MICROBEAM
TECHNOLOGIES, INC.

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October 1, 2021

Ms. Karlene Fine
Executive Director
ATTN: Lignite Research, Development and Marketing Program
North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Proposed Project entitled "Production of Germanium and Gallium Concentrates for Industrial Processes" for consideration for funding as part of the October 1, 2021 Grant Round.

We are pleased to submit this proposal for co-funding. The proposal was submitted in response to DOE funding opportunity announcement (FOA) DE-FOA-0002404 "Advanced Processing of Rare Earth Elements and Critical Minerals for Industrial and Manufacturing Applications," Area of Interest (AOI-2) Production of Critical Minerals (CM) Excluding Rare Earth Elements (REE) from Coal-Based and Alternate Resources. The project was selected for an award (Award No. is DE-FE0032124), and we anticipate a start date of December 2021 with a period of performance of nine month. North American Coal Company is also providing cost share funding.

The project will be led by Microbeam Technologies Inc with the assistance of the University of North Dakota Institute for Energy Studies and Dennis James (consultant). We also have an end user of germanium who is interested in the final product and will provide advice on form and purity.

Please let me know if you have any question or comments. We will send a check for $100 for the application fee.

Sincerely,

Steven A. Benson, PhD
President

c/enc. Mike Holmes, LEC

Shipping:
4200 James Ray Drive, Ste. 193
Grand Forks, ND 58202

Mailing:
PO Box 5
Victoria, MN 55386-0005

Phone: 701-757-6200
Fax: 701-738-4899
info@microbeam.com

Production of Germanium and Gallium Concentrates for Industrial Processes

Submitted to:

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
ATTN: Lignite Research, Development and Marketing Program
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Submitted by:

Microbeam Technologies Incorporated
4200 James Ray Drive, Ste. 193
Grand Forks, ND 58202

Principal Investigator:

Dr. Steve Benson
Phone: 701-213-7070
Email: sbenson@microbeam.com

10/01/2021

Total Project Costs: $189,943

NDIC Amount Requested: $20,000

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1.0 ABSTRACT

Microbeam Technologies Incorporated (MTI), project lead, the University of North Dakota (UND), North American Coal Corporation (NACC), and Dennis James (Consultant) will develop a conceptual design of a process to extract, separate, recover and purify germanium and gallium from lignite coal-derived rare earth element concentrates. The process will be integrated into the University of North Dakota's (UND) rare earth extraction process and will be designed to co-produce germanium and gallium concentrates. The project team plans to utilize existing research data, computational modeling, and minor in-lab testing of the UND concentrates to develop initial assessments and process flow diagrams as required to meet the project objectives in the assessment of high-purity germanium and gallium metal production pathways. This will include, but not be limited to: 1) Ge/Ga separation from UND REE concentrates, 2) Analysis of process conditions using ASPEN modeling platforms, and 3) Development and assumption of reasonable values of recovery on an element-by-element basis for each processing step utilizing existing technical literature. The overall effort involves an integrated concept that spans the supply chain, the feedstock sourcing, feedstock optimization, extraction/concentration/separation/refining, and product use in industrial applications. This effort is aimed at achieving major (>50%) domestic production of these energy-critical elements utilizing easily accessible (usable within 4-5 years) resources.

The duration of the project is projected to be 9 months, and the total cost of the project is $189,943 that includes $40,000 of cost share. Cost share will be received from NACC for $20,000. The NDIC share of the proposed project is $20,000. The remaining budget, $149,943, will be funded by the Department of Energy (DOE) through Award No. is DE-FE0032124.

2.0 PROJECT SUMMARY

The project team plans to utilize lignite resources analysis, existing research data, computational modeling, and minor in-lab testing of the UND concentrates to develop initial assessments and process flow diagrams as required to meet the project objectives in the assessment of high-purity germanium and gallium

metal production pathways. This will include, but not be limited to: *1)* Ge/Ga separation from UND REE concentrates*, 2)* Analysis of process conditions using ASPEN modeling platforms, and *3)* Development and assumption of reasonable values of recovery on an element-by-element basis for each processing step utilizing existing technical literature. The flowsheet and process flow diagram will be quantified with specific CM recovery rates, including Ge and Ga, and identification of logical off-take points within the processing chain will be identified (either as sale of the 90+% concentrate to a refiner, or direct refining to 99.99%+ purity metals).

3.0 PROJECT DESCRIPTION

3.1 Detailed Project Description

This proposed project is aimed at developing a concept to extract, separate, recover and purify germanium and gallium from lignite coal-derived rare earth element concentrates. The process will be integrated into the University of North Dakota's rare earth extraction process and will be designed to co-produce separated germanium and gallium concentrates. The overall effort involves an integrated development that spans the supply chain that involves feedstock sourcing, feedstock optimization, extraction/concentration/separation/refining, and product use in industrial applications.

