooling system (from 300ºC to 175ºC)

# Scientific/Technical Approach
# Proposed system concept






Cooling system - flask, valve, evaporation control, evaporating fluid, absorbing media



# Scientific/Technical Approach
# Alternate system concept



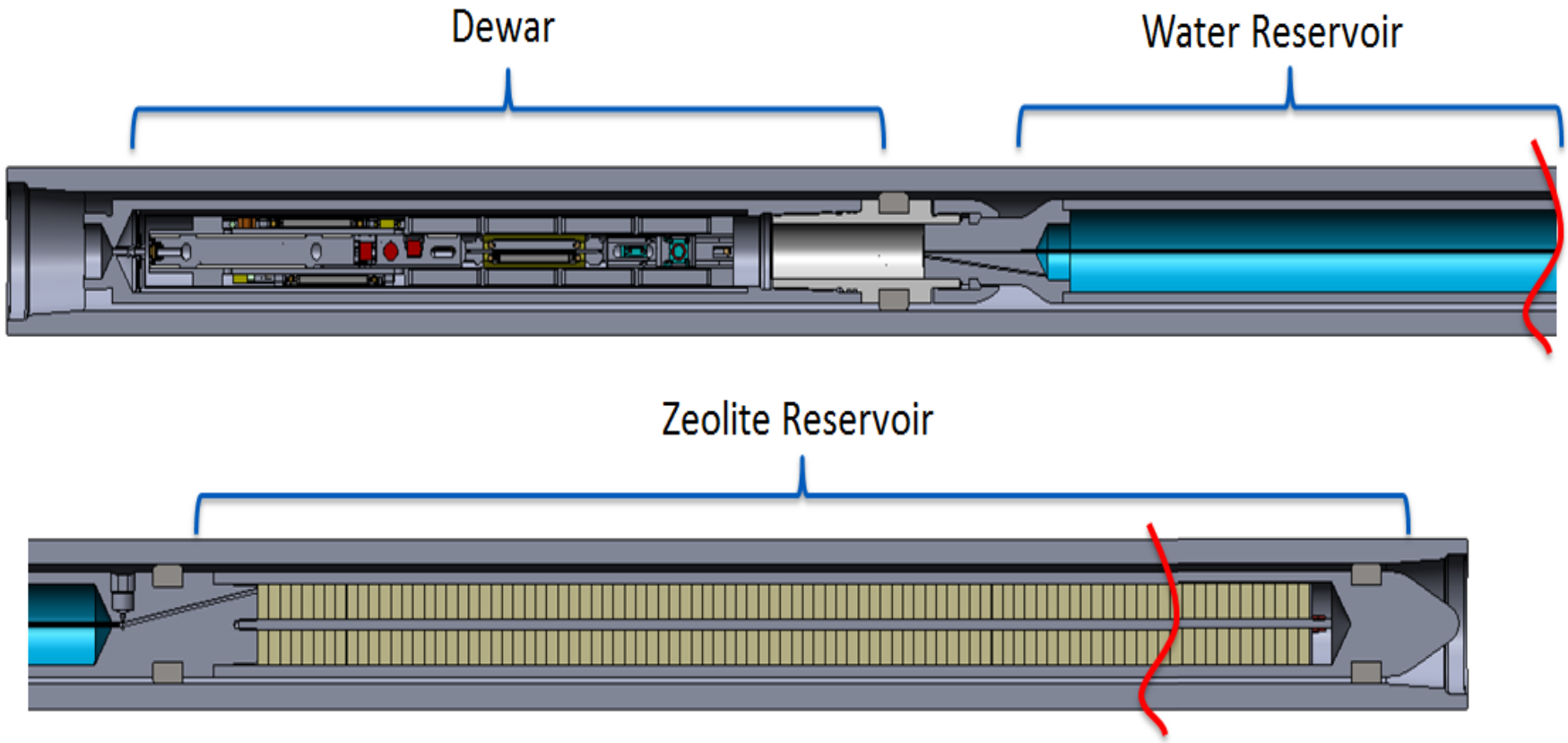
- Silicon on insulator 1 µm wafer technology may go up to 275ºC/300ºC – inadequate for powerful DSP or FPGA
- No availability of sensors at 300ºC
- Only Si-C power devices are available, not controller ICs
- Memories limited at 225ºC

