

Strategic Plan 2019 - 2021

Energetic Materials, Rock Characterization, and Geomechanics Research Center (EMRGe)

Executive Summary

The transition of the Rock Mechanics and Explosives Research Center to a newly oriented **Energetic Materials, Rock Characterization, and Geomechanics Research Center (EMRGe)** will address the many complex geomechanical challenges identified in different subsurface engineering disciplines whilst building the expanding the research efforts of energetic materials and combining them in joint subterranean exploration and national defense efforts. The goal for the next 3 years (academic years 2019-2021) is to continue and build on the existing energetics and geomechanics expertise provided by the diverse pool of faculty at Missouri S&T across several departments and establish **EMRGe** as a visible, sustainable URC promoting research excellence and integrating the different research disciplines. The long-term goal is to expand both disciplines to stand alone as separate URCs. To achieve this goal **EMRGe** will:

- 1) Serve as a research hub fostering an environment of creativity and team collaboration, and establish interdisciplinary research groups, which will focus on addressing the increasing demands of energetics and geomechanics research in many engineering applications.
- 2) Establish an Energetics Research Institute (ERI) for international visibility for faculty, collaboration and world class facilities, including the Energetics Research Facility with walk in blast chambers, as well as the new, proposed, open field blast site located between S&T and Fort Leonard Wood
- 3) Expand the existing research expertise (beyond faculty members) in energetics, rock characterization, and geomechanics by strategic hires of Post-Doctoral researchers and the best and brightest PhD students, and by modernizing and reinvesting in the existing laboratory facilities.
- 4) Strengthen industry relationships via venues of frequent exchange and strategic partnerships.
- 5) Establish an environment that is built on the integration of research and education through research mentorship programs for graduate and undergraduate students.
- 6) Promote and establish visibility and sustainability by industry outreach.

Mission: **EMRGe** performs advanced and innovative research in energetics, rock characterization, and geomechanics, enables the development of new scientific methodologies and technologies, integrates and engages graduate/undergraduate students in research, and fosters industry relations.

Values: **EMRGe** supports the values of S&T. **EMRGe**'s interpretations are listed below:

Lifelong Success: **EMRGe** prepares all its members (faculty, staff, researchers, and students) for rewarding careers build on excellence, confidence and sustainability.

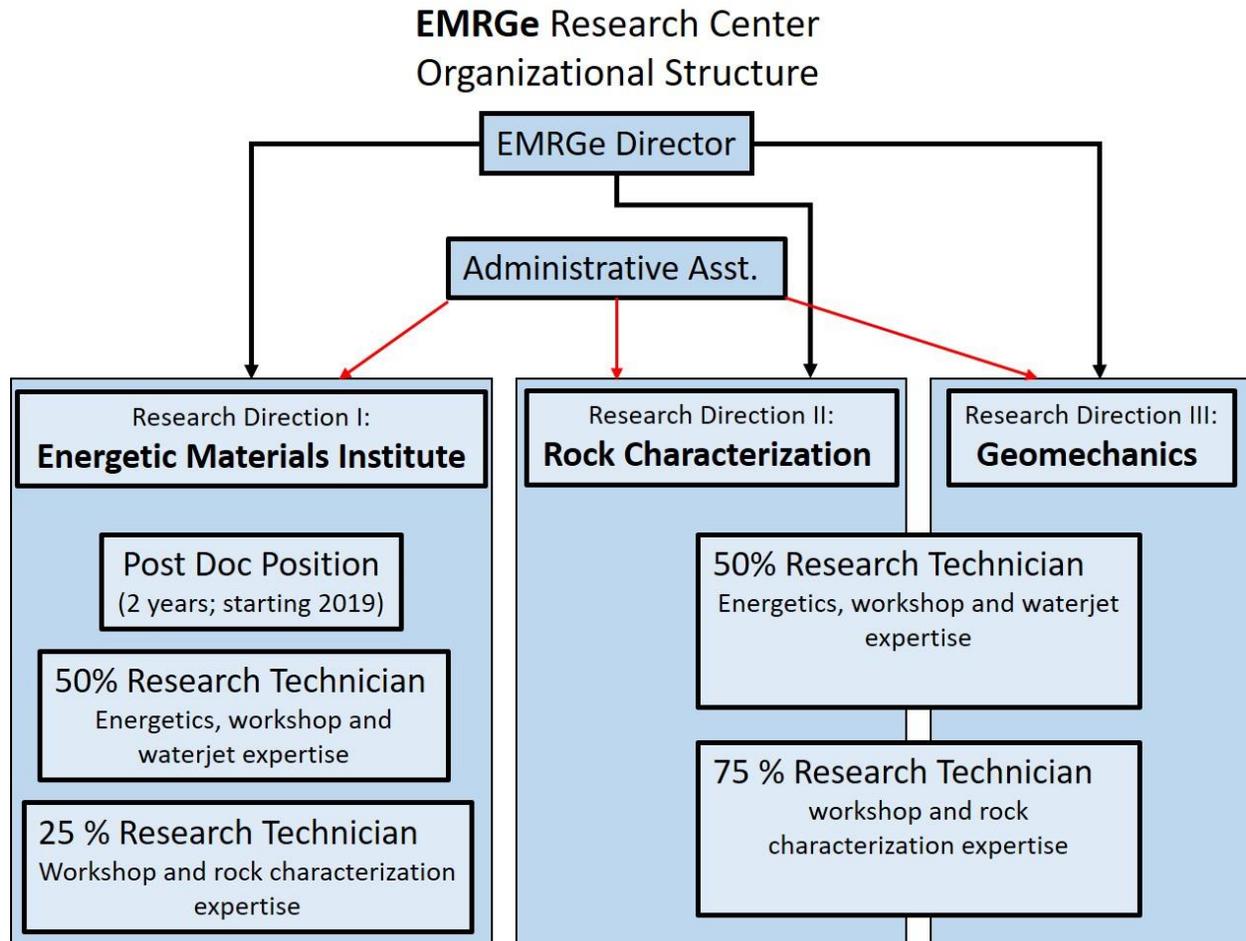
Creativity: **EMRGe** performs innovative research and advances fundamental knowledge.

