A Low-Frequency Electrode Array Tool for Fracture Diagnostics in Steel-Cased Wellbores

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presented by

David A. Glowka

E-Spectrum Technologies, Inc.

U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

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Project Team

E-Spectrum Technologies, Inc.

- Dave Glowka – PI and mechanical design
- Jeff Gabelmann – electronic design
- Tom Haas – electronic design
- Mark Oerkfitz – software design
- John Weiblen – mechanical design

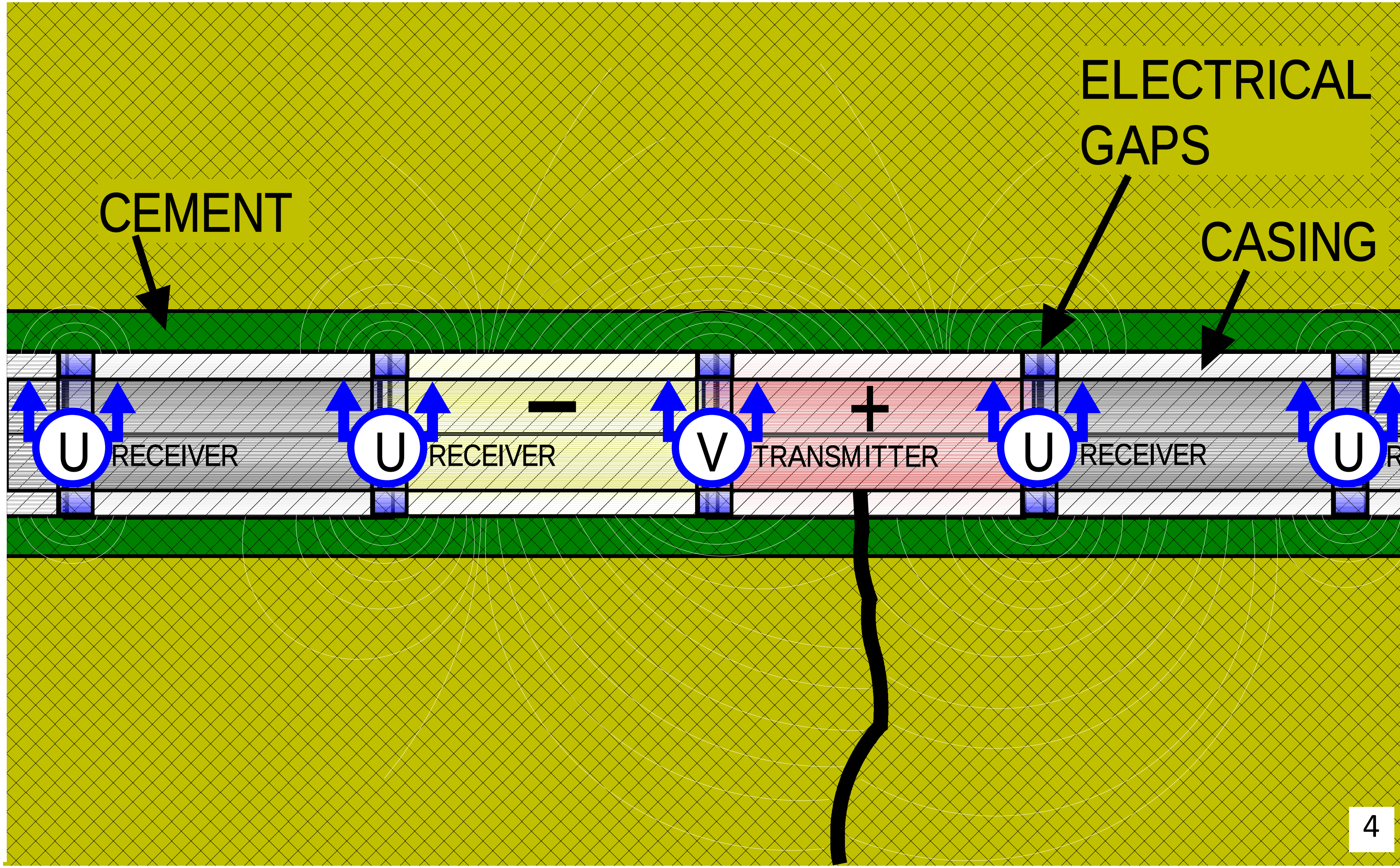
University of Texas at Austin

- Dr. Mukul Sharma – Tool modeling and data inversion
- Dr. Peng Zhang – Tool modeling and data inversion
- Javid Shiriyev – Tool modeling and data inversion

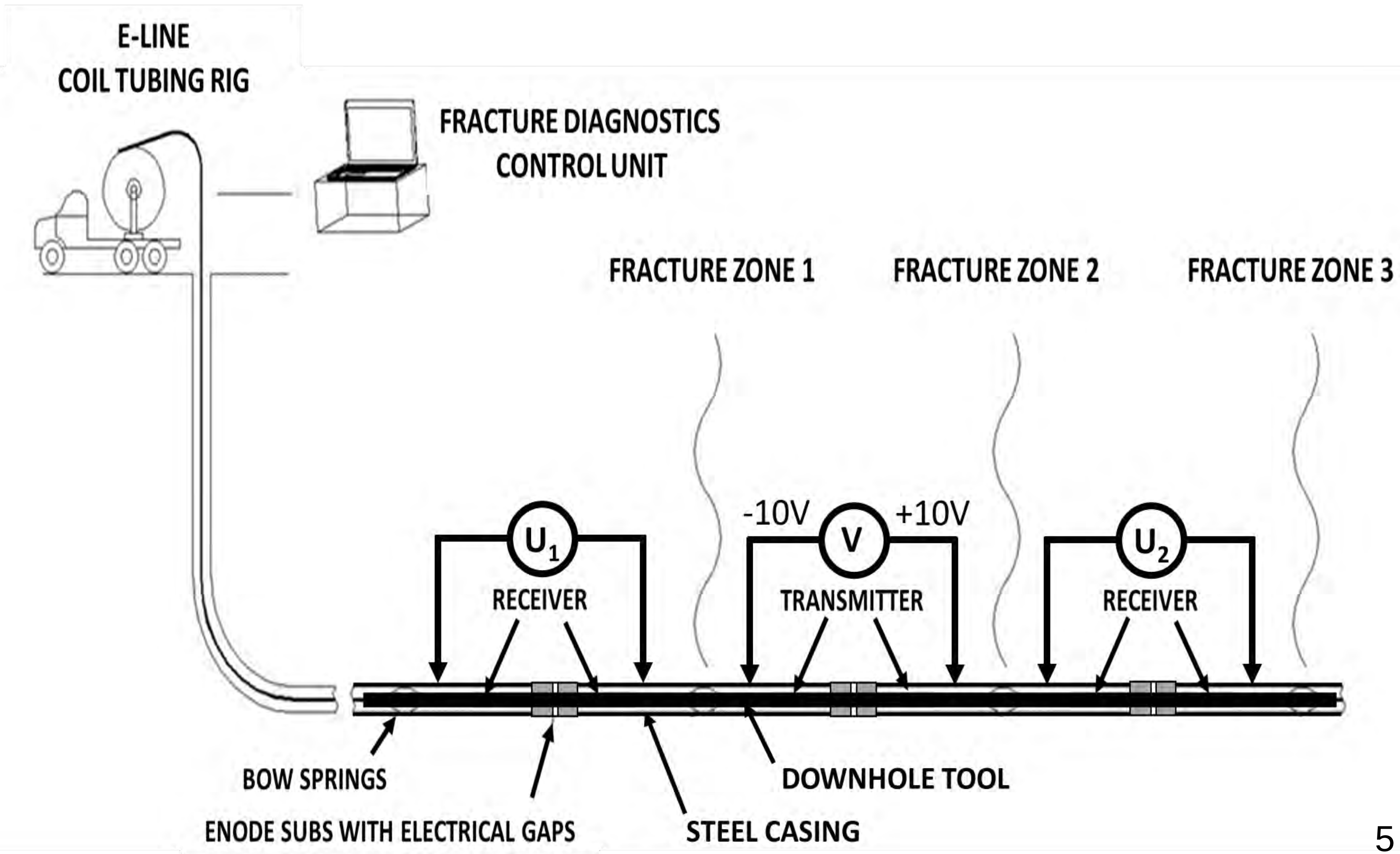
Presentation Outline

- Description of the Low-Frequency Electrode Array (LFEA) concept
- Results of the computational modeling of fractures interacting with electrically isolated and energized steel casing (The University of Texas at Austin)
- Description and status of the LFEA tool under development (E-Spectrum Technologies, Inc.)
- Accomplishments and challenges