Cooling system with flask is required

Compressor/Condensation based cooling system inside a flask at drilling vibrations and temperatures has to be an independent project

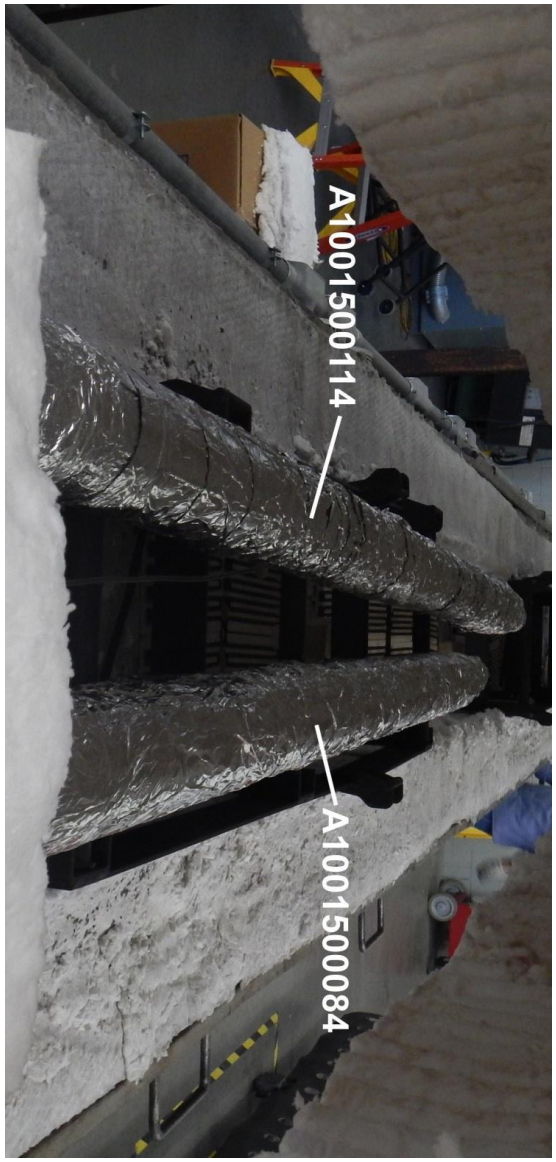
# Proposed active cooling system

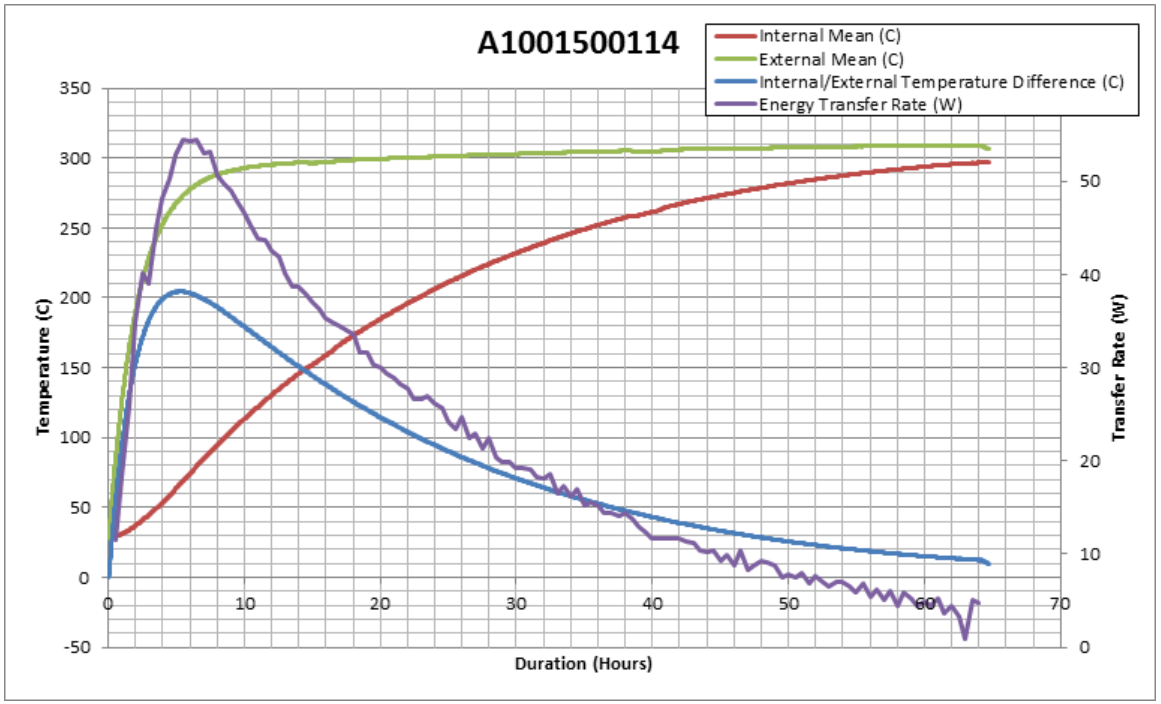




# Dewar flask challenges



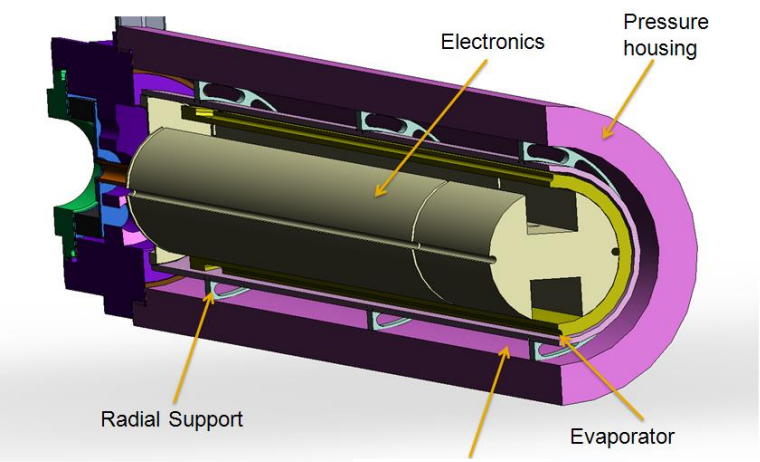


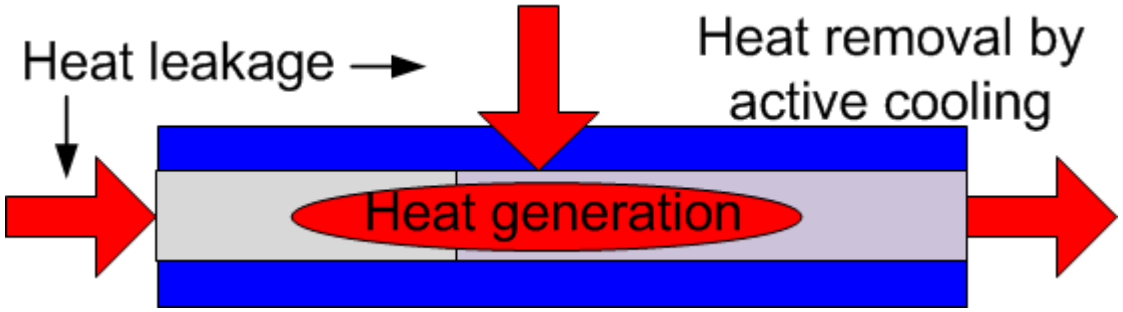



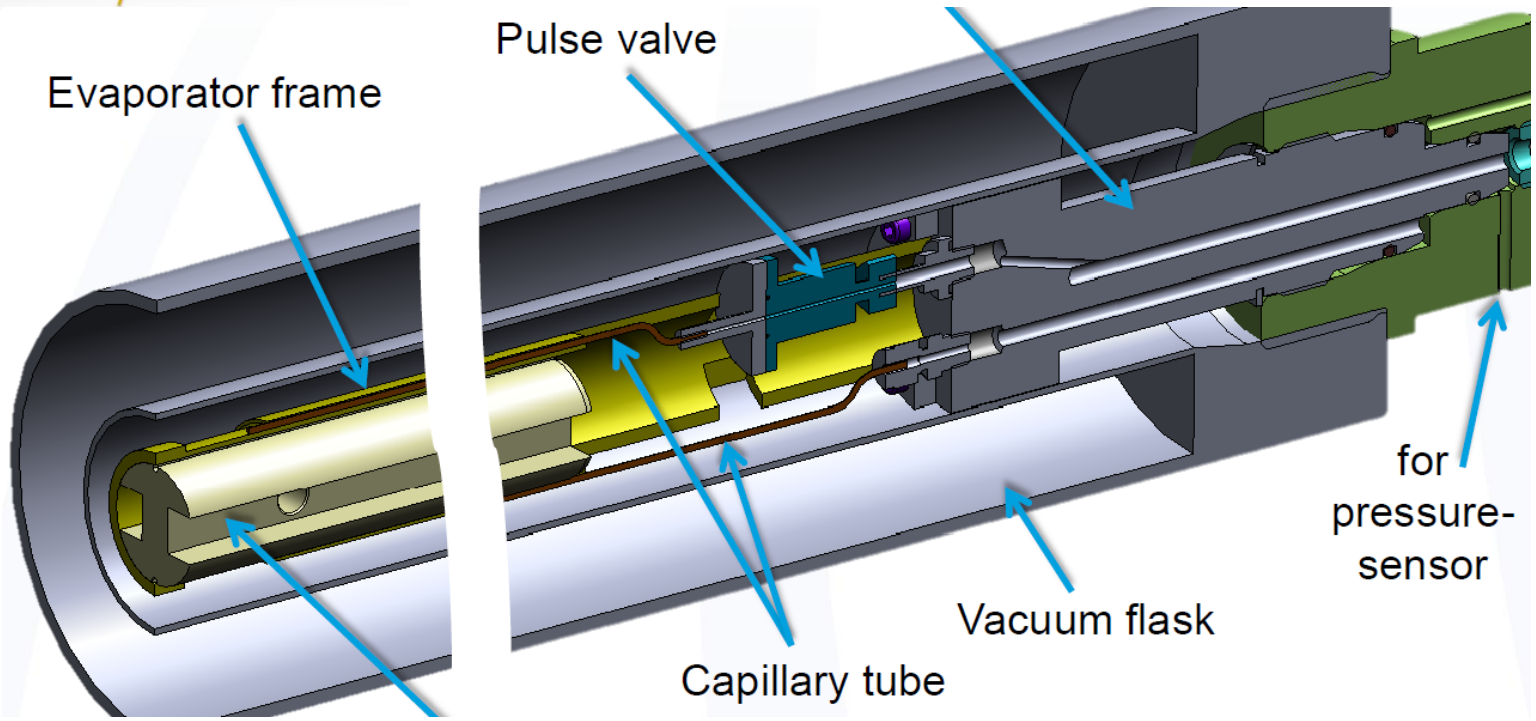

## Estimation of heat leakage

# Inside the dewar flask



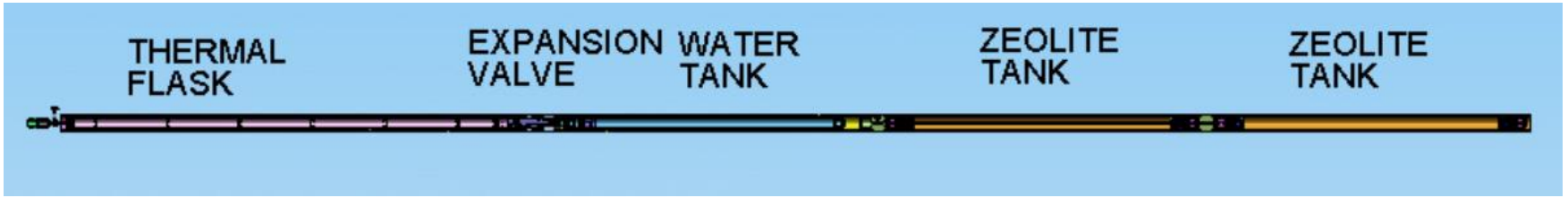