Integrity and inclusion: **EMRGe** provides a work environment free of any harassment, and is based on integration, inclusion, and collaboration.

Partnerships: **EMRGe** focuses on establishing sustainable partnerships between academia and industry.

Vision: **EMRGe** will bring universal visibility to its disciplines at Missouri S&T and establish S&T as a leading partner and institution of choice in the disciplines of energetics, rock characterization, and geomechanics.

Organizational Structure



Introduction

Energetic materials research by the Department of Defense and other government contractors is a multi-million per year industry, with new challenges developing as war conflicts continue. Establishing EMRGe and an Energetics research Institute will enable the research, testing and teaching expertise already held at Missouri S&T to be visible to these entities, further expanding our potential. 6 main areas of expertise will be used as a starting point to expand the external funding opportunities. These areas are blast induced traumatic brain injury, force protection, design of novel energetic materials, including additive manufacturing, structural response, detonation synthesis, and training and safety.

The demand for new hydrocarbons reservoirs have pushed industry to reevaluate the risks associated with targets that are more structurally complex, occur in deeper waters, or hosted in more challenging lithologies (e.g., shale gas, oil shale). Cost effective hydrocarbon exploration, well planning, and production from such targets, as well as geothermal energy production from structurally complex reservoirs, and safe geologic CO₂ sequestration require a thorough understanding of the subsurface state of stress and of the physical properties of reservoir rocks and fluids. A thorough geomechanical analysis and rock material characterization, approach is based on the integrated, cross-disciplinary and multi-scale (from μm to km scale) analysis describing the geometry, material properties, state of stress, and fluid pressures within

subsurface environments and their wider geological context. Such an approach greatly assists in identifying and understanding these challenges and provides a unified framework within which the mitigating of risks associated with these challenges can be addressed, by forming synergies between different disciplines in order to find suitable solutions. The recent advancements in computational technology (both for software and hardware) make the EMRGe Center a fertile area for future scientific and technological advances.

Establishment of the **Energetic Materials, Rock Characterization, and Geomechanics Research Center (EMRGe) at Missouri S&T within the next 3 years (academic years 2019-2021) will substantially strengthen the mutually beneficial relationships that currently exists between faculty with Energetics, Rock Characterization, and Geomechanics expertise across the Department of Geosciences and Geological and Petroleum Engineering, the Department of Mining and Explosives Engineering, and the Department of Civil, Architectural and Environmental Engineering at Missouri S&T, and help to address the challenges identified above. The four pillars and main objectives required to establish a highly successful EMRGe Center are:**

Research	Mentoring	Visibility	Sustainability
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A highly interdisciplinary approach requires research among several disciplines to be interconnected. Integration of research results into graduate mentoring efforts elevates student interest, which commonly leads to probing questions, stimulates new research ideas and attracts new students to pursue research problems. The visibility of the EMRGe Center as a future leader will be increased by the dissemination of research findings by EMRGe personnel through a variety of avenues including workshops, meetings, and publications. This increased awareness in the disciplines of Energetic Materials, Rock Characterization, and Geomechanics will create a positive attractor - more scientists and engineers will consider these disciplines as part of their research, more students will pursue a course of study in Energetics, Rock Characterization, and Geomechanics as part of their career goals and eventually more outside funding will support the EMRGe Center. Increased visibility and awareness will promote the long-term sustainability of EMRGe ensuring a continuous pool of young scientists and engineers capable of moving the disciplines of Energetics, Rock Characterization, and Geomechanics forward within industry and in academia.

Full integration of these four pillars within EMRGe will yield the following results:

- EMRGe will strengthen research collaborations that builds on existing technology and approaches;
- EMRGe will identify and foster development of new methodologies, strategies, and approaches within an academic environment which can be evaluated for integration into industry work processes and business decisions;
- EMRGe will establish and expand an interdisciplinary research group at Missouri S&T (faculty, researchers, and graduate students);
- EMRGe will focus on research projects that will expand the application of Geomechanics and thereby increase the significance of Geomechanics for scientific research;
- EMRGe will establish an energetic materials test facility as part of the Energetic Materials Institute that will foster internal and external research collaboration in response to national needs.
- EMRGe will establish a strong relationship with Fort Leonard Wood's explosives personnel to meet the Army's research and teaching needs;

- EMRGe will provide high quality training and mentoring of engineers and scientists at Ph.D., MS, and BS level with an increased level of awareness of understanding earth processes and engineering solutions to problems in complex geologic terranes;
- EMRGe provides industry with unique recruiting opportunities for excellent graduate students and assists the Nation and the State of Missouri in meeting the demands of a skilled and educated workforce;
- EMRGe promotes the reputation of Missouri S&T as a high quality research institution and EMRGe as a leader in Energetic Materials, Rock Characterization, and Geomechanics.

