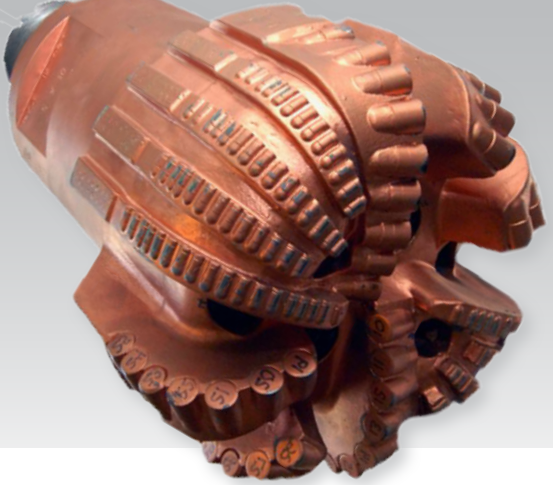

SPECIAL ISSUE: Advanced Geothermal Well Construction Technologies

Sandia's INNOVATION MARKETPLACE

A Quarterly Update of Available Technologies for Industry

Sandia National Laboratories

August 2016• Vol 3, Issue 3

Welcome to Sandia National Laboratories' Intellectual Property Magazine

Sandia's Innovation Marketplace is a quarterly magazine published by Sandia National Laboratories. This publication highlights exceptional opportunities for licensing Sandia's intellectual property, including patents, copyrights (generally software), trademarks, and mask works. Listings within should not be construed as an offer to license technology. All licenses are subject to negotiation and availability of the intellectual property for licensing. This publication is intended for indications of interest only.

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Sandia National Laboratories

Exceptional service in the national interest

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TABLE OF CONTENTS

4 *Introduction to Sandia's Geothermal Well Construction Program*

6 *High Temperature Downhole Motors*

7 *Auto-Indexer for Percussive Hammers*

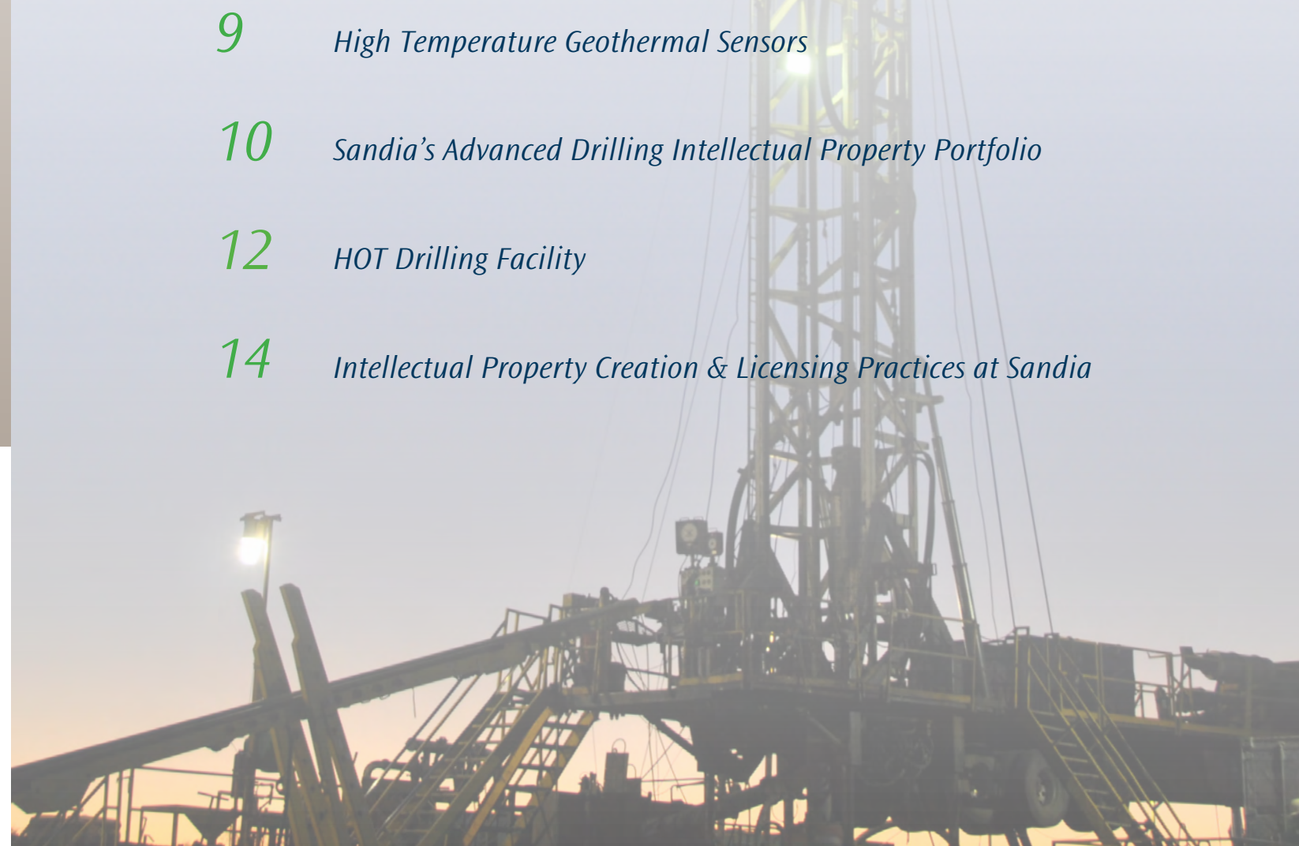
8 *Active Suppression Systems for Drill String Stability*