Low-Frequency Electrode Array
Fracture Diagnostics Concept



Low-Frequency Electrode Array Fracture Diagnostics Concept



SBIR-DOE Phase II Project
- Technical Objectives -

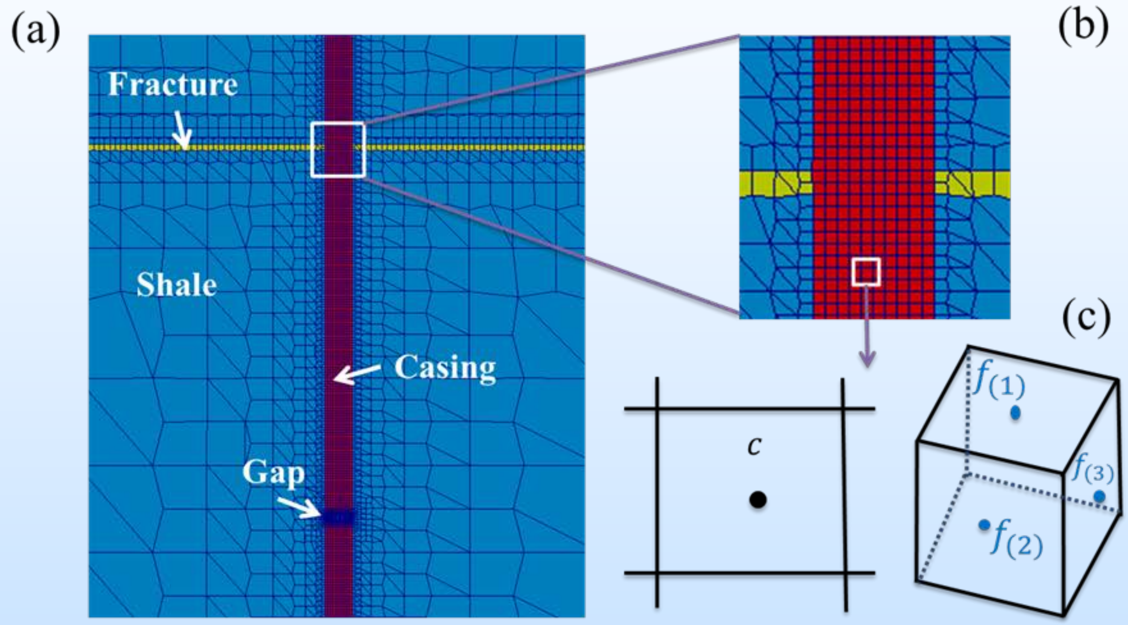
- Develop a model for casing-excited fracture measurements
- Develop a fracture parametric inversion algorithm for cased holes
- Design, fabricate, and bench test the electronics, firmware, and mechanical components of the tool
- Deploy the complete LFEA system in a conductively propped well to validate the tool

Computer Modeling of a Steel-Cased Well

(Peng Zhang and Mukul Sharma, UT Petroleum Engineering Dept.)

Governing Equation

$$\nabla \cdot \left(\sigma(\boldsymbol{X})\nabla\Phi(\boldsymbol{X})\right) = 0$$



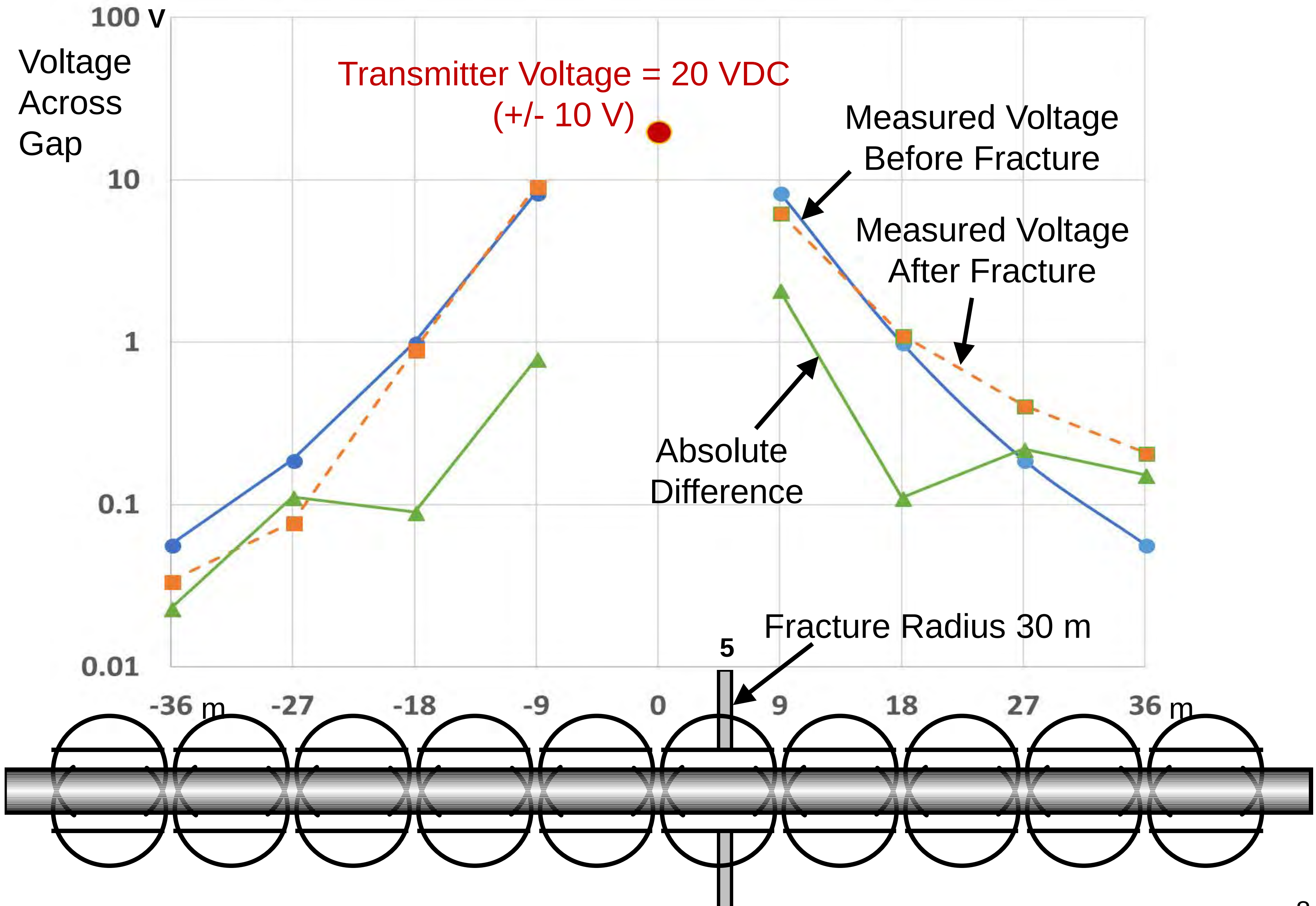
$$\iiint_V \nabla \cdot (\sigma_c \nabla \Phi_c) dv = 0$$

$$\iint_S (\sigma \nabla \Phi) \cdot \boldsymbol{ds} = \sum_{p=1}^{P} \boldsymbol{S}_{f(p)} \cdot (\sigma_{f(p)} \nabla \Phi_{f(p)}) = 0$$