# Active cooling demonstration



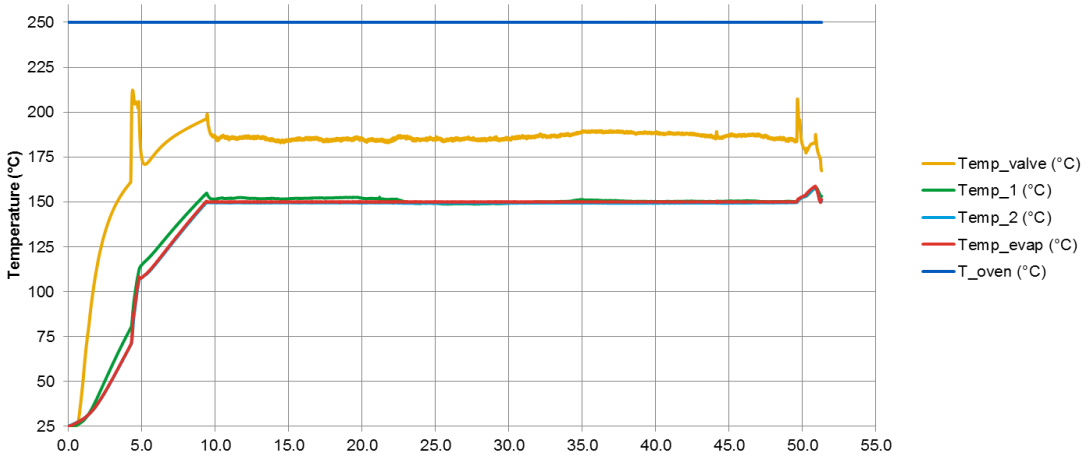




Evacuation & P-Sensor Zeolite reservoir

Safety Valve & P-Sensor water reservoir

T-Sensors, heating resistors

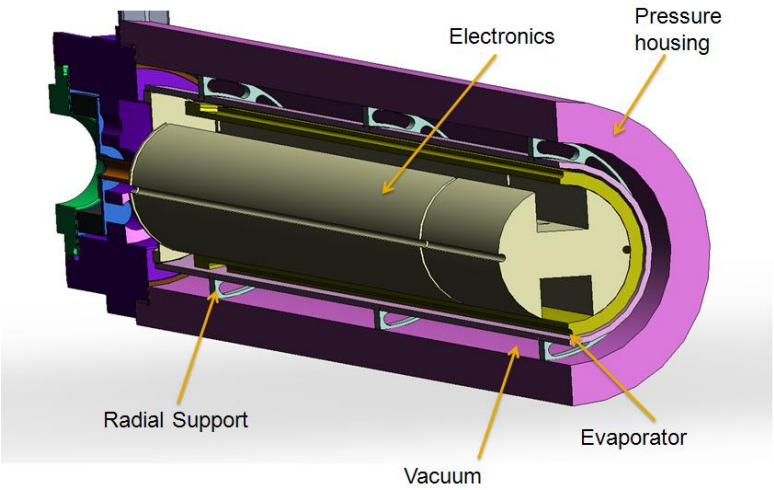


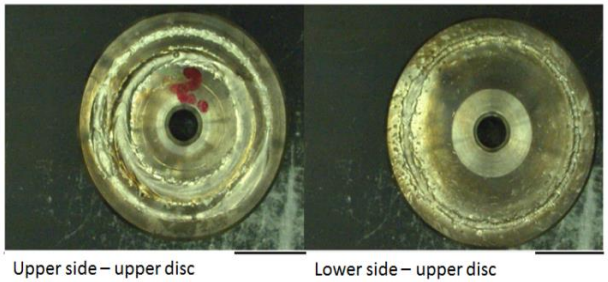

At Celle, Germany facility
Other funding sources –
GEBO, Lower Saxony program

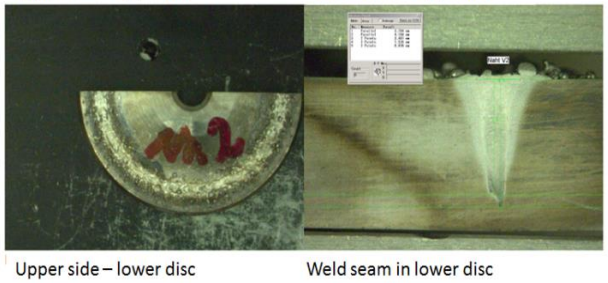
Outside 250ºC
Inside 150ºC
For 50 Hours

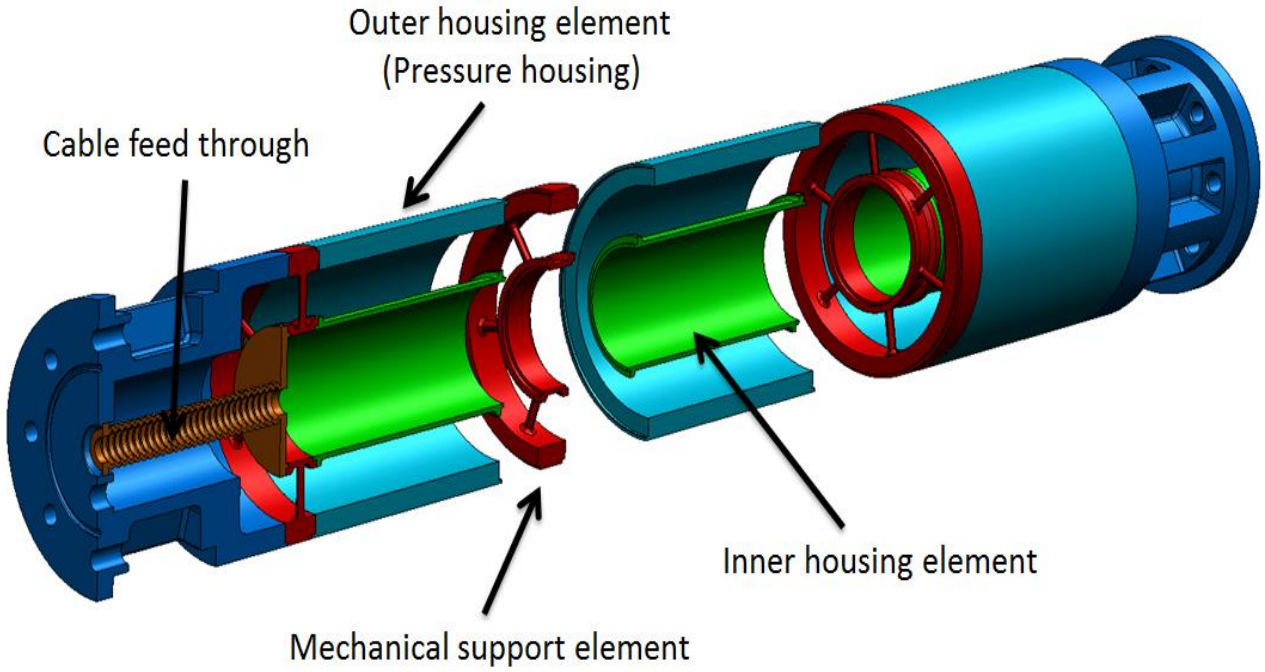