The objectives of Phase 1 will involve the following: 1) identify and analyze potential feedstocks rich in Ge and Ga, 2) perform literature review and identify industrial applications, 3) develop process flow diagrams for the production of Ge/Ga materials in existing pilot-scale facilities, and 4) perform a market analysis to determine the resource needed to produce quantities of refined product.

3.2 Project Objectives

This proposed project is aimed at developing a concept to extract, separate, recover and purify germanium and gallium from lignite coal-derived rare earth element concentrates. The process will be integrated into the University of North Dakota's (UND) rare earth extraction process and will be designed to co-produce germanium and gallium concentrates. The germanium and gallium process developed will

be compatible with the UND rare earth element recovery process to separate, concentrate and refine gallium and germanium. The overall effort involves an integrated development that spans the supply chain, the feedstock sourcing, feedstock optimization, extraction/concentration/separation/refining, and product use in industrial applications. This effort is aimed at achieving major (>50%) domestic production of these energy-critical elements utilizing easily accessible (usable within 4-5 years) resources.

3.3 Methodology

The scope of work for the Phase 1 involves the development of an environmentally benign concept to produce Ge and Ga that is fully integrated with downstream uses and with the properties of the mixed rare earth oxides/mixed rare earth salts (MREO/MRES) properties. The first task is project management and planning that will involve the coordination of the project in order to attain all project objectives and provide deliverables on time and within budget. The second task will involve the characterization of midstream feedstocks from UND's bench and pilot facility as well as potential lignite feedstocks. The third task will be aimed at performing a review of literature on methods to recover and refine Ge and Ga and identifying industrial applications. The fourth task will involve the development of process flow diagrams of the Ge/Ga final product production route including a mass and energy balance. The fifth task will be aimed at performing a market analysis to determine the resource needed to produce quantities of refined product.

Task 1.0 – Project Management and Planning

Microbeam will manage and direct the project in accordance with a Project Management Plan to meet all technical, schedule and budget objectives and requirements. Microbeam will coordinate activities in order to effectively accomplish the work. Microbeam will ensure that project plans, results, and decisions are appropriately documented, and project reporting and briefing requirements are satisfied.

Microbeam will update the Project Management Plan 30 days after award and as necessary throughout the project to accurately reflect the current status of the project. Examples of when it may be appropriate to update the Project Management Plan include: (a) project management policy and procedural changes; (b) changes to the technical, cost, and/or schedule baseline for the project; (c) significant changes in scope,

methods, or approaches; or (d) as otherwise required to ensure that the plan is the appropriate governing document for the work required to accomplish the project objectives.

Management of project risks will occur in accordance with the risk management methodology delineated in the Project Management Plan in order to identify, assess, monitor and mitigate technical uncertainties as well as schedule, budgetary and environmental risks associated with all aspects of the project. The results and status of the risk management process will be presented during project reviews and in quarterly progress reports with emphasis placed on the medium- and high-risk items.

Task 2.0 – Feed Stock Identification and Characterization

Midstream REE concentrates will be characterized in detail to determine the abundance and forms of Ge and Ga. The samples will be characterized using ICP-MS or ICP-OES to determine the abundance of critical materials that includes all REE, Ge, Ga, Mo, Sc, and Y. X-ray diffraction will be used to identify any crystalline phases. In addition, scanning electron microscopy and x-ray microanalysis will be performed to examine microstructure and determine the composition of selected features that can be used to ascertain associations of elements. The team will also work with coal mines to identify feedstocks that are rich in Ge and Ga.

Task 3.0 – Literature Review and Identify Industrial Applications

The project team will develop a detailed literature review of technologies utilized to separate, concentrate, and refine Ge and Ga from conventional and non-conventional feedstocks. The project team will also identify industrial applications for the Ge and Ga. Partnership with end users will be further developed to identify end products needed and incorporated into process flow diagrams. Based on this information, a complete and detailed technical research plan will be developed. The detailed plan will include letters of commitment from a coal-based or alternate resource supplier, pilot-scale MREO/MRES and/or CM facility operator, advanced separation and purification and reduction to metal process developers, and an industrial partner(s) who is/are able to utilize the material(s) produced.

Task 4.0 – Product Testing and Analysis

Process flow diagrams (PFDs) will be developed to produce Ge and Ga in forms that are required to produce end products from the feedstock materials used in this project. The production route for the refined metal, salt, or oxide as required by the end user will be developed. PFDs of the complete process including mass and energy balance will be developed through the use of ASPEN. The purity of the materials at each step will be provided. The production of > 90% purity Ge and Ga concentrates are expected from the process. This will be based on model simulation of the entire process and on past work conducted on developing concentrates of Ge. The quantity of MREO/MRES needed to conduct the laboratory or bench testing will be determined through modeling, limited laboratory testing, and quantities available from the pilot project.