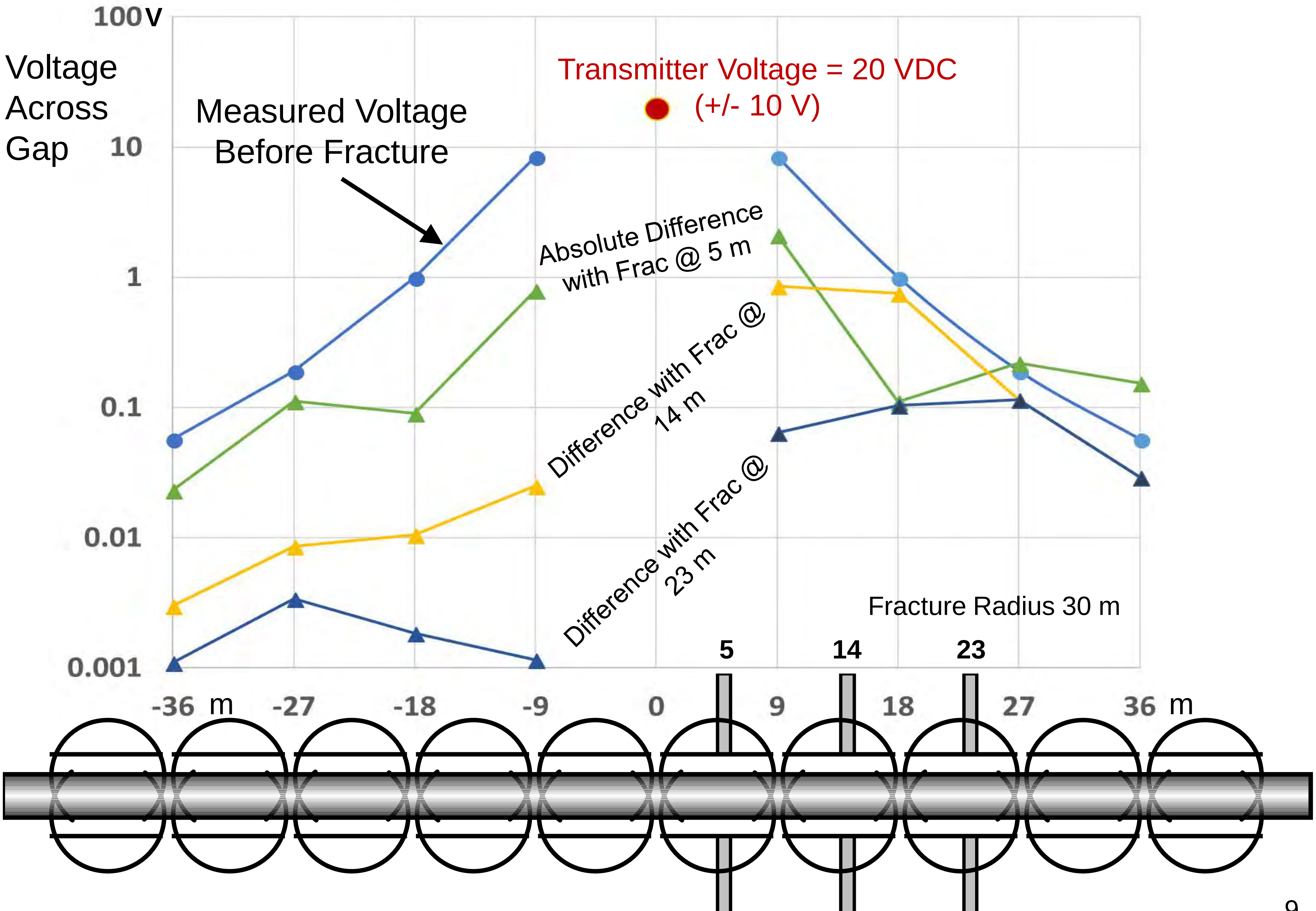
Finite difference

- Forward Simulation Technique -

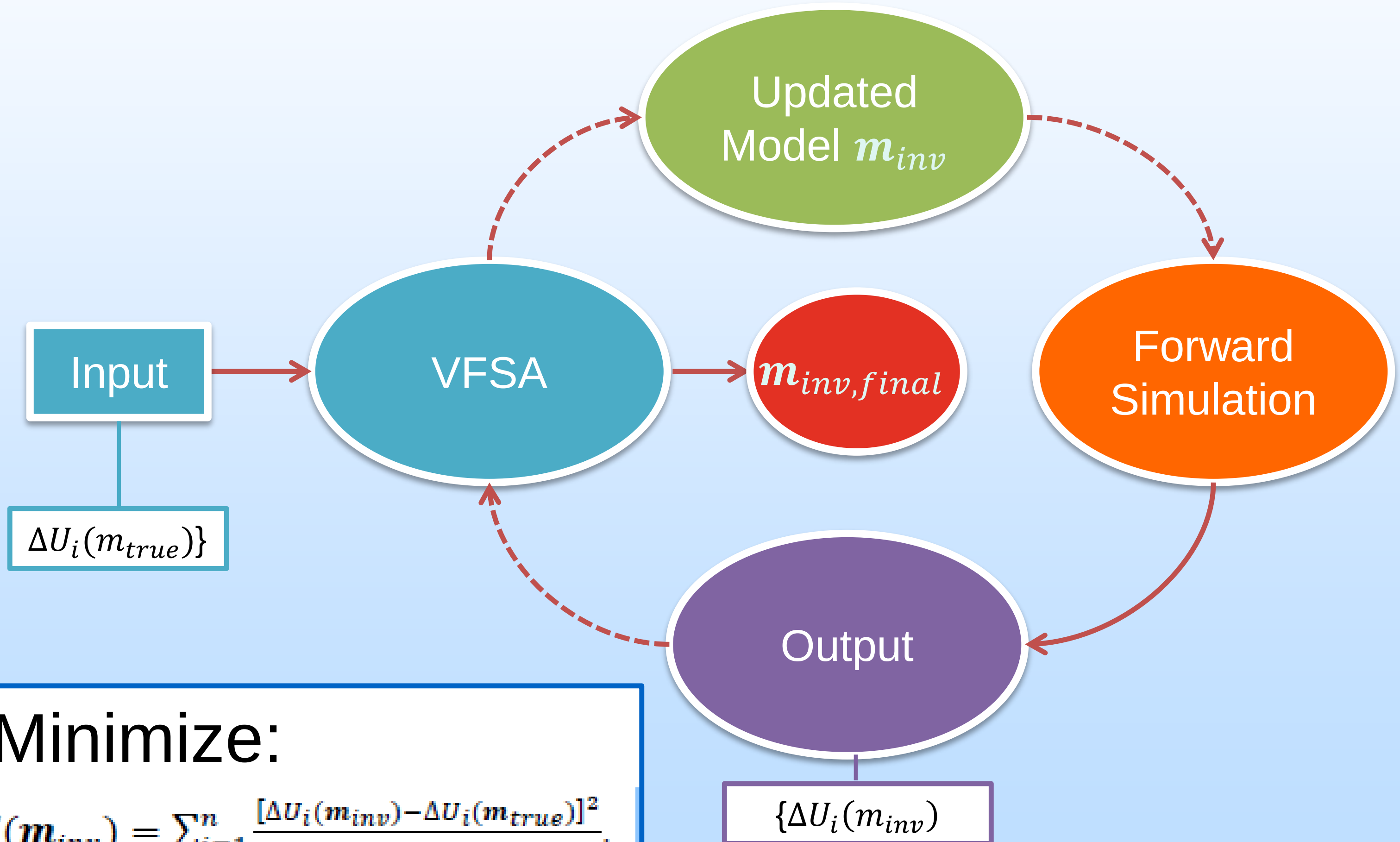
Forward Simulation Results for a Single Fracture