EMRGe Research Focus

EMRGe research areas will be in three main categories: 1) Energetic Materials; (2) Multi-scale Geomechanics; and 3) Rock characterization. These research areas will build on existing research expertise and strategically aim to establish expertise in the sub-disciplines highlighted in Figures 1, 2 and 3.

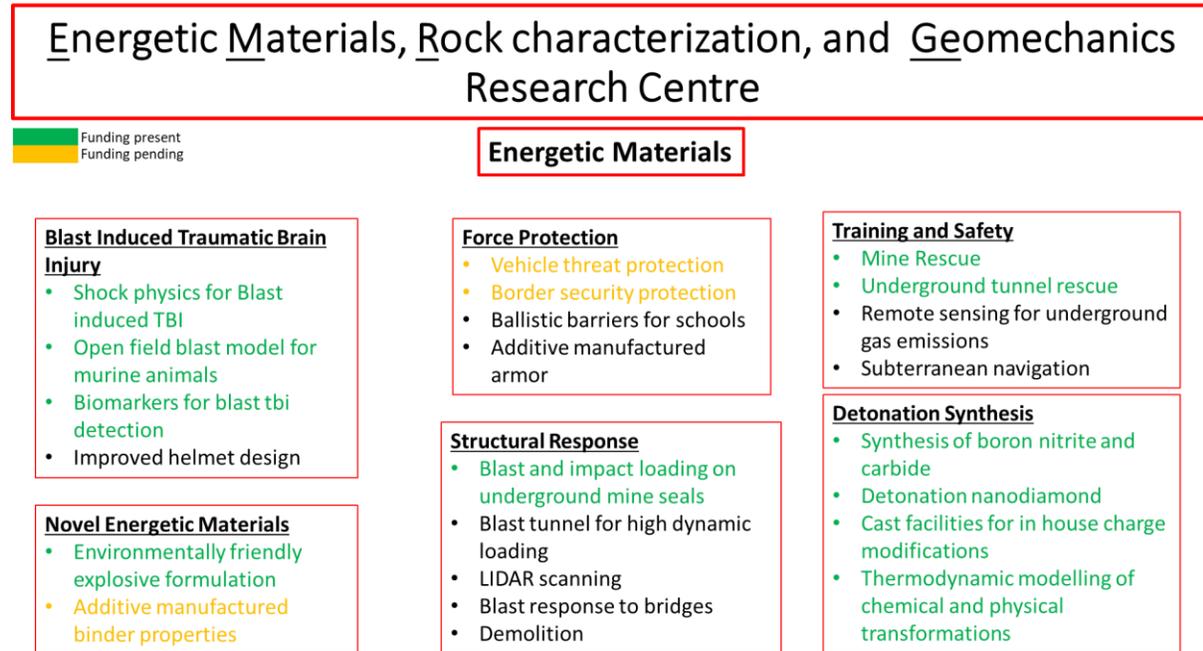


Figure 1: Compilation of EMRGe research directions and focus areas in energetic materials.

Energetic Materials, Rock characterization, and Geomechanics Research Centre

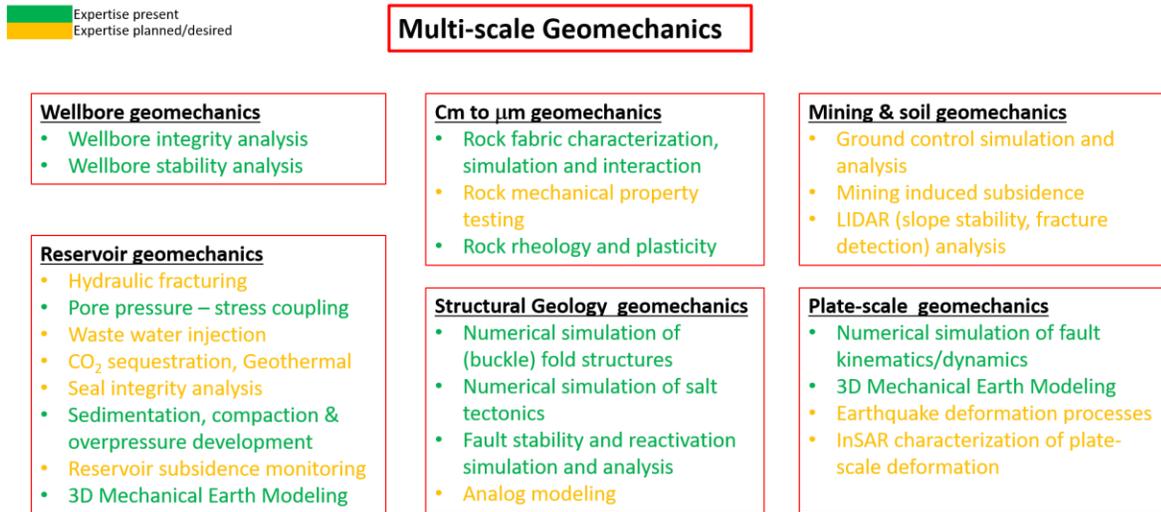


Figure 2: Compilation of EMRGe research directions and focus areas in multi-scale geomechanics.