Task 5.0 – Market Analysis

An analysis of the market regarding the current and future uses of Ge and Ga products will be conducted and an assessment of the potential of the quantity of Ge and Ga that can be produced from this process if scaled to a 1 to 3 tonne/day REE-CM production facility will be performed. The market analysis will be conducted with the support from end users.

3.4 Anticipated Results

This project is the first phase that will develop a conceptual design of a process to recover Ge and Ga from MREO/MRES concentrates. The overall four phase effort involves an integrated development that spans the entire supply chain that includes: feedstock sourcing, feedstock optimization, extraction/concentration/separation/refining, and product use in industrial applications.

3.5 Facilities and Resources

Microbeam Analytical and Testing Labs – MTI has a wide array of analytical capabilities and equipment relevant to materials testing and analysis. MTI has available high temperature furnaces, advanced computer-controlled scanning electron microscopy (CCSEM), chemical fractionation equipment, and associated sample preparation equipment.

University of North Dakota Laboratories and Facilities – *Advanced Materials Characterization Lab (UND)* -- The AMCL has experienced technicians and analytical chemists and has a vast array of analytical equipment and capabilities, including SEM-EDS, XRF, XRD, ICP-OES and thermal gravimetric analysis.

Pilot-Scale REE Extraction Facility (UND) -- UND is in the process of constructing a pilot facility capable of processing 500 kg/hr of cleaned coal through the aforementioned REE extraction and recovery process with low rank coals. The facility operates in a continuous mode in producing a pre-concentrate at a rate of roughly 8-10 kg (pure REE basis, despite a concentration near 60-70%) per week of a 300 ppm feedstock. The facility, when completed in October 2021, will utilize a vast array of continuous sensing, process control methods, and other automation strategies to determine the steady-state conditions for bulk processing.

3.6 Environmental and Economic Impacts

The technology proposed is an environmentally benign process to produce 90 to 99 percent pure germanium and gallium oxides, salts, or metals from REE concentrates derived from coal, following which refining to >99% is achievable. The technology is consistent with the objectives of the FOA to develop domestic sources of critical materials that includes germanium and gallium.

International production rates of the two elements identified as critical mineral targets in this work are estimated at 130 tonnes and 300 tonnes per year for Ge and Ga, respectively. US consumption of each mineral totaled 23% and 5%, respectively, and the US was 100% import reliant[1,2]. For example, a single 1-3 MTPD REE concentrate plant would be able to mitigate up to 23% and 42% of the US demand for each of the Ge and Ga, and this while utilizing a lignite more enriched in the REE than Ge and Ga specifically. The UND process for REE recovery simultaneously concentrates these critical minerals from the lignite sources, resulting in a major opportunity for domestic production (potentially past current consumption rates) of these two critical minerals *with minimal additional cost over REE production.*

[1] Jaskula, B. W. "Mineral Commodity Summaries: Gallium." United States Geologic Survey, p62, 2021.
[2] Tolcin, A. C. "Mineral Commodity Summaries: Germanium." United States Geologic Survey, p68, 2021

3.7 Relevance and Outcomes/Impacts

The benefit of the project is the development of a domestic source of Ge and Ga from the abundant lignite resources. The elements are extensively used in military and domestic applications and demand for these elements is expected to increase. Germanium and Gallium are heavily used in renewable energy computing fields, with major markets of each including solar energy (either as cells themselves or components), optical devices and fiber optics, and LEDs. Lignite's with concentrations in excess of 25 ppm on a dry whole-coal basis for *each* critical mineral have been identified *inside and outside of active mines*, making these elements easily recoverable from lignite in quantities to completely offset US import demands.

4.0 STANDARDS OF SUCCESS

This effort described in this proposal is only for Phase I. The success criteria for each phase of the program are provided for overall context and are summarized below.

End of Phase I Success Criteria 1) Identification of lignite feedstocks that are rich in Ge and Ga, 2) Determination of the abundance and form of Ge and Ga in the lignite coal-derived MREO/MRES, 3) Development of a conceptual design of a process to produce high purity Ge and Ga products that meets industry specifications, and 4) A market analysis that shows the need for a domestic source of Ge and Ga.

End of Phase II Success Criteria

- Demonstrated ability to produce 90% pure Ge and Ga oxides/salts/metals in a laboratory- or bench-scale facility.

End of Phase III Success Criteria

- Demonstrated technical and economic feasibility of Phase II laboratory- and bench-scale testing.

End of Phase IV Success Criteria

- Design an integrated process for recover of Ge and Ga for a 1-3 Tonnes MREE as oxides or salts per day plant that is integrated with downstream manufacturing of products for consumers.