Effect of Single-Fracture Location



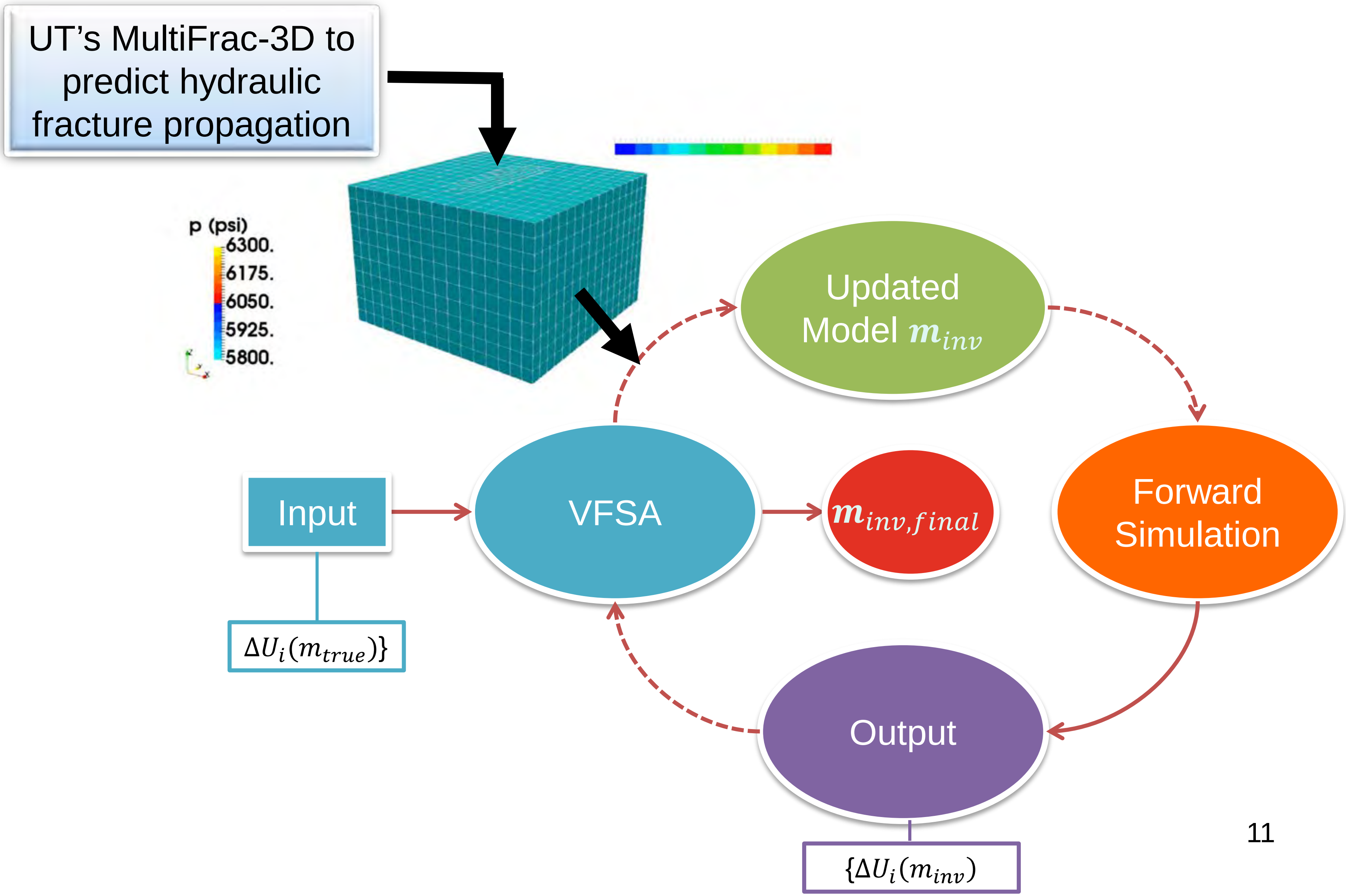
Work Flow Diagram for the Inversion of Field Data



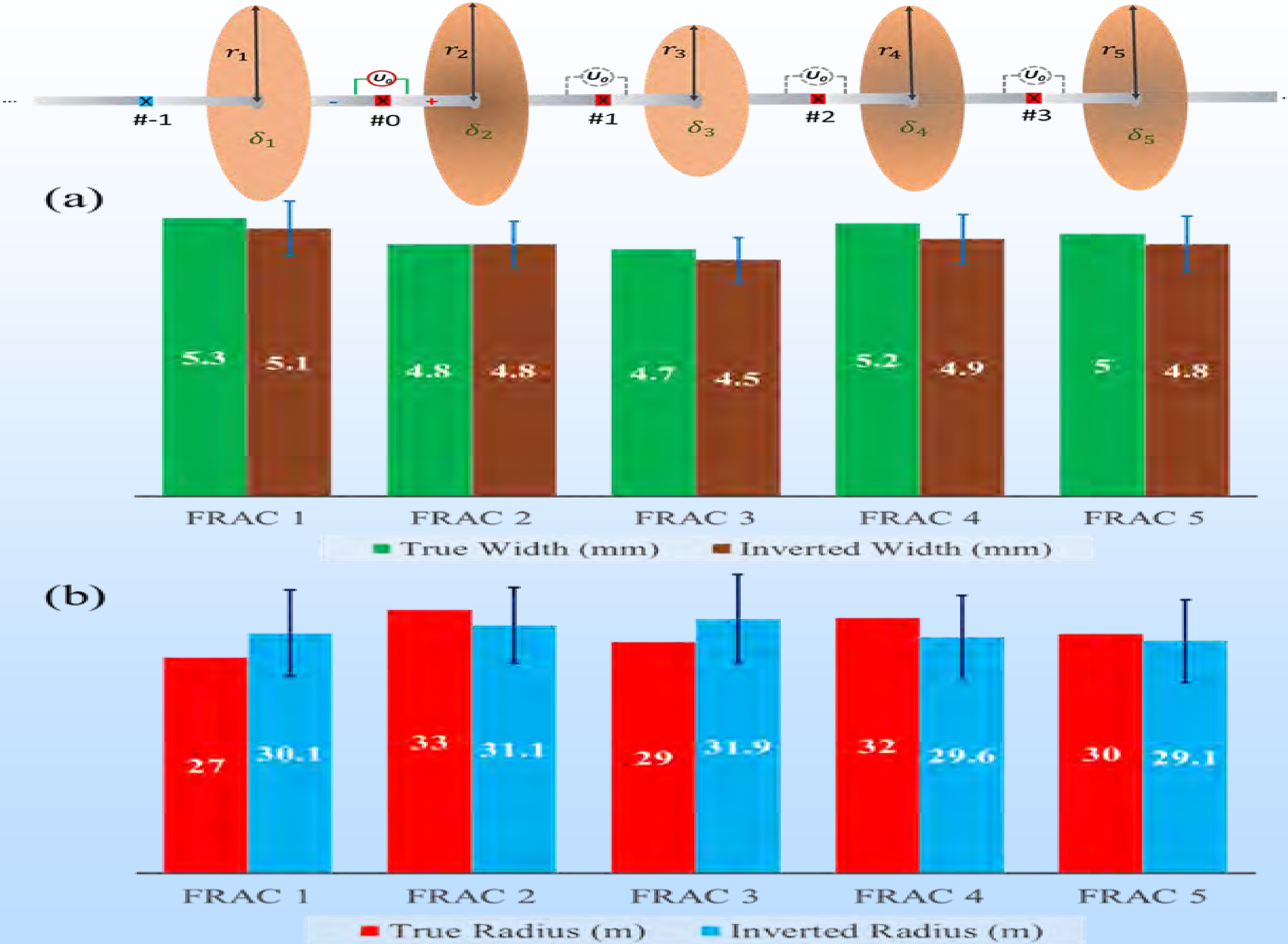
Minimize:

$$E(\boldsymbol{m}_{inv}) = \sum_{i=1}^{n} \frac{[\Delta U_i(\boldsymbol{m}_{inv}) - \Delta U_i(\boldsymbol{m}_{true})]^2}{[\Delta U_i(\boldsymbol{m}_{true})]^2}.$$