Energetic Materials, Rock characterization, and Geomechanics Research Centre

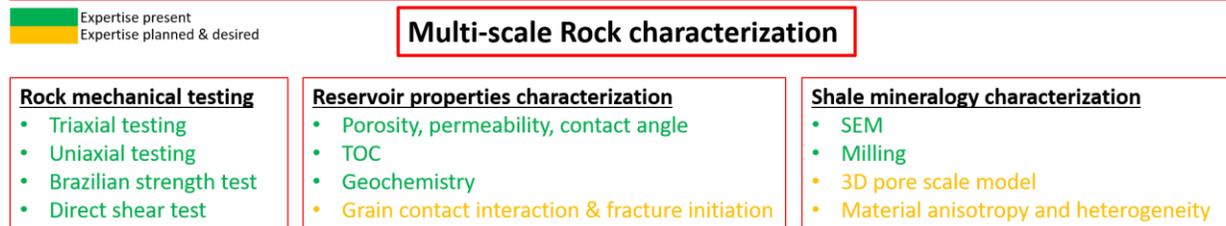


Figure 3: Compilation of EMRGe research directions and focus areas in multi-scale rock characterization.

Goals and Strategies to achieve EMRGe’s mission and objectives

The proposed goals and strategies are chosen to establish the new EMRGe Center within a period of 3 years, and aim to allow seamless integration of research, education, and outreach activities, as well as increased access to facilities and research opportunities.

Goal 1: Establish and promote excellence in research

Goal 1 and associated strategies link to Missouri S&T Compact *Excellence in Research and Creative Works*:

Objective 1, Strategy A

Objective 2, Strategy A, B

The significant current and future challenges associated with:

- sustainable hydrocarbon production from complex and unconventional reservoirs;
- the safe and sustainable production of subsurface geothermal energy;
- the safe geologic sequestration of CO₂;
- the safe injection of waste water during hydrocarbon production operations;
- the safe operation in underground mining;
- the seismic response from earthquakes (induced or natural) on multiple scales;

will rely on continued advancement in the field of Geomechanics, and closely related disciplines such as Rock Characterization.

The major challenges associated with energetic materials research are:

- Blast induced traumatic brain injury, a signature wound of recent war conflicts
- Improved armor design for vehicles and buildings
- The safe handling and use of energetic materials
- Structural response to buildings and bridges under blast conditions
- Fundamental explosive chemistry including thermodynamics and kinetics.
- Novel energetic material formulations and additive manufacturing

will rely on energetic material expertise and advanced testing facilities.

The EMRGe Center represents the ideal setting to enable advanced research within the College of Engineering and Computing at Missouri S&T. EMRGe will serve as a science hub, connecting faculty from different departments as well as outside researchers. The interdisciplinary structure of the Department of Geosciences, Geological and Petroleum Engineering (GGPE), and the fact the Mining Engineering Program is located in the same building as GGPE, shows the great potential of establishing an interdisciplinary research center. In addition, recent and future hires in GGPE, Mining Engineering, as well as Civil Engineering have increased the pool of expertise in Energetic Materials, Rock Characterization, and Geomechanics resulting in a significant and necessary expertise overlap. This provides an excellent opportunity and starting point to strengthen existing research efforts, promote new collaborations, and cultivate synergies that result in new research opportunities through collaborative efforts. Challenges identified in the various areas listed above will be addressed, and solved through interdisciplinary research approaches embedded in the following strategies:

Strategy 1.1: Establish an academic ‘think tank’ environment that fosters research collaborations and teamwork

It is vital for this strategy that EMRGe serves as a centralized hub where research ideas can be discussed, promoted and put forward into interdisciplinary and collaborative research proposals, projects, and publications. Key components and initiatives of this strategy are:

- Establish a group of faculty, i.e., a critical mass, that strives to work in a collaborative, teamwork oriented environment.
- Establish the EMRGe as a centralized hub consisting of shared computation labs, rock testing labs, graduate student offices, and meeting room/s.
- Create an environment of ‘*idea-sharing*’ where faculty have the opportunity to meet regularly to discuss ideas, challenges and new practices, which result in the submission of research proposals and publications.
- Create an environment of ‘equipment sharing’ where EMRGe faculty have the opportunity to utilize the shared equipment (see lever 1.4).
- Create an environment that promotes interdisciplinary research, resulting in the submission of large-scale (>\$1,000,000), interdisciplinary, and multi-PI proposals.

Strategy 1.2: Expand research expertise

Based on the existing pool of participating faculty, EMRGe seeks to promote and expand research expertise through the following venues:

- Use a significant portion of the EMRGe budget to hire a “permanent” Post-Doctoral researcher in Energetics research; this position’s responsibility is to assist the faculty in writing proposals and disseminate research.
- Proposals targeting industry funding are encouraged to include Post-Doctoral researchers.
- Proposals targeting federal funding are encouraged to include PhD students.
- Proposals to be submitted through EMRGe are based on Stipend X salaries (50% FTE) for PhD students, in order to attract the “best and the brightest”.
- Encourage faculty to travel (in collaboration with the Office the Vice Chancellor of Research) to e.g., NSF, DOE, DoD headquarters to meet program directors to strategically plan new proposals.
- Coordinate future faculty hires with home departments of faculty members.
- Establish a mentorship program for tenure-track assistant professors.
- Establish a mentorship program for Post-Doctoral researchers.