5.0 BACKGROUND

Critical Materials (CM) are utilized in a suite of high importance end-uses, such as cell phones, hybrid and electric vehicles, magnets, computer components, catalysts, and many others. The uses for CM are increasing and many of the CM sources and markets are controlled by entities outside of the US. Lack of a domestic source of CM has a significant impact on our national security, energy independence, environmental future, and economic growth. Germanium and gallium are critical minerals that are present in North Dakota lignite coal and associate sediments[3]. Selected lignite coal is well-known for the incorporation and elevated concentrations of these critical minerals. As examples, a study by PacMag Metals found germanium levels averaging 106 ppm in selected lignite seams in the Harmon Hansen coal zone in southwest ND[4]. The NDGS has been performing sampling and analysis efforts associated with REE and CM.[5]

Ge and Ga are present in the MREEMRES concentrates produced in UND's pilot REE extraction and concentrating pilot plant[6]. Extracting, concentrating, and refining these elements is the focus of this work. The process builds upon research previously developed by MTI for Ge recovery from coal ash[7] as well as knowledge of the form and abundance of Ge and Ga in lignite[8].

The proposed work allows for low-cost generation of high-purity Ge/Ga concentrates (~50%) devoid of usual contaminants generated from other conventional processes due to the nature of preliminary concentration (in the REE plant). The proposed method seeks to take advantage of this new pathway of metal production by utilizing low-cost and environmentally friendly pathways for final separation. Additionally, preliminary analysis of potential coal sources available to a 1-3 tonnes per day REE concentrate plant could produce Ge quantities in excess of 10% of the US requirement (coal analysis of 15-

[3] Moxness, L., Critical Minerals In North Dakota, NDGS, Geo News, January 2021.
[4] PacMag Metals, Investor Presentation, Sept 2008, www.pacmag.com.au.
[5] Murphy, E., Germanium in North Dakota Lignites, DMR Newsletter, Vol 36, No 1, 2009.
[6] Mann, M; Theaker, N; Benson, S; Palo, D. "Investigation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks – Final Report", DE-FE0027006, Submitted March 31, 2020.
[7] Microbeam Technologies Inc, NSF SBIR Phase II: Feasibility of On-line Metalloid Recovery in Gasification Systems, NSF Award Number: 0422050, Final Report, July 31, 2007

25 ppm Ge whole coal basis for lignite coals within active mines), allowing the potential for complete domestic production by unconventional coal sources by 2030.

6.0 QUALIFICATIONS

The personnel who are part of the project team are uniquely qualified to perform the project. The personnel include geologists who have knowledge of the forms and abundance of critical mineral in the lignite feedstocks, fuel scientists who understand the behavior of critical minerals during processing, chemical and mechanical engineers who have direct experience with the recovery of critical minerals, and chemists who can analyze the materials. The project team will work together to develop the overall concept for the recovery of Ge/Ga that is consistent with refining and end use requirements.

Dr. Steve Benson, Microbeam President, and the Microbeam team have conducted over 1600 projects worldwide on the association and behavior of major, minor and trace elements in coal conversion systems. Dr. Benson has specific experience in recovering REE-CM from coal and ash-related materials. He has extensive experience associated with the transformation and fate of germanium in energy conversion processes.

Mr. Alex Benson, Project Manager, will assist in coordinating activities of the project. Mr. Benson has focused his attention on REE-CM recovery from coal. He has extensive experience with the High REE-CM-containing coals in the Williston Basin and has worked with the ND Geological survey to obtain larger quantities of samples for testing. Mr. Benson also brings experience in moving technologies from R&D to production as well as in the management and supervision of large teams.

Mr. Eric Kolb, Associate Research Engineer at Microbeam, has been working on the design and construction of a pilot-scale REE and CM processing plant (DE-FE0031835). His expertise will be used to integrate the Ge/Ga recovery concept into the UND REE recovery and concentrating process.

Mr. Nolan Theaker, Research Engineer at the UND Institute for Energy Studies, was key in developing the UND Pilot-scale process for recovering and concentrating REE-CM derived from lignite coal (DE-

FE0031835). Mr. Theaker has experience in the use of ASPEN to design various processes and has conducted numerous economic studies associated with coal mining, processing, and REE-CM.

Dennis James, Consultant, has over 40 years of coal industry experience in geology and geochemistry, with involvement in exploration, development, operations, and reclamation of coal mines. Utilization of coal has been a primary focus area as it relates to identifying and solving coal quality-related issues at plants utilizing coal. In addition, Mr. James has worked with design engineering groups to design and build new facilities to recover critical materials on a commercial scale.