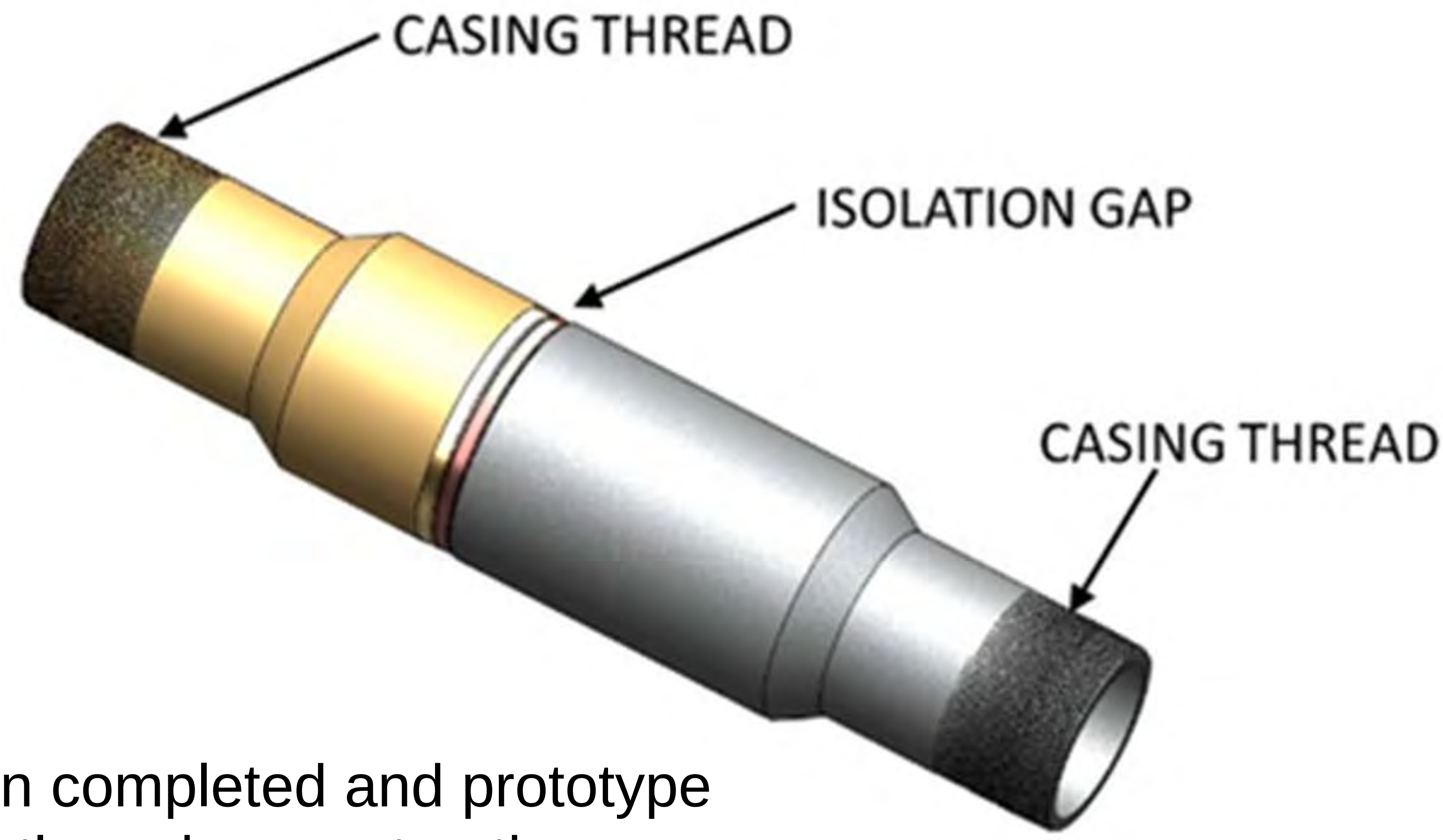
Incorporating a Geomechanical Model to Constrain the Inverse Solution