9 *High Temperature Geothermal Sensors*

10 *Sandia's Advanced Drilling Intellectual Property Portfolio*

12 *HOT Drilling Facility*

14 *Intellectual Property Creation & Licensing Practices at Sandia*



Sandia's work in drilling technology is aimed at reducing the cost and risk associated with drilling in harsh, subterranean environments. The historical focus of the drilling research has been directed at significantly expanding the nation's utilization of geothermal energy. This focus in geothermal related drilling research is the search for practical solutions to challenges associated with tapping the most intense sources of heat, typically found well below the earth's surface in very severe environments.

Because a large portion of the cost and risk of generating electricity from geothermal sources is associated with drilling and completing exploration, production, and injection wells, Sandia's primary focus has been on the development of improved drilling and completion technologies such as diagnostics while drilling, high-temperature electronics, advanced drill bit technologies, and wellbore integrity technologies to reduce and mitigate problems associated with loss of circulation.

We also actively work on advanced drilling concepts to provide economical access to deeper and hotter resources in the future. Most of these research projects are conducted in cooperation with geothermal operators and companies within the well service industry. On a cost-per-foot basis, geothermal drilling is among the most expensive type of drilling performed; and Sandia's work in this area has created natural synergies that benefit other industries and agencies (e.g.,Oil & Gas and DOD) requiring drilled access to the underground.

Reliable drilling is also vital to ensure access to our oil & gas reserves. These remaining hydrocarbons are often found in deep reservoirs with ever increasing downhole temperatures and pressures. Many of the challenges in oil and gas drilling are similar to those encountered in geothermal well construction

Sandia also supports a variety of non-energy related governmental programs requiring drilling research in support of other national security objectives. Through a strong application-oriented R&D approach, Sandia is uniquely qualified to apply drilling technology to these applications and develop new technologies to address the challenging problems necessary to ensure our national security.

Program Activities

- High Temperature Electronics
- Advanced Bit Development
- Geothermal Energy & Drilling Technology
- Advanced Systems & Diagnostics While Drilling
- Computational Modeling
- Wellbore Stability
- Energetic Stimulation

HIGH TEMPERATURE DOWNHOLE MOTOR

U.S. Patent Application No. 15/090,282

Drilling costs amount to over half of the total cost of geothermal energy production. To address the high cost of well construction, Sandia engineers are developing a high temperature downhole motor that provides a high-power downhole rotation solution for directional drilling. Commercially available downhole motors, such as Positive Displacement Motors (PDM), rely on elastomeric material, limiting operations to approximately 350°F or less, making them unreliable for extended use in geothermal wells. Sandia's downhole motor is designed using proprietary advanced materials to withstand prolonged exposure to high temperature and pressure. Unlike conventional drilling motors, this motor allows for downhole directional control when drilling high temperature formations, resulting in preferential targeting of geothermal resources.

