National Laboratory Assistance with In-Situ Testing of High-Temperature Module

At Ozark Integrated Circuits, exhaustive testing is used at every stage of product development. In fact, our design efforts ***begin*** with high-temperature characterization of every component and material used to realize our electronics modules. For example, Ozark IC has characterized several ceramic wiring board systems to 400 ℃ to understand the life-at-temperature characteristics of isolation leakage, IR drop, and electromigration. In addition, active and passive components such as microprocessor, analog-to-digital converters, resistors, capacitors, inductors, diodes are characterized at high-temperature. This approach ensures that an integrated high-temperature data acquisition module, such as the XN-AQ-250 in Figure 1, can operate within specifications at high temperature (300 ℃). Additive manufacturing steps, such 3-D printed ceramic connectors and high-precision printed conductor traces, are proven out through test coupons followed by rigorous testing and characterization. This testing enables high-confidence design of integrated modules. This testing has also established the design rules for integrating the module using additive manufacturing; design rules such as space-and-trace, component density, and escapement to connectors. Once the design is complete, such that the rules are satisfied, module integration follows in rapid succession, as shown in Figure 1, concluding with a working instrument.

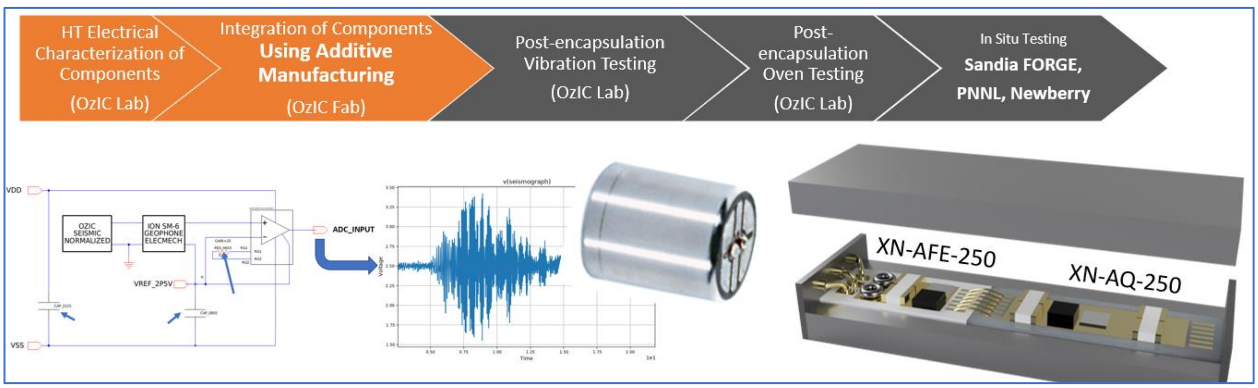


Figure 1: Characterization, Integration and Laboratory Testing at Ozark IC Labs.

Once the instrument is encapsulated, room temperature vibration testing begins with a standard battery of MIL-STD-810 vibrations tests, such as tonal, random, and shock stimuli. The encapsulated instrument is then operated while being vibrated with a space-shuttle transport (SST) profile to ensure no intermittent shorts and opens appear that would create shock-induced faults.

The encapsulated instrument is then operated in one of Ozark IC's environment ovens to characterize data collection performance over temperature; in this application, from room temperature to 300 ℃.

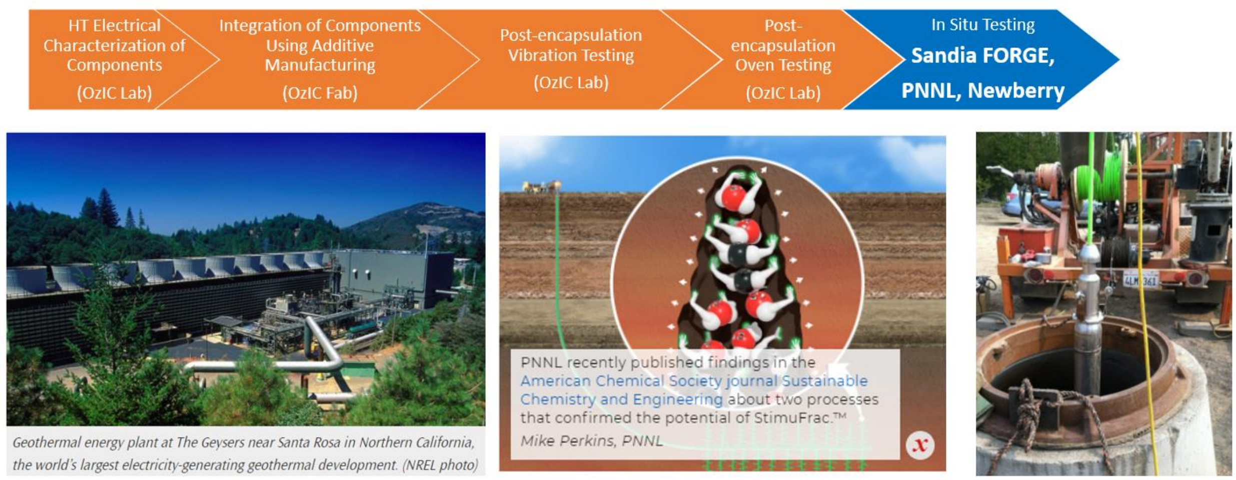
At this point, the next logical step is to operate the instrument in situ in a geothermal environment. Ozark IC, with area expertise provided by AltaRock Energy will need the assistance of a national laboratory to provide advanced testing capability such as:

- Advance laboratory testing to perform simultaneous high-temperature and vibration testing
- A geothermal observatory with a high-temperature open hole well site

- A geothermal observatory with naturally occurring or artificially created seismic sources.

Ozark IC and AltaRock Energy have identified the following National Laboratories, shown in Figure 2, that could help Ozark IC take the next step in instrument testing:

- Sandia's Frontier Observatory for Research in Geothermal Energy (FORGE)
- Pacific Northwest National Laboratory's Newberry Volcano Site



Sandia Frontier Observatory for Research in Geothermal Energy (FORGE) [1]

Pacific Northwest National Laboratory (PNNL)[2], Oregon State University (OSU), and AltaRock Energy[3].

[1] https://energy.sandia.gov/sandias-frontier-observatory-for-research-in-geothermal-energy-forge-phase-1-proposals-were-both-successful/
[2] https://www.pnnl.gov/news-media/pnnl-fracturing-fluid-cost-effective-option-geothermal-energy
[3] http://altarockenergy.com/projects/newberry-geothermal-energy-newgen/

Figure 2: Laboratory testing at Ozark IC Lab promotes module for testing in more advanced National Laboratories or in situ in National Laboratory sites

These laboratories can provide the ***critical next step*** in hardware validation of the additively manufactured instrument.