Inverse Model Predictions with 5% Gaussian Noise

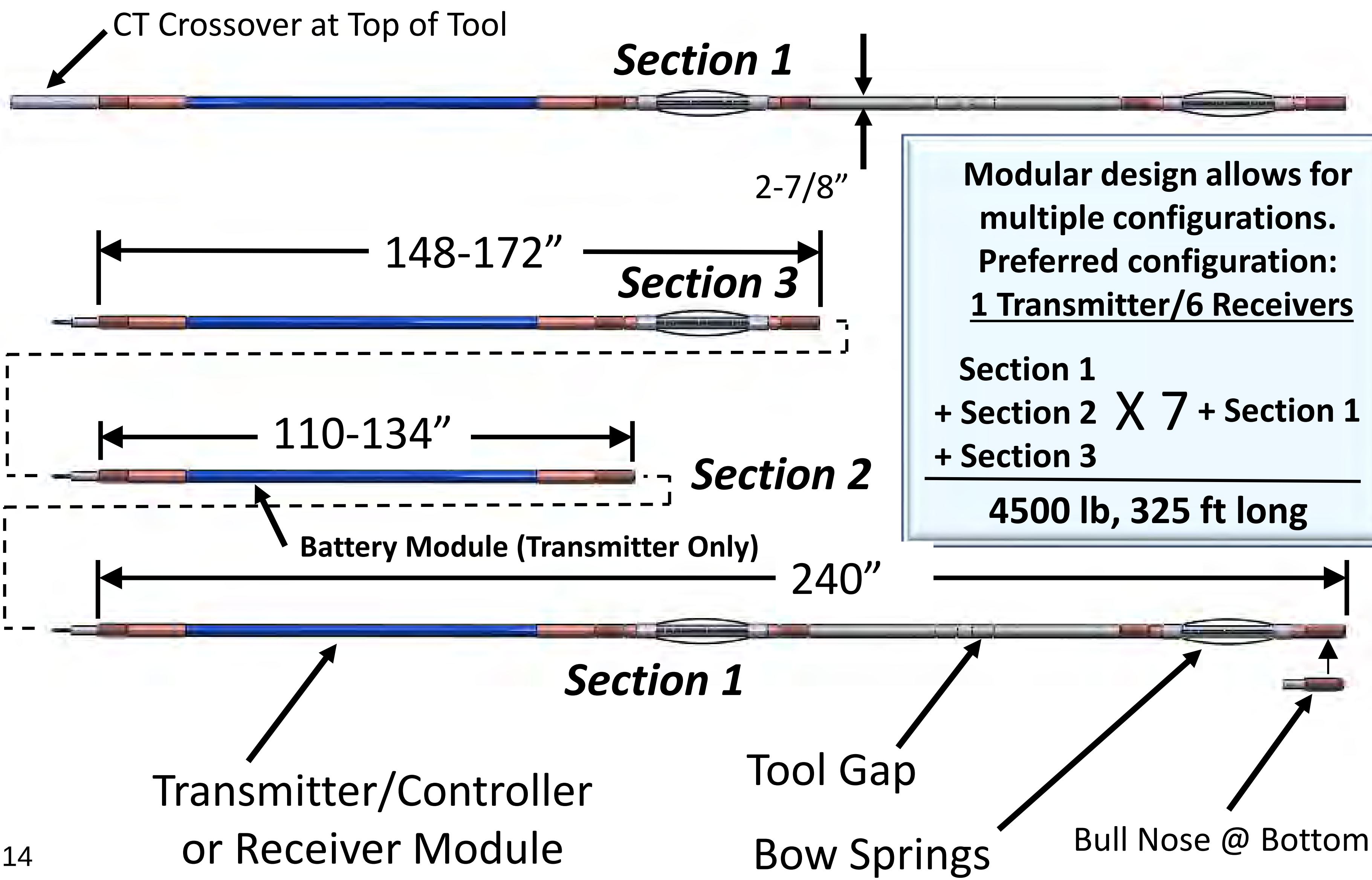


ENODE Casing Coupling Design



Design completed and prototype currently under construction

EDRIVE Tool Configuration



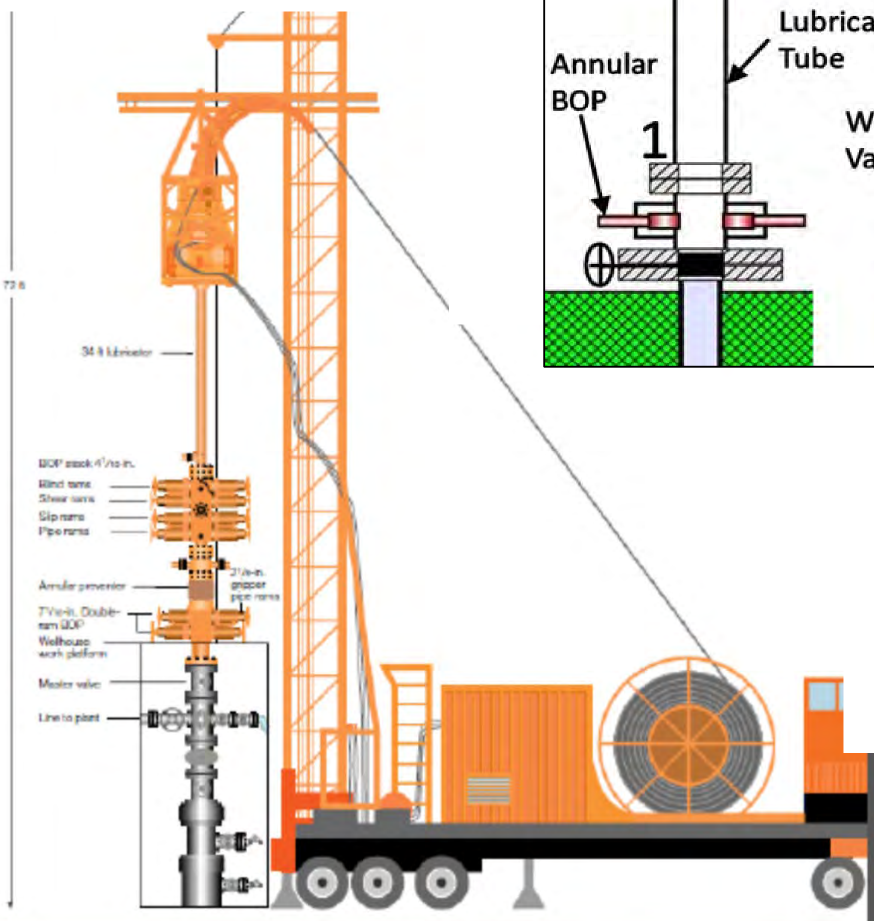
Modular design allows for multiple configurations.
Preferred configuration:
<u>1 Transmitter/6 Receivers</u>

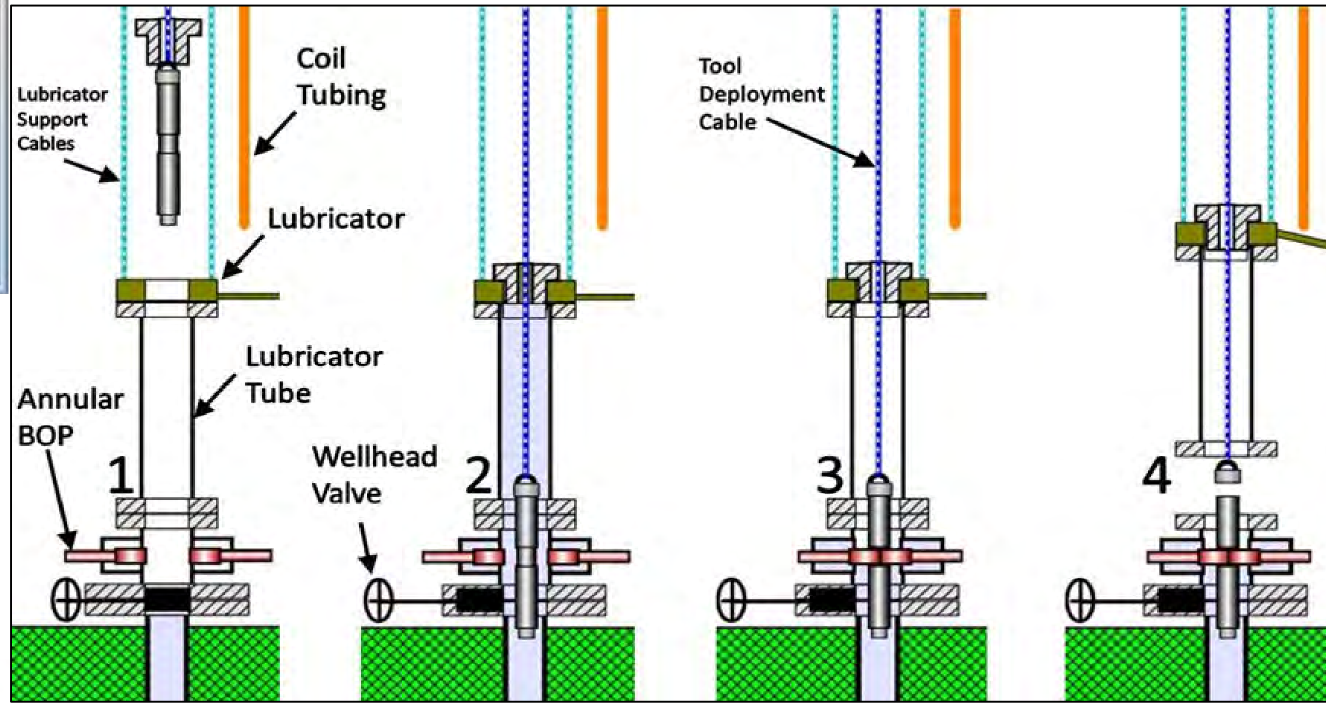
Section 1
+ Section 2 X 7 **+ Section 1**
+ Section 3