Sandia's downhole motor works by converting longitudinal oscillatory motion of a piston into uniform rotational motion, in turn powering the attached drill bit. High pressure fluid (gas or liquid) is pumped from the surface downhole to the piston, causing the piston to cycle. The axial motion of the piston is then converted into rotational motion in a rotor. All rotor components remain on the centerline, ensuring no dysfunctional lateral vibrations are introduced into the drillstring.

This novel downhole motor concept has the ability to produce wells with multilateral completions resulting in improved geothermal resource recovery and well construction economics, thus making geothermal a more affordable alternative energy source. Additional applications for high-torque linear motors have also been conceived.

TECHNOLOGICAL BENEFITS

- Reliable access to deep, hot geothermal resources
- Cost-efficient, durable
- Directional control during drilling
- Geothermal wells with multilateral completions
- Decreased environmental impact
- Reduced lateral vibrations

ADDITIONAL APPLICATIONS

- Mobile hydraulics (construction equipment)
- Oil & gas
- Auto industry
- Aerospace

AUTO INDEXER FOR PERCUSSIVE HAMMERS

U.S. Patent Application No. 14/191,664

At Sandia our engineers are developing a high-temperature drill motor solution capable of performing in extreme conditions such as those encountered during geothermal well construction. Unlike conventional drilling motors, the Auto Indexer for Percussive Hammers is designed to operate without elastomeric components or gear sets to transmit power enabling its operability in high temperatures.

Similar to other downhole drilling motors, the Auto Indexer consists of three main components: a power generation section, a power delivery section, and a bearing section. The power generation section consists of an elastomer-free motor driven by a working gas or fluid. The motor generates rotation through the supply pressure and expansion of the working fluid in the motor chambers.

Power is delivered to the bit by transferring angular momentum generated by the fluid through the power delivery section. The power delivery section is composed of elements that apply force to a shaft to generate rotation in the desired drilling component. The power delivery elements are driven to a specified angular velocity before impacting the drill bit. Upon impact, energy is transferred from the Auto Indexer to the bit, resulting in rotational advancement. The bearing section provides rotational and axial support to the driven shaft.

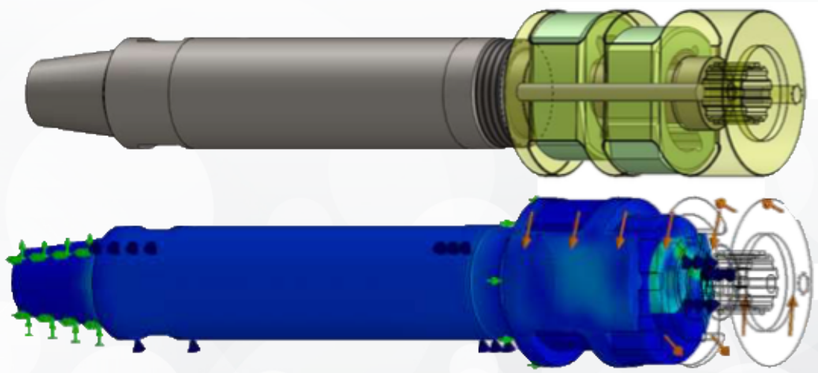
The relative simplicity of the Auto Indexer for Percussive Hammer makes it well suited for performing in challenging environments. The resulting product allows for high torque generation in a compact package that is durable enough to withstand the harshest conditions.