Strategy 1.3: Expand instrumentation and software

Based on the existing inventory of the EMRGe Center, EMRGe will focus on continuously expanding the Center’s infrastructure. The following strategies will be employed:

- A significant portion of the Center’s income (i.e. moneys generated from the F&A portion of EMRGe research projects) will be reinvested in the EMRGe infrastructure.
- Seek industry donations for equipment, equipment upgrades, and software.
- Use the faculty incentive plan (see lever 4.1) for EMRGe members to make their equipment available to other EMRGe members when not using it (See Appendix: EMRGe Responsibilities and Expectations).

Strategy 1.4: Build and establish shared instrumentation laboratories

In collaboration with the GGPE Department which has university financial commitment to renovate laboratory spaces for a Rock Characterization laboratory in McNutt Hall (rooms 259 and 261), EMRGe will be hosted in shared laboratories. Key components and initiatives of this strategy are:

- All EMRGe faculty share the equipment designated under the umbrella of EMRGe. All faculty members are able to use the equipment at minimal costs (i.e., material/supply expenses). I.e., equipment purchased by individual faculty members is available to use for other EMRGe members when the ‘faculty owner’ is not using the equipment (See Appendix: EMRGe Responsibilities and Expectations).
- All EMRGe members have access to the Research Support Staff.
- The majority of graduate students are working in shared office space to promote communication and research exchange.

Timelines for action items/deliverables associated with Goal 1

Academic Year 2019-2020:

- Compile inventory of facilities, equipment and software.
- Identify “lacking” equipment.
- Establish and organize shared EMRGe laboratories and offices.
- Initiate search for EMRGe Post-Doctoral Energetics position starting January 2020.
- Establish EMRGe research team.
- Establish faculty expectations document.
- Establish strategic proposal submission plan and timelines.
- Streamline and optimize expenditures and financial planning.

Academic Years 2020-2022:

- Establish mentoring program for Assistant Professors.
- Hire EMRGe Post-Doctoral researcher beginning January 2020 (at the latest).
- Establish laboratories and obtain/purchase equipment for Rock Characterization laboratory facilities in McNutt rooms 259, 261.
- Obtain funding sources through research grants to support PhD student workforce of 10-15 students.

Longer term:

- Establish funding sources through F&A returns, donations, and research grants to hire 2-3 more Post-Doctoral Researchers.

Goal 2: Establish an environment that fosters integration of research excellence with graduate and undergraduate research mentoring

Goal 2 and associated strategies link to Missouri S&T Compact *Excellence in Research and Creative Works*:

Objective 2, Strategy C

The development and enhancement of future researchers' skills is of paramount importance. In order to achieve this, an integration of education and research is necessary, and will be based on the following strategic levers:

Strategy 2.1: Promote research excellence through mentorship program for graduate students

The development of graduate students' research skills are critically dependent on an environment that fosters frequent collaborations, communication, peer review and mentorship. The integration of these components in EMRGe will be obtained through:

- Establishment of a EMRGe monthly research seminar, which will serve as a venue for faculty, Post Docs, PhD and MS students to regularly present their research and receive constructive reviews and comments beyond their individual advisor/mentor.

Strategy 2.2: Establish professional development opportunities

A crucial part of education at the graduate level is the application of disparate skill sets on a daily basis to research projects. This will ensure exposure to the necessary skills of tomorrow's technical workforce. EMRGe will provide the following opportunities for graduate students:

- As interdisciplinary research areas, energetic materials, rock characterization, and geomechanics requires familiarizing students with relevant software packages and the application of skill sets and analysis skills through self-study. As part of their EMRGe affiliation students will be introduced to the software packages and laboratory equipment relevant for their research.
- Integrate and facilitate PhD student participation in grant/proposal writing. This strategy will leverage on the research proposal requirement for PhD students and will elevate their research proposal to a stage, so that students can "pitch" their ideas in the context of addressing industry relevant research, and federal agency issued RFPs. This will have long-term benefits for the students and prepare them for a career as future researchers by giving them the tools necessary to be competitive in fund-seeking opportunities.
- The participation at relevant workshops is considered an integral part of graduate education. Each student should at least visit one workshop outside of Missouri S&T that is relevant to their research topic. Furthermore, each student will be required to present her/his work at professional conferences and conventions (e.g. AAPG, ARMA, AGU, GSA, SCCM, ISEE, EFEE, MHSRS).

Strategy 2.3: Develop research training opportunities for undergraduate students

Identify talented undergraduate students and immerse them in GRC graduate research groups so that they can be trained/mentored to conduct graduate level research. This strategy will use the venues of the S&T

OURE program as well as “Special Topics” classes within the students’ academic department to provide incentives for student participation.