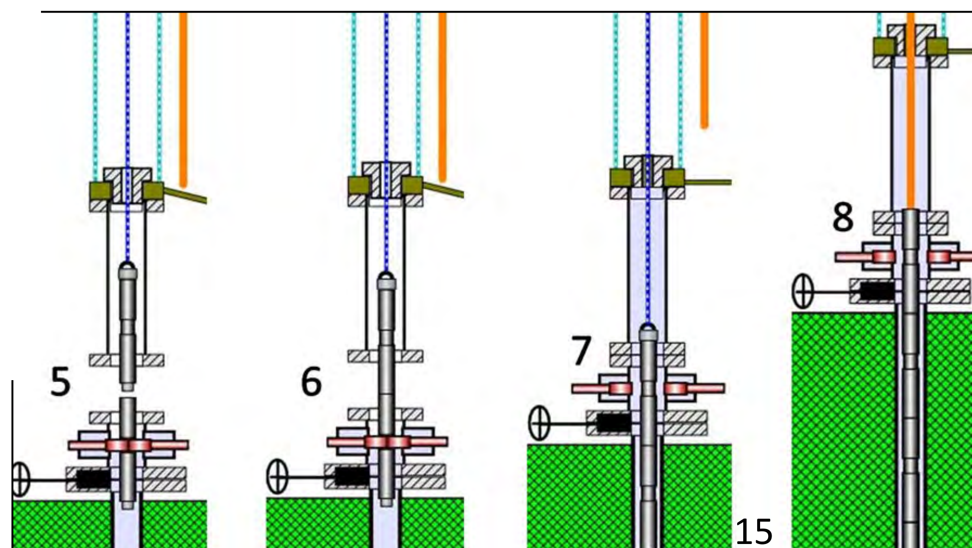
4500 lb, 325 ft long

LFEA-Coiled Tubing Deployment Procedure

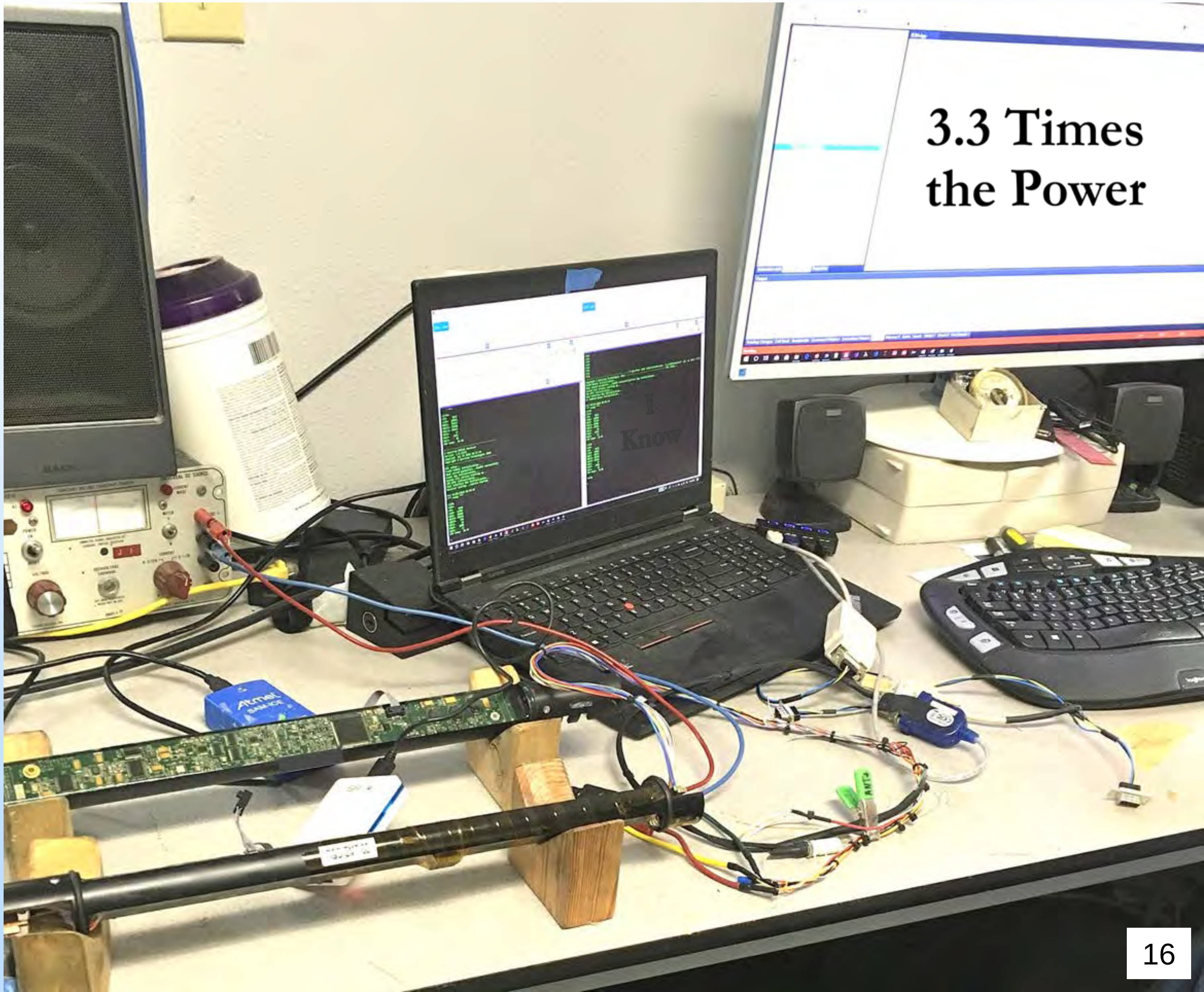
Use Lubricator and Blow-out-Preventer to deploy the tool into a well under pressure.