TECHNOLOGICAL BENEFITS

- Enables advanced drilling techniques through downhole rotation
- High torque generation in a compact package
- Promotes the use of hammer drilling in geothermal formations
- Improves Rate of Penetration in hot, hard rock
- Expands driller's tools for expanded drilling capabilities

ADDITIONAL APPLICATIONS

- High temperature drilling
- Oil & gas



ACTIVE SUPPRESSION SYSTEMS FOR DRILL STRING STABILITY

U.S. Patent Application No. 62/219,481

Drill string stability is an essential component in cost reduction associated with deep well construction. Vibrations in the drill string can damage drill components, reduce lifespan of bits and tools, and reduce rate of penetration. Industry currently uses damping tools to suppress vibrations. However, active control is required to enforce stability and reduce vibrations in order to increase the reliability of overall well construction as conditions continually change during the well construction process.

Sandia's expertise in computer-based modeling has allowed our engineers to develop technologies to ensure drill string stability throughout the construction of deep wells.

Spring-Based Suppression:

Sandia has conceived several different spring-based suppression systems with modifiable spring rates to effectively suppress the transmission of vibrations from the rock drilling to the rest of the drill string. One of these concepts utilizes Belleville spring stacks within the bottom hole assembly. The springs are activated by shifting splines powered by a Shape Memory Alloy actuator. When splines are aligned, motion is resisted by the module spring. If the splines are not aligned, the spring is not engaged. This assembly is fitted with a load cell and displacement transducer to continuously monitor response. A preferred spring stiffness guards against self-induced vibrations. The system is stabilized at low vibration levels as vibration is absorbed and eliminated by the adjustment of the spring stiffness internal to the tool.

Further, an array of these drill string elements of equal or different constituent stiffness, can be coupled together to introduce a preferred net effective stiffness. These modules are selectively activated or deactivated to change the overall stiffness of the assembly. These spring-based systems are controllable, with variable spring stiffness to account for the varying conditions experienced during drilling.

Active Cancellation:

Sandia has also proposed a concept for an array of individual elements designed to suppress a range of frequencies throughout the drill string. Conceptually, these elements independently provide longitudinal and/or rotational counter motion to actively cancel out vibrations to the drill bit. Each individual element can be designed with vibration sensors and control features, to adapt to the ever-changing environment encountered in well construction. These drill string elements can be designed to communicate to adjacent elements, ensuring optimization of stability throughout the drill string.

HIGH TEMPERATURE GEOTHERMAL SENSORS

U.S. Patent Application No. 14/502,821; 14/023,209; 14/698,773

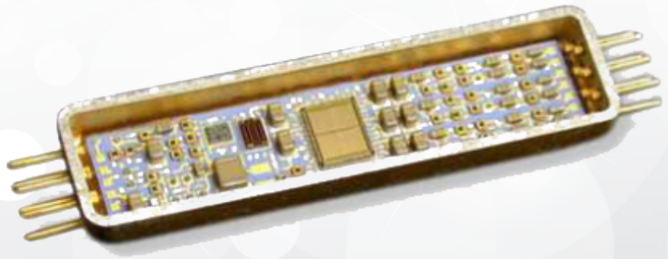
Sandia has developed numerous tools and sensors that allow for long-term downhole monitoring of geothermal wells. These technologies range from the sensors themselves to the high temperature compact motors required to run the instrumentation.

Real time data is essential to develop and maintain the productivity of geothermal fields. Current methods of monitoring utilize chemical tracers to characterize the fracture network. These chemical tracers are introduced into the injection well, measured from samples collected at the production wellhead, and sent off for laboratory analysis. In order to provide a real time monitoring solution, Sandia developed sensors capable of withstanding high temperatures and pressures with the ability to measure and monitor chemical tracers downhole. Our solid-state ion selective electrodes remain stable at temperatures up to 225°C and 5000 psi, providing accurate tracer concentration and pH levels along the depth of the well. This technology allows drillers the ability to understand the depth of fractures and flow patterns—a vast improvement over current methods.

Sandia engineers also designed a geothermal charge amplifier designed to work with high temperature accelerometers to monitor for seismic activity associated with geothermal exploration. Its multichip module (MCM) design provides increased temperature rating and reliability, while remaining compact. This charge amplifier converts charge signal from an accelerometer to voltage with a fully differential charge-to-voltage converter. This device has the ability to use voltage output for working with digital electronics or current output for directly driving logging cables. By adding external resistors, this charge amplifier becomes an instrumentation amplifier, greatly broadening its downhole sensing applications.