In addition, EMRGe will be the host center for the American Association of Petroleum Geologists (AAPG) Imperial Barrel Award undergraduate student competition. EMRGe will provide the participating student team with access to high performance computing stations necessary for this competition and will host mentoring sessions to enhance student success.

Timelines for action items/deliverables associated with Goal 2

Academic Year 2019-2020:

- Establish monthly seminar and research group meetings.
- Support S&T AAPG Imperial Barrel Award team.

Academic Years 2020-2022:

- Hold workshop for graduate students about “How to write a grant?”
- Identify several capable undergraduate students and immerse in research groups.

Goal 3: Develop strategies to ensure EMRGe visibility and grow outside/industry engagement

Goal 3 and associated strategies link to Missouri S&T Compact *Excellence in Engagement and Outreach*:

Objective 2, Strategy B

Objective 4, Strategy A

EMRGe needs to be a highly visible institution for several reasons. A successful research center depends on the excellence of the work performed and how well this “excellence” is perceived and evaluated by peer institutions. Visible success will serve to attract quality personnel to interact with EMRGe to pursue research and educational opportunities. Visibility is achieved via a twofold strategy: industry outreach and academic recognition (S&T-wide and nationally). The following strategies will be employed:

Strategy 3.1: Establish new Energetic Materials Institute (EMI) as part of EMRGe

EMRGe will house a new Energetic Research Institute, which will aid in the visibility of energetics research at Missouri S&T in order to expand and be its own center within five years. The energetics Research Institute will encompass a new test site with 184 acres and over ten pound charge limit as well as five blast chambers with uses including gas measurement and detonation soot collection under vacuum. The following strategies will be employed to ensure success.

- Invite national laboratory and government contractors to the facilities to demonstrate capabilities
- Fund faculty to visit and present seminars at potential funding sources
- Increase members of the institute through collaboration.

- Apply for larger center grants through DTRA, DARPA, ONR, NSF amongst others.

Strategy 3.2: Develop and establish industry partnerships and collaborations

Industry driven research is a key component of a successful EMRGe. EMRGe's facilities, its number and range of expertise of its faculty, and its supporting technical staff provide the necessary conditions to conduct industry-sponsored research. Establishing strong industry relationships can provide students with employment and internships opportunities, provide faculty with research funding and access to commercial-scale facilities/field sites, and provide faculty with insight on key research needs for a particular company. The following strategies will be employed to ensure such connections:

- Establish a seminar series bringing industry professionals to S&T to learn and exchange about contemporary industry challenges. The goal is for these encounters to lead to the submission of seed grants.
- Encourage and support faculty travel to industry oriented professional meetings such as AAPG, URTeC, ARMA, etc.
- Establish collaborations for industry consultants to submit proposals through EMRGe at S&T.
- Promote developments of new, advanced energetic materials and geomechanical applications within an academic environment for evaluation and integration into industry work processes and business decisions.
- Develop a strategic industry outreach plan.

Strategy 3.3: Promote visibility of EMRGe (S&T-wide and nationally)

EMRGe will need to be aggressive in promoting its research mission. Visibility and associated recognition (university wide and nationally) of EMRGe is based on employing the following strategies:

- Sponsoring graduate students and promoting unity and identification of the students within EMRGe.
- Encourage faculty members to include at least 1-2 other EMRGe faculty on their PhD students' committees. This will raise awareness in department committees about EMRGe.
- Encourage EMRGe members to participate in S&T's "We dig research" events to raise visibility and promote university wide collaborations.
- Hosting workshops and convening symposia/sessions at conferences like ARMA, AAPG, URTeC, etc.
- Publishing results in trade and peer reviewed journals.
- Establish a strong web presence including homepage (pc and mobile formats) and social media platform/s.

Timelines for action items/deliverables associated with Goal 3

Academic Year 2019-2020:

- Initiate Energetics Research Institute
- Initiate EMRGe webpage and social media platforms.

- Organize and host International Continental Scientific Drilling Program (ICDP) workshop in Antigua, Guatemala, in the summer of 2020.
- Participate in “We dig research event”.

Academic Years 2020-2022:

- Invite 2-3 industry professionals to the EMRGe seminar.
- Plan professional sessions to be chaired by EMRGe members at AAPG, ARMA.
- Invite NSF/DOE program managers to EMRGe for strategic research meetings.

Longer term:

- Establish industry outreach plan.
- Establish industry consortium within EMRGe.

Goal 4: Sustainability

Goal 4 and associated strategies link to Missouri S&T Compact *Excellence in Research and Creative Works*:

Objective 1, Strategy A

Objective 2, Strategy A, B

One crucial long-term goal for EMRGe is continued research success through financial sustainability and member commitment to EMRGe’s mission. Besides meeting URC performance metrics, a sustainable EMRGe is based on steady income revenues and continued and long-lasting research productivity of its members. In addition to generating income from grants, EMRGe will seek other income streams, such as industry services, professional workshops, etc. The following strategies will be followed:

Strategy 4.1: Develop an environment of research productivity

The establishment of a productive and collaborative research center is based on clearly documented benefits and incentives for faculty members as well as EMRGe membership expectations.