7.0 VALUE TO NORTH DAKOTA

This project has the potential to utilize the abundant lignite resource to produce critical minerals. The technology would be implemented in North Dakota and would provide high paying jobs associated with the extraction, concentrating, separation and refining to produce a high value product. In addition, ND will facilitate in the development of a domestic source of Ge and Ga from the abundant lignite resources. The elements are extensively used in military and domestic applications and demand for these elements is expected to increase.

8.0 MANAGEMENT

The management structure for the project is shown in Figure 1, which is designed on a task-by-task basis with the task leaders and key/essential personnel for each task identified. The team brings together the unique expertise required. The organization of the project, illustrated in Figure 1, shows the breakdown of the project by task and the personnel who will be contributing to the effort. The project will be co-funded by DOE, NDIC, and North American Coal Company.

Dr. Steve Benson is the principal investigator and will manage the overall effort. He has managed numerous DOE and industry projects similar in complexity and size to this proposed project. Dr. Benson and the project team will be advised by a refining/end user of Ge who will provide insight into the quality of the materials produced. In addition, Barr Engineering has agreed to review the conceptual design and how it will be integrated with the UND process. Nolan Theaker and Dennis James will provide assistance

in coordinating the technical effort. Financial management of the project will be performed by Ms. Roxanne Benson.

Microbeam utilizes several project management tools that include Smartsheet and Jira. Jira is used to track personnel time and Smartsheet is used to track project schedule. Smartsheet is a software used to track project progression, assignment of tasks, allocation of resources, and adherence to project timeline. Smartsheet can also be used to notify individuals of upcoming action items, provide Gantt charts for reporting, and as a location for notes and comments regarding progress updates. Information from Jira on personnel time for each project is utilized by Quickbooks to track spending and is used for invoicing.

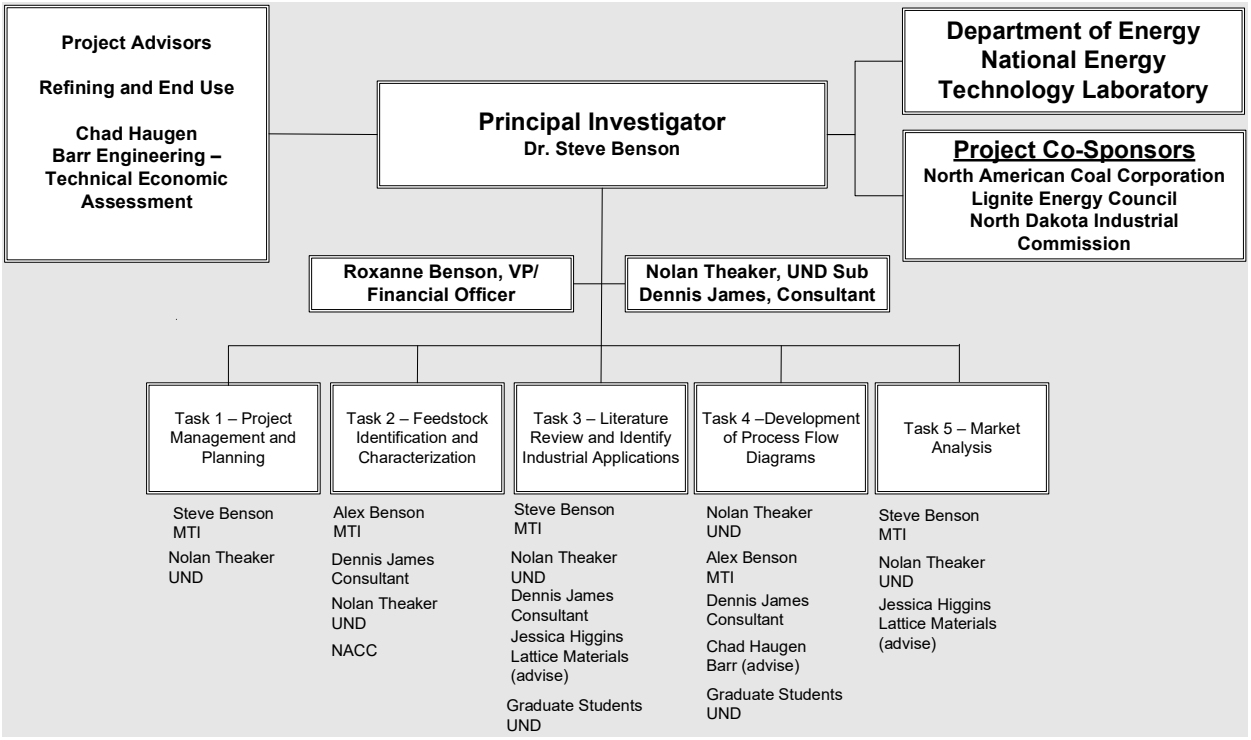
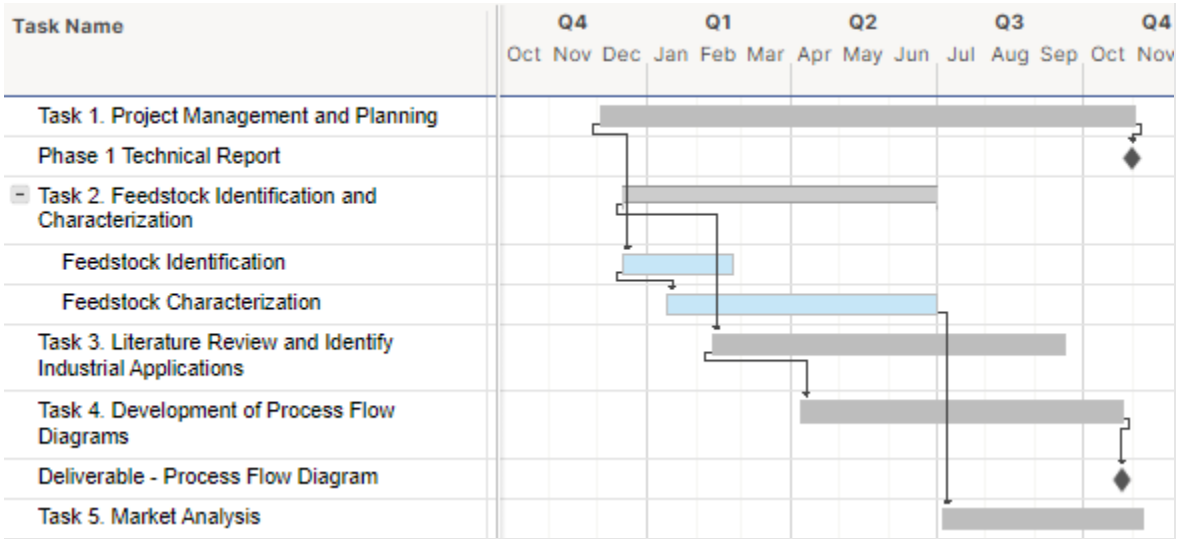