Sandia also developed a compact high temperature brushless motor controller to drive downhole monitoring equipment. This motor is designed to withstand high temperatures without the use of a heatshield, allowing for long term deployment and reduction in size. This compact motor can be used to operate seismic monitoring equipment, televiewers, valve actuators, clamping arms, and pumps, among other tools and instruments.

Sandia's geothermal sensors and high temperature interface electronics are all designed to assist in the creation of highly productive geothermal wells.



Sandia's Geothermal Drilling Technology IP

Title	Patent #	Filing Date
Drilling Fluid Compatible High Temperature Downhole Motor	Application Filed	4/4/2016
Gas Phase Bipropellant Fracturing System	Application Filed	
High Temperature Gas Generator for Downhole Stimulation	Application Filed	
Active Cancellation of Drill String Vibrations Using Inertial Exciters	Application Filed	9/16/2015
High Temperature Charge Amplifier for Geothermal Applications	9,209,766	
Methods for detecting and locating electrically conductive proppant	8,931,553	
Tagged Nanoparticles for Fluid Flow Monitoring	Application Filed Pub. No. 2016-0075937 A1	9/17/2014
Downhole Tool for the Measurement of Tracer Concentration and Ph	Application Filed	4/28/2015
High-Temperature Brushless DC Motor Controller	Application Filed	9/30/2014
Deployable Powered Centralizers	Application Filed	3/4/2014
Characterization of Stimulated Fractures Using Natural Tracers	Application Filed	8/30/2013
Single well injection-withdrawal tracer tests for proppant detection	Application Filed	8/11/2011
Simulating Current Flow through a Well Casing and an Induced Fracture	Application Filed	8/9/2011
Self Consuming Structural Materials and Composites	Application Filed	7/17/2013
Air Driven Downhole Drilling Motor	Application Filed	2/27/2014
Reduced-Impact Sliding Pressure Control Valve for Pneumatic Hammer Drill	8,176,995	
Sliding Pressure Control Valve for Pneumatic Hammer Drill	8,006,776	
Self-Assembling Segmented Coiled Tubing	Application Filed	2/16/2009
Downhole Geothermal Well Sensors Comprising a Hydrogen-Resistant Optical Fiber	6,853,798	
Method of Reducing Injection Loss in Drill Strings	6,791,470	
Controllable Magneto-Rheological Fluid-Based Dampers for Drilling	7,036,612	
Impedance-Matched Drilling Telemetry System	7,362,235	
An Improved Acoustic Transducer	6,147,932	
Drill Bit Assembly for Releasably Retaining a Drill Bit Cutter	6,427,791	

Downhole Sensing/Fracture Mapping

Drill Motors

Drill String Stabilization

Energetic Stimulation

Other

Sandia Labs News Releases

Designing a Geothermal Drilling Tool That Can Take the Heat

Sandia Labs works on a new type of downhole hammer

Sandia National Laboratories and a commercial firm have designed a drilling tool that will withstand the heat of geothermal drilling.

The downhole hammer attaches to the end of a column of drill pipe and cuts through rock with a rapid hammering action similar to that of a jackhammer. Downhole hammers are not new — the oil and gas and mining industries have used them since the 1950s — but the older design, with its reliance on oil-based lubricants, plastic and rubber O-rings, isn't suited for the hotter temperatures of geothermal drilling.

"The technology behind the new hammer is fundamentally the same, but Sandia worked with Sweden-based Atlas Copco in material selection and dry lubricant technology that will work in the high-temperature environment," said mechanical engineer Jiann Su, Sandia's principal investigator on the project with Atlas Copco, which operates worldwide and makes specialized equipment and systems for drilling, mining and construction.

The Department of Energy (DOE) Geothermal Technologies Office funded Atlas Copco as prime contractor on the project, and the company partnered with Sandia as the subcontractor.