- Establish a faculty incentive plan of EMRGe membership. A detailed description is provided in the Appendix: EMRGe Responsibilities and Expectations. Faculty incentives include:
 - EMRGe income generated from F&A of research grants will be used to fund EMRGe’s Post-Doctoral researcher, maintain and upgrade EMRGe laboratories and equipment; priority will be assigned to equipment used for funded projects.
 - Free use of lab space and computer labs including software.
 - Free support of administrative services with respect to proposal preparation, travel reimbursement, etc.
 - Access to support of technical support staff.
 - The technical support staff will keep a calendar to manage workloads; if work load is not used 100%, the technical support staff will work on maintenance of equipment and can increase time on specific, funded projects.

- Travel support/supplement for EMRGe faculty (amount at discretion of director)
- CAREER grant incentive: EMRGe members who receive a CAREER grant (e.g., NSF, NASA, DOE, etc.) will receive the F&A returned to EMRGe (7%) to spend freely for their grant.
- Establish a faculty expectations plan (to be discussed and detailed with faculty members as EMRGe gets established), i.e., EMRGe membership needs to be earned. Faculty members must attend EMRGe meetings, submit proposals, present at conferences, and publish.

Strategy 4.2: Meet productivity metrics and use them to spur growth

EMRGe will use the URC productivity metrics to show continuous growth and improvement. It is vital for EMRGe planning that the director holds the members accountable of the expectations associated with their membership. Key components to establish and maintain sustainability will be:

- Continuously meet URC ROI requirements and show growth.
- Establish and organize ‘steady’ proposal submission plan.
- Establish employment plan for full-time researchers: fund 1 Post-Doctoral researcher from base budget; generate enough F&A returns to fund additional Post-Doctoral researcher. A key responsibility of these full time researchers is to continuously write and submit proposals in collaboration with the EMRGe faculty.

Strategy 4.3: Establish industry services to generate income from royalties

- Define, advertise and establish EMRGe’s industry services (e.g. rock mechanical testing, sample characterization, explosive tests etc.).
- Use royalties income for updating equipment and purchasing new equipment.
- Use industry service contracts to leverage research implications for possible grants.

Timelines for action items/deliverables associated with Goal 4

Academic Year 2019-2020:

- Streamline and optimize EMRGe budget for strategic success.
- Initiate search for EMRGe Post-Doctoral position starting September 2020.
- Write faculty performance expectations plan.

Academic Years 2020-2022:

- Establish and advertise EMRGe industry services plan.
- Provide large range of industry services to generate royalties income.
- Hire EMRGe Post-Doctoral researcher beginning September 2020 (at the latest).

Performance and productivity indicators

The importance of metrics for evaluating performance is an integral part of EMRGe operations. EMRGe plans to use metrics to assess research productivity, dissemination of research results, and student

participation and accomplishments. EMRGe will employ metrics for evaluating performance in accordance with the Missouri S&T Office of Sponsored Programs document for operations of a University Research Center.

- Research productivity metrics will include:
 - Total funding
 - Requested funding through proposals
 - Number of total proposals
 - Proposal success rate
 - Average award size
 - Expenditures
 - F&A return
 - Diversity of funding sources
 - Number of PostDocs and/or graduate students (by level) supported per research grant
 - Number of graduate students (by level) supported per research grant who graduated
 - Number of research faculty supported
 - Number of faculty associated with the Center with their departments and Colleges
 - ROI: royalties+F&A generated+gifts, etc. divided by base funding+F&A returned to the URC+other centralized funding.
- Dissemination productivity metrics will include:
 - Number of peer-reviewed publications
 - Number of conference proceedings and/or non-peer reviewed publications
 - Number of keynote presentations
 - Number of invited presentations
 - Number of student publications
 - Number of citations
 - Publications per research grant

Previous performance metrics and 3-year outlook

Performance Metrics	FY 2018	FY 2019	Projected numbers		
	2017-2018	2018-2019	FY 2020	FY2021	FY2022
Requested funding through proposals	\$ 5,578,979.40	\$ 13,803,335.43	\$ 10,557,096.07	\$ 13,946,590.78	\$ 15,050,761.63
Number of total proposals	35	58	53	70	75
Diversity of funding sources	3	4	6	8	10
Expenditures: Direct Split	\$ 769,069	\$ 697,142	633,426	836,795	903,046
Expenditures: Indirect Split	\$ 287,930	\$ 237,894	422,284	557,864	602,030
Expenditures: Total Split	\$ 1,057,000	\$ 935,037	1,055,710	1,394,659	1,505,076
Number of PhD students supported	13	15	15	17	20
Number of MS students supported	5	5	5	7	10
Number of research faculty supported	0	2	2	2	2
Royalties income	\$ 19,180.00	\$ 10,580.00	\$ 15,000.00	\$ 20,000.00	\$ 25,000.00
Gifts income	\$ -	\$ 50,000.00	\$ 6,800.00	\$ 6,800.00	\$ 6,800.00
Base Funding			\$ 340,510.00	\$ 350,725.30	\$ 274,773.10
ROI			1.2	1.5	2

Scholarly contributions					
# of peer-reviewed publications	98	67	70	80	90
# of non-peer-reviewed publications	64	43	50	60	70
# of keynote presentations	2	5	5	6	6
# of invited presentations	27	24	25	27	30

The projected performance metric numbers are based on the projected growth of ROI. Assumptions in the calculations are that the average proposal funding request is \$200,000, average proposal success rate is 10%, and average F&A rate is 40% (due to shared credit with other URCs and/or reduced F&A rates required by the sponsor).