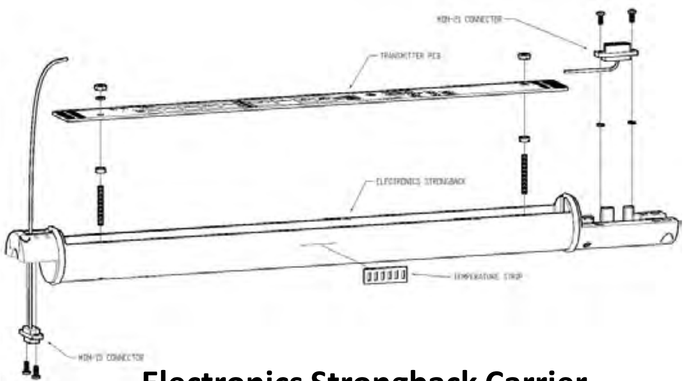




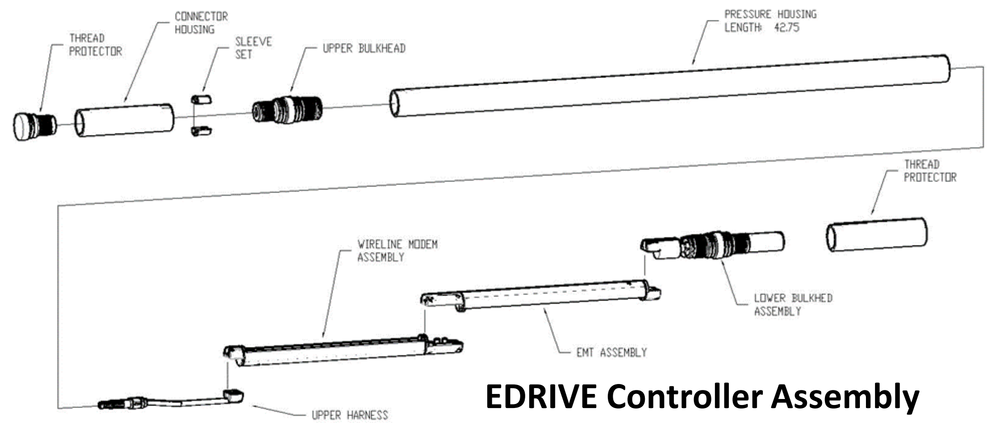
Developing a High-Power Transmitter



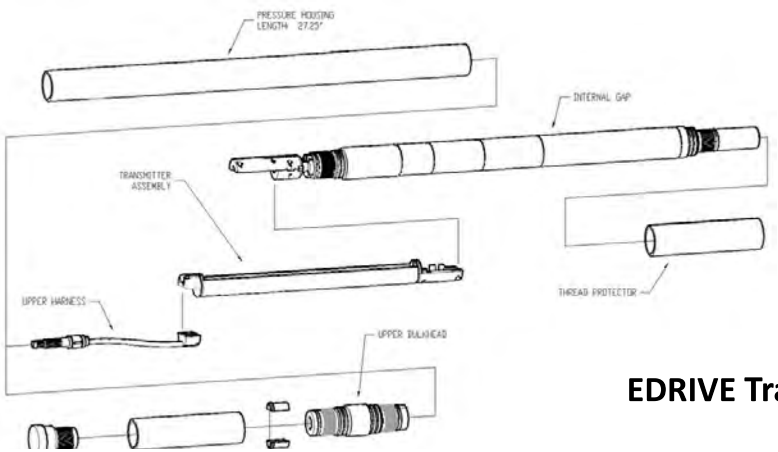
Interior Tool Design

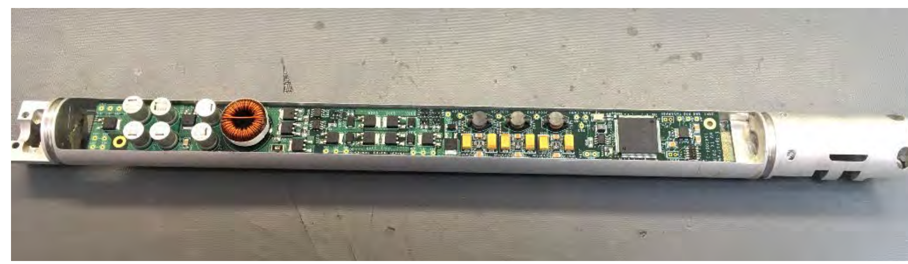


Electronics Strongback Carrier

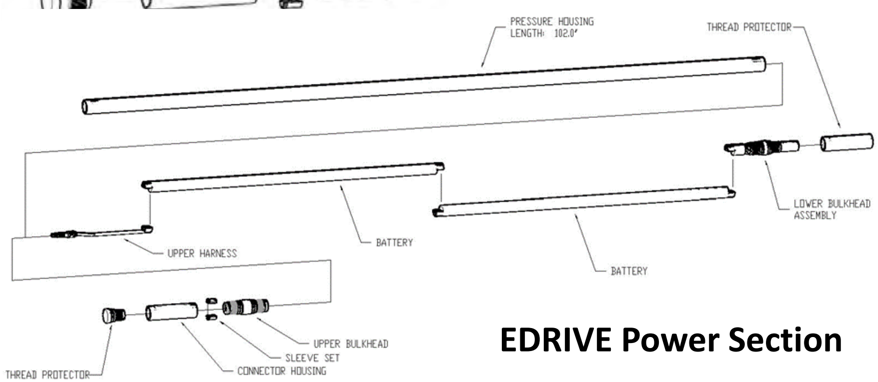


EDRIVE Controller Assembly

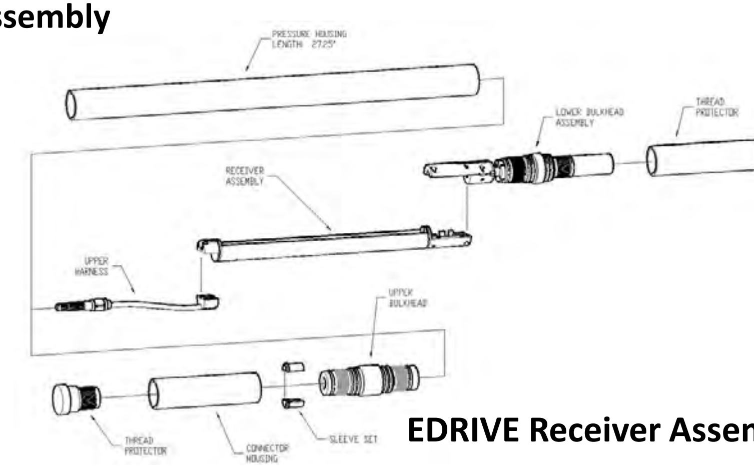




EDRIVE Transmitter Assembly



EDRIVE Power Section



EDRIVE Receiver Assembly

Accomplishments to Date

- Successfully developed a forward simulation model and an inversion technique that can be used to analyze the measurements taken by the LFEA tool
- Completed the design of the ENODE casing coupling and began construction of a prototype
- Completed a top-level mechanical design of the EDRIVE tool
- Confirmed general tool design and deployment technique with field experts
- Developed a transmitter module with more than 3 times the power output as a previous design

Lessons Learned

– Unanticipated Research Difficulties:

Exploring the tool configuration and deployment options and selecting a configuration compatible with field practices required more time than anticipated.

– Challenges:

- BHP (our original proposed field-test partner) sold all their US shale assets to BP last month.
- Other field-test partners will be sought.
- Full-scale surface testing of the prototype tool will provide the proof of concept we need to convince a well operator to participate in a field test.

Project Summary

- Project is on schedule.
- Computer modeling work indicates that data which could be acquired with the Low-Frequency Electrode Array tool is capable of yielding important information about hydraulic fractures extending from the wellbore.
- Work is underway to design and build a prototype LFEA tool.
- Seeking field testing opportunities.

Publications

- Zhang, P., Brick, Y. and Sharma, M.M., Numerical study of an electrode-based resistivity tool for fracture diagnostics in steel-cased wellbores. Geophysics, 83(2), pp. D41-D48, 2018.

- Zhang, P. Sen, M.K., Sharma, M.M., Gabelmann, J., and Glowka, D. Modeling of Low Frequency Downhole Electrical Measurements for Mapping Proppant Distribution in Hydraulic Fractures in Cased-Hole Wells, SPE-189884-MS, SPE Hydraulic Fracturing Technology Conference, The Woodlands, TX, USA, 23-25 January 2018.

Thank You

Questions

Benefit to the Program

This project is developing a technique and a downhole tool for determining important hydraulic fracture characteristics, such as location, extent, and conductivity. The technology, when successfully demonstrated, will provide an understanding of hydraulic fracture propagation that is currently not available to the industry. This technology contributes to the Fossil Energy Program's draft objective to catalyze the development and demonstration of new technologies and methodologies for limiting the environmental impacts of unconventional oil and natural gas development activities.

Synergy Opportunities

The fracture diagnostics technologies reviewed in this session are significantly different, but collaboration among projects could have a synergistic effect in the following areas:

- Downhole tool design – common design challenges could have common solutions
- Field validation – using more than one technique on a given well could yield additional data and insight

Project Overview

Goals and Objectives

- Develop a model for casing-excited fracture measurements
- Develop a fracture parametric inversion algorithm for cased holes
- Design, fabricate, and bench test the electronics, firmware, and mechanical components of the tool
- Deploy the complete LFEA system in a conductively propped well to validate the tool

These project objectives describe a tool-based path toward the DOE programmatic goal of advancing our ability to diagnose, quantify, and map hydraulic fractures for the purpose of limiting environmental impacts.

The metric for success is the development and field demonstration of a tool and software for acquiring and analyzing hydraulic fracture data.

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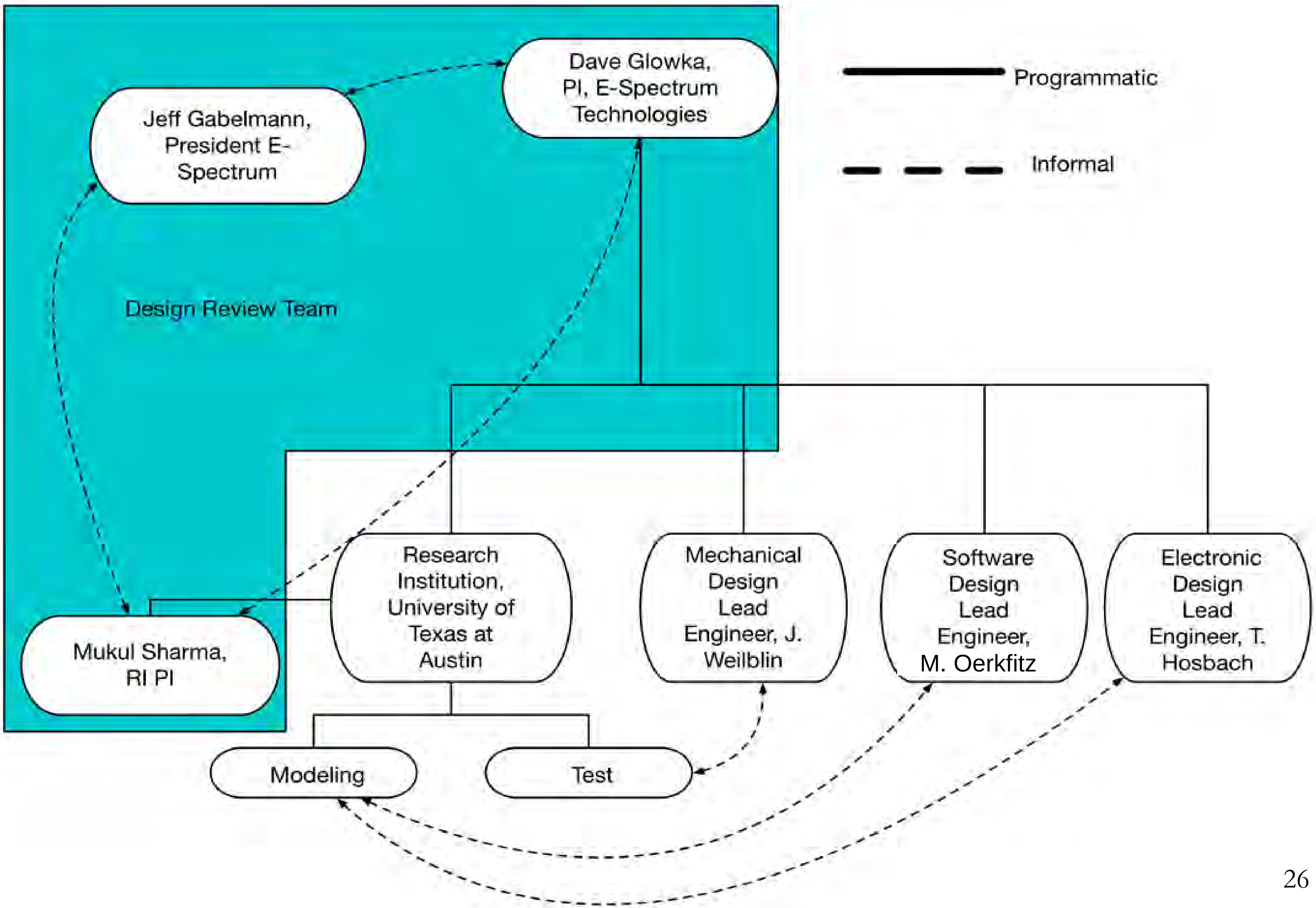

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