"Part of what the DOE's Geothermal Program is looking to do is help lower the cost of getting geothermal energy out to customers," said Su, a researcher in Sandia's geothermal research department. "Some of reducing the cost is lowering exploration and development costs, and that's one of the areas we're helping to tackle."

The Geothermal Energy Association's 2016 annual production report said the U.S. had about 2.7 gigawatts of net geothermal capacity at the end of 2015. In addition, the U.S. market was developing about 1.25 gigawatts of geothermal power, and new renewable portfolio standards in states such as California and Hawaii could create opportunities for geothermal energy, the report said.

Su said the high temperature hammer could help reach those development goals.

New downhole hammer will be plus for drillers

Su considers the three-year project a success, and said the team and Atlas Copco are looking for opportunities to deploy the tool.

"We developed a tool that can be used in high-temperature environments that can help increase the drilling rates and the rate of penetration to maybe 5 to 10 times that of conventional drilling operations, so that's a big plus for drillers," he said. "It adds to the available options drillers have. This is not necessarily the final option for every drilling situation but it does provide a good option for the right situation."

Atlas Copco turned to Sandia for its expertise in materials, understanding of how moving surfaces interact and high-temperature testing and operations. "Atlas Copco is the expert at designing and manufacturing the hammers, but Sandia is better equipped to handle the high-temperature challenges, the lubrication and materials," Su said. "And high-temperature testing isn't something that Atlas Copco typically does."

A critical piece of the project was developing lubricious coatings, which help reduce friction between parts, important in geothermal operations. "As temperatures increase, the oils essentially cook and you get this sooty mess inside. It's like running your car too long without changing your oil," Su said. The hammer has internal moving components that require lubrication, similar to a piston in a car engine.

His team's work on materials and lubricious coatings built on decades of Sandia research in those areas. The team worked with Sandia's Materials Science and Engineering Center on a multilayer solid lubricant capable of operating at high temperatures. Similar solid lubricants are used commercially, for example, to improve the lifespan of moving components in cars, but Su's team worked with a formula tailored to the operating conditions and base materials.

"If we were starting from scratch, the difficulty level would have been high, but since Sandia has a history of experience in that arena, we had some idea of what to start with," he said. "It made things a lot easier."

Development took three years

The project began by determining whether a high-temperature hammer was even possible. The Sandia team initially tested materials and coating combinations that would survive the expected environments while Atlas Copco designed a hammer without plastic parts, Su said. They proved the concept, and the project spent the next two years building hammers and a facility for high-temperature testing.

The hammers proved successful. "We were able to reach our drilling rates, the materials held up, the coatings worked well," Su said.

Sandia's new facility is designed to test hammers under real-world operating conditions, including temperatures up to 572 degrees Fahrenheit (300 degrees C). Conventional drilling generally sees temperatures of less than 320 degrees F (160 degrees C).

The high operating temperature (HOT) test facility, a three-sided open concrete structure, houses a 20-foot-tall drill rig, heating chamber and process gas heater. Researchers can simulate conditions deep underground and the elevated temperatures affecting the hammer and can drill into different types of rock, like the granite commonly found in geothermal-rich areas. The facility is instrumented to measure drilling parameters.

HOT was in itself a large project. "We took a little more time in the development process, but when we put it all together, everything worked pretty much as we expected it to," Su said. The work required integrating multiple subsystems, including electrical, mechanical, pneumatic and control systems. Sandia also worked with Atlas Copco on what instrumentation was required to collect the necessary data.

"We're using the facility for other activities that we're doing now," such as developing drilling automation, Su said. "That's a plus for Sandia."

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Intellectual Property Creation & Licensing Practices

INTELLECTUAL PROPERTY CREATION

Sandia's intellectual property results primarily from R&D conducted for the government in the national security sector. Our laboratory collaborates with industry, leveraging different strengths to develop innovative technology. We perform internal R & D directed at the most challenging issues in national security, for which breakthroughs would provide exceptional value to government and industry. All totaled, Sandia has more than 1600 patents and 550 commercial copyrights, the bulk of which are available for licensing.