Figure 1. Overall project organizational chart.

9.0 TIMETABLE

The project is expected to take 9 months to complete. The timeline is shown in Table 1.

Table 1. Proposed project timeline.



The project deliverables described below are summarized as follows:

1. Teaming Plan: Teaming plan with letters of commitment from a coal-based or alternate resource supplier, pilot-scale MREO/MRES and/or CM facility operator, advanced separation and purification and reduction to metal process developers, and an industrial partner(s) who is/are able to utilize the material(s) produced.

2. Technical Research Plan: A complete and detailed Technical Research Plan will be developed.

3. Purity Estimates: An estimate of the purity obtainable for materials produced from each proposed process. This will likely be a rough estimate but should be backed by a scientific discussion.

4. Process Flow Diagrams: Process Flow Diagram showing proposed production route(s), including a mass and energy balance. The PFD should include the entire production process from MREO/MRES to refined metal, and/or production of CM materials.

5. Resource Quantities: Identification of quantities of resource (e.g., MREO/MRES) needed, and quantities of refined product to be produced if the project were scaled to a pilot project.

6. Analytical Data: Analytical chemical characterization data generated in Phase 1 will be provided to DOE.

7. Phase 1 Final Technical Report.

The deliverables and time for completion are listed in Table 2.

Table 2. Deliverables

Task Number	Deliverable Title	Due Date
1	Project Management Plan	Update due 30 days after award. Revisions to the PMP shall be submitted as requested by the NETL Project Manager.
1	Kick-off meeting	Within 30 days of project award
1	Chemical characterization or analytical data if generated in Phase 1	At completion of Phase 1 (to be uploaded to NETL's EDX system)
2	Feedstock Identification	Within 30 days of project award
2	Feedstock Characterization	Within 210 days of project award
3	Teaming Plan	Within 210 days of project award
3	Technical Research Plan	Within 210 days of project award
3	Purity Estimates	Within 210 days of project award
3	Process Flow Diagrams	Within 240 days of project award
4	Identification of Quantities of Resource Needed	Within 240 days of project award
5	Preliminary Technical Economic Assessment	Within 240 days of project award
5	Phase 1 Final Technical Report	End of project

10.0 BUDGET

The overall project and UND subrecipient budgets are summarized in Tables 3 and 4.

Table 3. Overall Project Budget.