# Different Dewar flask concepts





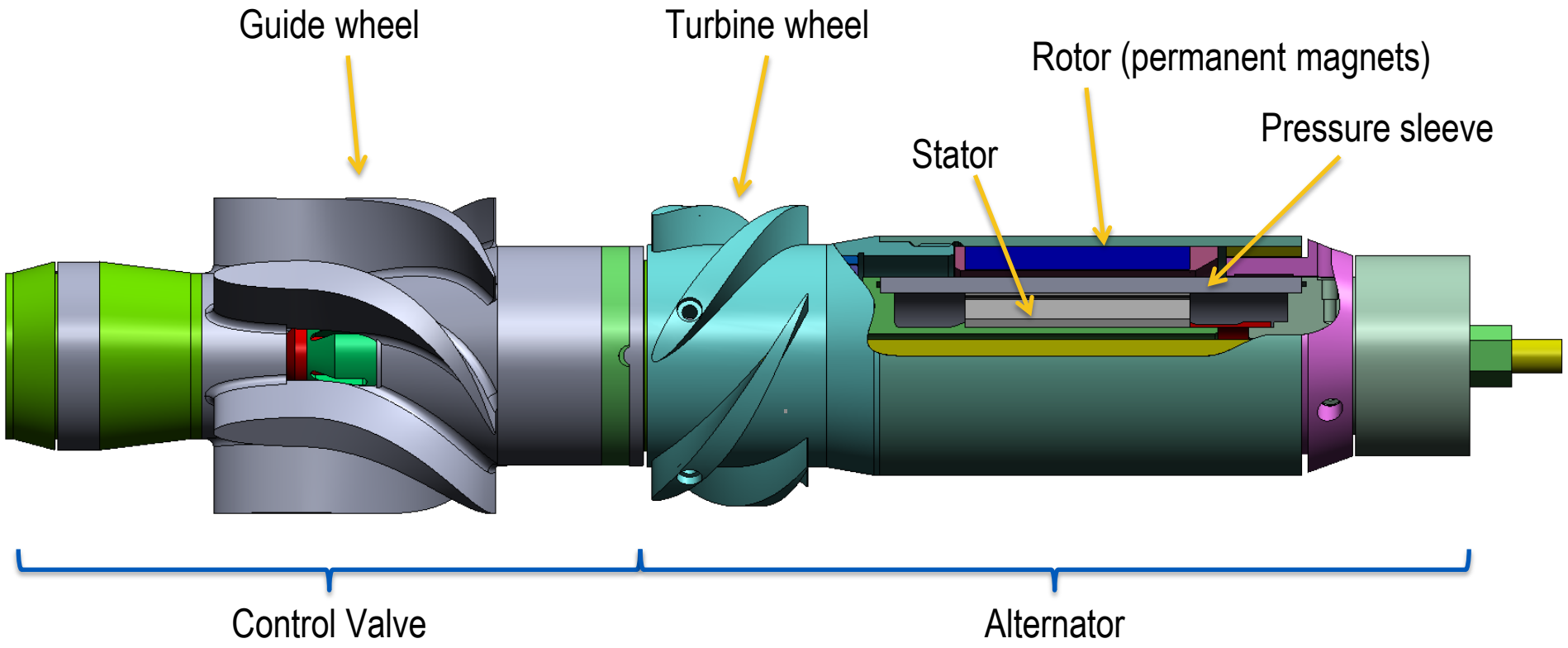



# Pulser and Alternator concepts



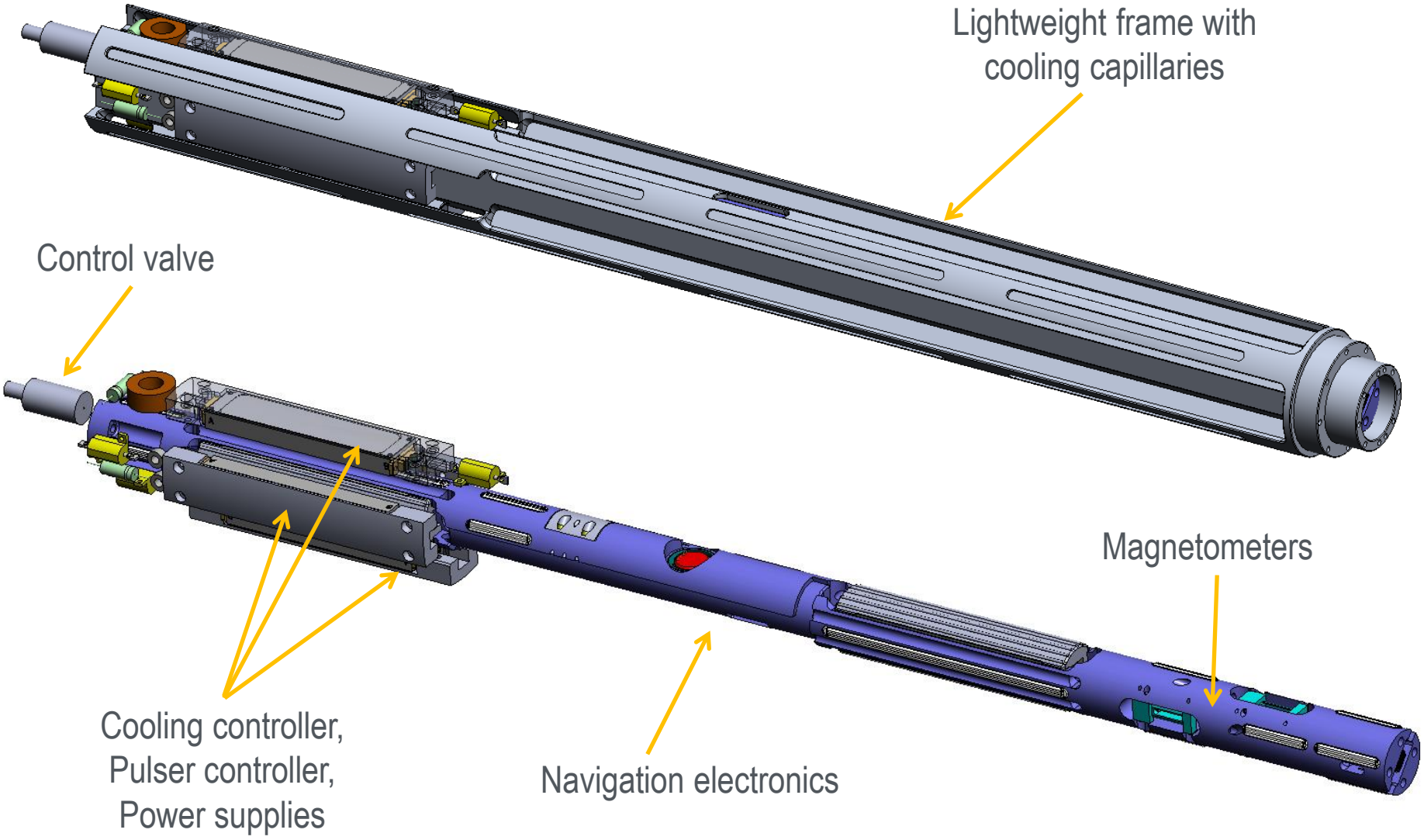



Elastomer-free control valve in pulser

Ceramic (or Inconel) sleeve in alternator

# Directional electronics





# Accomplishments, Results and Progress



- Concept evaluation (Phase I) complete. Confident about the feasibility of the proposed system. Active cooling concept has been demonstrated in a laboratory prototype tool