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A QUARTERLY UPDATE OF AVAILABLE TECHNOLOGIES FOR INDUSTRY

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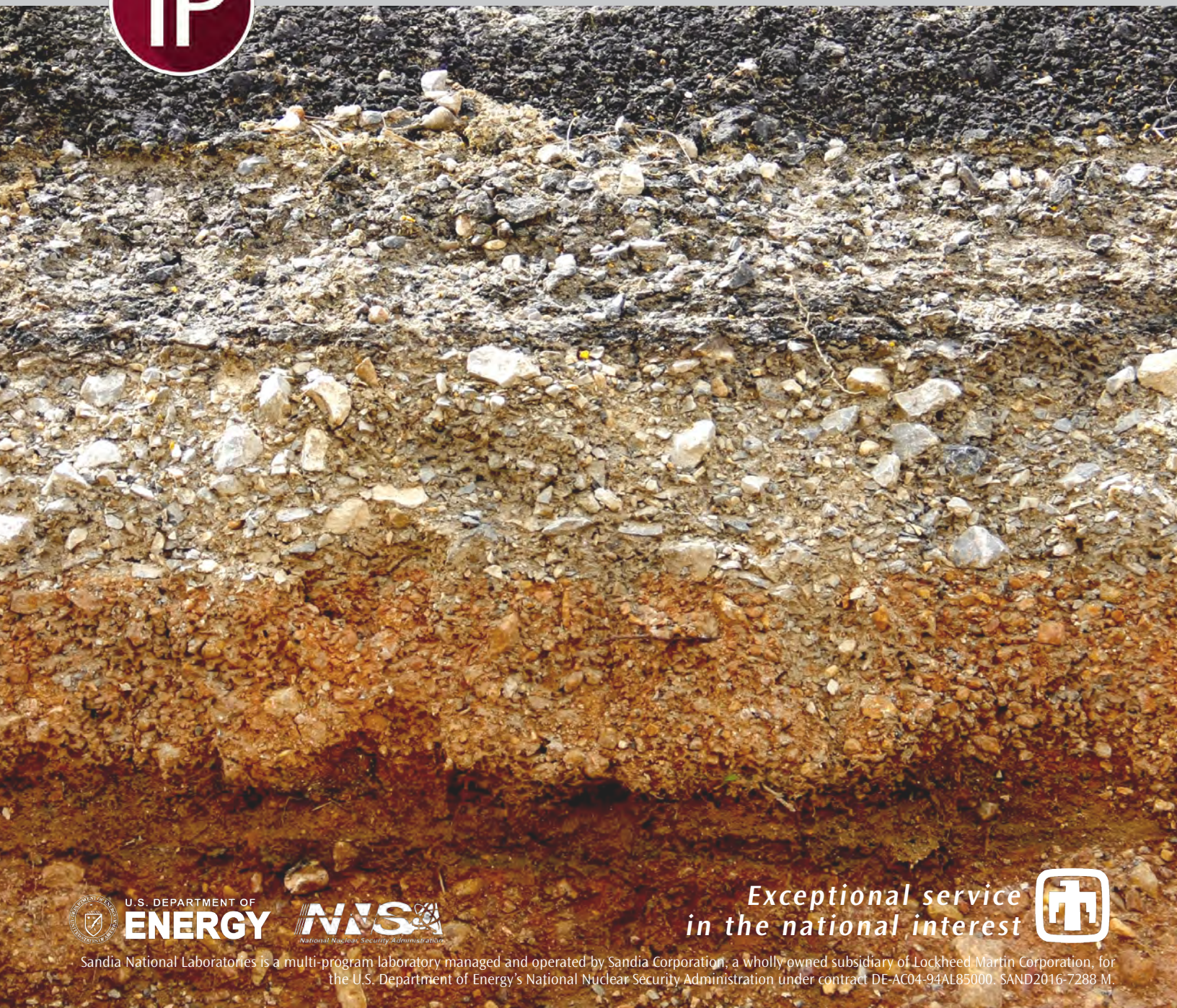

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