Section A - Budget Summary					
		Federal	Cost Share	Total Costs	Cost Share %
	Budget Period 1	$149,943	$40,000	$189,943	21.06%
	Budget Period 2	$0	$0	$0	0.00%
	Budget Period 3	$0	$0	$0	0.00%
	Total	$149,943	$40,000	$189,943	21.06%
Section B - Budget Categories					
CATEGORY	Budget Period 1	Budget Period 2	Budget Period 3	Total Costs	% of Project
a. Personnel	$40,466	$0	$0	$40,466	21.30%
b. Fringe Benefits	$8,445	$0	$0	$8,445	4.45%
c. Travel	$1,173	$0	$0	$1,173	0.62%
d. Equipment	$0	$0	$0	$0	0.00%
e. Supplies	$819	$0	$0	$819	0.43%
f. Contractual					
Sub-recipient	$40,000	$0	$0	$40,000	21.06%
Vendor	$20,000	$0	$0	$20,000	10.53%
FFRDC	$0	$0	$0	$0	0.00%
Total Contractual	$60,000	$0	$0	$60,000	31.59%
g. Construction	$0	$0	$0	$0	0.00%
h. Other Direct Costs	$50,188	$0	$0	$50,188	26.42%
Total Direct Costs	$161,091	$0	$0	$161,091	84.81%
i. Indirect Charges	$28,852	$0	$0	$28,852	15.19%
Total Costs	$189,943	$0	$0	$189,943	100.00%

Table 4. UND subrecipient budget and cost share.

Section A - Budget Summary					
		Federal	Cost Share	Total Costs	Cost Share %
	Budget Period 1	$40,000	$0	$40,000	0.00%
	Budget Period 2	$0	$0	$0	0.00%
	Budget Period 3	$0	$0	$0	0.00%
	Total	$40,000	$0	$40,000	0.00%
Section B - Budget Categories					
CATEGORY	Budget Period 1	Budget Period 2	Budget Period 3	Total Costs	% of Project
a. Personnel	$19,300	$0	$0	$19,300	48.25%
b. Fringe Benefits	$3,381	$0	$0	$3,381	8.45%
c. Travel	$0	$0	$0	$0	0.00%
d. Equipment	$0	$0	$0	$0	0.00%
e. Supplies	$0	$0	$0	$0	0.00%
f. Contractual					
Sub-recipient	$0	$0	$0	$0	0.00%
Vendor	$0	$0	$0	$0	0.00%
FFRDC	$0	$0	$0	$0	0.00%
Total Contractual	$0	$0	$0	$0	0.00%
g. Construction	$0	$0	$0	$0	0.00%
h. Other Direct Costs	$5,688	$0	$0	$5,688	14.22%
Total Direct Costs	$28,369	$0	$0	$28,369	70.92%
i. Indirect Charges	$11,631	$0	$0	$11,631	29.08%
Total Costs	$40,000	$0	$0	$40,000	100.00%

Table 5. Summary of NDIC budget for sample analysis.

		Task 1 - Management and Reporting		Task 2 - Feedstock Identification and Characterization		Task 3 - Literature Review and Indentify Industrial Applications		Task 4 - Development of Process Flow Diagrams		Task 5 - Market Analysis		Totals	
Period 1:	**Rates**	**# of samples**	**Total $**	**# of samples**	**Total $**	**# of samples**	**Total $**	**# of samples**	**Total $**	**# of samples**	**Total $**	**# of samples**	**Total $**
Sample Prep	$ 69	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CCSEM I/E	$ 871	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CCSEM	$ 672	$ -	$ -	$ 8	$ 5,379	$ -	$ -	$ -	$ -	$ -	$ -	$ 8	$ 5,379
Morphology	$ 242	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
X-ray Diffraction	$ 403	$ -	$ -	$ 8	$ 3,226	$ -	$ -	$ -	$ -	$ -	$ -	$ 8	$ 3,226
Prox/Ult	$ 181	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
ICP-OES - REE	$ 108	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
ICP-MS - Standard lab	$ 397	$ -	$ -	$ 22	$ 8,734	$ -	$ -	$ -	$ -	$ -	$ -	$ 22	$ 8,734
Partial Chem Fractionation	$ 887	$ -	$ -	$ 3	$ 2,661	$ -	$ -	$ -	$ -	$ -	$ -	$ 3	$ 2,661
Ash Comp	$ 246	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Analysis BP1		$ -	**$ -**	$ 41	**$ 20,000**	$ -	**$ -**	$ -	**$ -**	$ -	**$ -**	$ 41	**$ 20,000**

11.0 MATCHING FUNDS

Other committed sources and amounts of funding in addition to the $20,000 requested from NDIC is from. North American Coal Corporation will provide $20,000 in in-kind support in the form of coal samples and analysis from their North Dakota mines for use in the technical and economic analysis.

12.0 TAX LIABILITY

None

13.0 CONFIDENTIAL INFORMATION

None

14.0 APPENDICIES

14.1 Resumes

14.2 North American Coal Corporation Letter of Support

14.3 University of North Dakota Letter of Commitment

14.4 James Letter of Commitment

14.5 Barr Engineering Letter of Support

14.6 DOE Award Letter

STEVEN A. BENSON, PH.D.