- Significant progress in the detailed design of directional measurement package. We are upgrading an existing design to 175ºC operation. The directional unit to be ready in Q3.
- Laboratory tests with available wireline flasks has been conducted and thermal leakage loads has been studied to determine the cooling system capacity.
- Detailed design of high temperature pulser and alternator is underway. FEA of the Pulser design has been performed and crucial parameters like plunger force and current has been studied. FEA of the alternator has been performed to aid in design.

| Original Planned Milestone/ Technical Accomplishment | Actual Milestone/Technical Accomplishment | Date Completed |
|---|---|---|
| Concept evaluation Phase I | Completed | March 2014 |
| Phase II approval | | Jan 2015 |
| Phase II work started | | April 2014 |

# Future Directions



- Detailed design of each subsystem started. The subsystems are: pulser, alternator, dewar flask, directional electronics package, water chamber, zeolite tank.
- Complete the detailed design by September.
- Order long lead components by August.
- Subsystem prototypes ready, start testing in the laboratory by 2015 end.
- Complete design iteration based on the outcome of laboratory testing and build a prototype tool, test it at BETA (Baker Experimental Test Area) by October 2016, field trial November 2016.

| Milestone or Go/No-Go | Status & Expected Completion Date |
|---|---|
| Phase II approved | January 2015 |
| Subsystem prototypes ready | November 2015 |
| Prototype tool | July 2016 |
| Field trial | November 2016 |

# Mandatory Summary Slide



- Phase I: Feasibility and Concept evaluation complete.
- Prototype demonstration of active cooling in laboratory.
- Adsorption based active cooling enables the use of robust 175ºC electronics inside a flask. The cooling system cools from 300ºC ambient to 175ºC.
- Significant progress made in the upgrade of directional electronics unit.
- Detailed design of 300ºC temperature pulser and alternator started.
- Laboratory prototype of subsystems expected in Q4 2015, Prototype tool ready in Q3 2016.