Appendix:

EMRGe Responsibilities and Expectations

This Policy details the basic responsibilities and expectations between each EMRGe Research Investigator and the Energetic Materials, Rock Characterization, and Geomechanics Research Center, effective September 1st, 2019.

A. *EMRGe Responsibilities to the Investigator:*

1. EMRGe income generated from F&A return of research grants (7%) will be used to fund EMRGe's Post-Doctoral researcher/s, maintain and upgrade EMRGe laboratories and equipment; priority will be assigned to equipment used for funded projects.
2. CAREER grant incentive: EMRGe members who receive a CAREER grant (e.g., NSF, NASA, DOE, etc.) will receive the F&A returned to EMRGe (7%) to spend freely for their grant.
3. To provide research/laboratory space for the investigator if available.
4. To provide office space for the investigator, but only when such space will serve as the investigator's primary office. EMRGe reserves the right to reassign any office space if the EMRGe Director determines the space is not being used consistently.
5. To provide shared office space for investigator's graduate students, but only when such space will be the student's only office. EMRGe reserves the right to reassign any graduate office space if the Director determines the space is not being used consistently, or the space is being used in an inappropriate manner.
6. To provide use of EMRGe resources to the investigator under EMRGe staff supervision when in compliance with other EMRGe safety, access, and use policies. Approved Internal Equipment Rates will apply where applicable.
7. To provide research support to each investigator under the following conditions:
 - a. Grant funded support: Technical support by the EMRGe Technicians will be provided as specified in the funded grant. Salary and benefits for the hours utilized will be charged to the grant, with the release time being credited to EMRGe. Work performed by technical staff for funded grants will take priority over other work.
 - b. Non-funded grant research support: To be determined

- c. Other: Technical support beyond the 40 hours or outside the scope of research support may be provided if funded by the investigator and approved by the Director. An agreement specifying the work, hours, MOCODE, and rate shall be in place before any such work is undertaken.
8. To provide frequent opportunities for research discussions and strategic research planning in research focused faculty meetings.
9. To provide the EMRGe investigator assistance with preparing grants and budgets (ePSRSs), reviewing and tracking grant opportunities, preparing grant applications, and tracking of funded grants and expenditures.
10. To provide a Center purchasing credit card if requested, and assistance with monthly account reconciliation.
11. To provide assistance with preparing and submitting travel expense and other reimbursements for investigators and their graduate students as requested.
12. To provide use of EMRGe trucks (individual must have a valid Missouri Driver's License) without charge to investigators and their graduate students for local EMRGe - related trips (less than 30 miles). The cost of diesel for the vehicle will be charged to the investigator for longer EMRGe - related trips until an Approved Internal Equipment Rate is instituted. No personal use of the truck is permitted. Trucks require a reservation prior to need to ensure availability.
13. To provide use of the 35-seat EMRGe Classroom (with computer and overhead projector) as classroom schedule permits. Any use of the classroom needs to be scheduled through the EMRGe administration.
14. To provide use of the EMRGe Conference Room (with computer and projector) for meetings, presentations, etc. as schedule permits. Any use of the conference room needs to be scheduled through the EMRGe administration.

B. Research Investigators' Responsibilities to EMRGe:

1. To include EMRGe on Proposal Signature Routing Sheets (ePSRS) for all grants and proposals for research directions outlined in the EMRGe Strategic Plan, and acknowledge EMRGe in papers and publications as applicable.

2. To be aware of EMRGe's productivity measures and contribute to the best of their possibilities for EMRGe to meet the productivity requirements for S&T URCs.
3. To collaborate with other EMRGe Investigators on research proposals and projects whenever possible. Unwillingness to collaborate and not submitting proposals over extended periods of time may result in cancellation of EMRGe membership. The EMRGe Director will meet with faculty to advise and encourage on research collaborations and proposal submissions.
4. To provide a shared laboratory culture under the EMRGe Research Center umbrella. EMRGe members are encouraged to offer their labs and equipment for collaborative research efforts to other EMRGe members during idle times. EMRGe members comply by using the internal usage rates for laboratory sharing. A MOCode is to be provided to purchase any consumables or repair any equipment damaged during use by the investigator or graduate students.
5. To include technical staff time in research proposals and grants at a reasonable level, and appropriately charge such time to the funded project.
6. To fully utilize any laboratory or office space assigned, and to ensure that graduate students under his/her supervision also properly utilize office space provided to them.
7. To understand and adhere to all MS&T safety and environmental compliance rules and regulations, and to immediately resolve any compliance issues. To ensure that all research and other activities carried out at the Center by the investigator or graduate students also comply with all EMRGe Policies and directives from the Center Safety Officer.
8. To purchase or provide a MOCode to purchase any consumables or machine replaceable parts to be used in EMRGe RC for the investigator or graduate students projects or activities, and to provide a MOCode to purchase or repair any EMRGe equipment damaged during use by the investigator or graduate students.
9. To participate in EMRGe Faculty meetings when possible, and to contribute to the Center's growth as discussed in EMRGe faculty meetings.

USE OF THE EMRGe FACILITIES CONSTITUTES ACCEPTANCE OF THIS POLICY.