Education and Training:

Minnesota State University	Chemistry	B.S. 1977
Pennsylvania State University	Fuel Science	Ph.D. 1987

Research and Professional Experience:

1991 – Present President, Microbeam Technologies Incorporated. Dr. Benson founded Microbeam Technologies Incorporated (MTI), a spin-off company from the University of North Dakota to conduct service analysis of materials using automated methods aimed at assessing efficiency and reliability problems in renewable and fossil energy conversion systems. Dr. Benson is responsible for technical direction, data interpretation and proposal preparation.

2015 – 2017 Associate Vice President for Research, Energy & Environmental Research Center, University of North Dakota -- Dr. Benson was responsible for developing and managing projects on the clean and efficient use of fossil and renewable fuels.

2008 – 2015 Professor, Chemical Engineering; Chair, Petroleum Engineering; and Director, Institute for Energy Studies – coordinated energy related education and research activities that involve faculty, research staff, and students.

1986 – 2008 Associate Director for Research/Senior Research Manager, EERC, UND -- Dr. Benson was responsible for the direction and management of programs related to integrated energy and environmental systems development.

1984—1986 Graduate Research Assistant, Fuel Science Program, Pennsylvania State University.

1983 – 1984 Research Supervisor, Distribution of Inorganics and Geochemistry, Coal Science Division, UND Energy Research Center -- He was responsible for management and supervision of research on coal geochemistry.

1977 – 1983 Research Chemist, Energy Resources Development Administration (ERDA) and U.S. Department of Energy Grand Forks Energy Technology Center, Grand Forks, North Dakota.

Selected Publications:

1. Laudal, D. and Benson, S.; Rare Earth Extraction from Coal; US Patent 10,669,620 B2; June 2, 2020.
2. Laudal, D. A., Benson, S.A., Addleman, R.S., and Palo, D., Leaching behavior of rare earth elements in Fort Union lignite coals of North America, International Journal of Coal Geology, Volume 191, 15 April 2018, Pages 112-124.
3. Benson, S.A., Crocker, C.R., Hanson, S.K., McIntyre, K.A., Just, B.J., Raymond, L.J., Pflughoeft-Hassett, D.F, Srinivasachar, S., Barry, L.T. and Doeling, C.M., "JV Task 115- Activated Carbon Production from North Dakota Lignite – Phase IIA," Final Report, U.S. DOE. DE-FC26-98FT40321, June 2008.
4. McCollor, D.P., Sweeny, P.G., and Benson, S. A., Coal/char Reactivity, Final Technical Report, DE-FC21-86MC10637, May 1988.
5. Kleesattel, D.R.; Benson, S.A.; Jones, M.L.; McCollor, D.P. A Petrographic Examination of Char Produced by the Rapid Pyrolysis of Low-Rank Coal. In Proceedings of the Joint Conference Western States and Japanese Sections; The Combustion Institute, 1987; pp 122–124.

Synergistic Activities:

- American Chemical Society (ACS) -- Member, Executive Committee, Energy and Fuels Division – 2004– 2009 – Participated on the Executive Committee involved in the coordination and direction of division activities, including outreach, programming, finances, and publications. Chair of Energy and Fuels Division 2004-2005.
- Lignite Energy Council, Distinguished Service Award, Research & Development, 1997, 2003, 2005, and 2008.
- College of Earth and Mineral Science Alumni Achievement Award, Pennsylvania State University, 2002
- Science and Technology Award, Impacts of Fuel Impurities Conference, 2014.

ALEXANDER S. BENSON

Education and Training

University of St. Thomas Mechanical Engineering B.S. 2011

Professional Experience

2019 – Present Project Manager, Microbeam Technologies Incorporated. Alex Benson is responsible for the management of multiple commercial projects and subcontracts on Department of Energy Projects. He develops project plans and manages resources to meet deadlines and financial commitments. He has created commercialization plans for a DOE sponsored Rare Earth Element extraction from coal project. Alex also interprets analysis results and uses computer-based models to predict fuel performance for multiple fuel types. Mr. Benson also prepares proposals and writes reports for clients.

2017 – 2019 Sr. Research Engineer (part-time), Microbeam Technologies Incorporated. Alex Benson analyzed datasets using statistical methods to determine potential relationships and correlations between fuel properties and plant parameters. Worked with computer scientists to develop neural networks based on observed correlations.

2017 – 2019 Manufacturing Manager, Medtronic – Minimally Invasive Technology Group. Alex Benson managed manufacturing operations of a medical device manufacturing plant with an annual budgeted Cost of Production of $360M. He was responsible for managing a three-shift manufacturing team of 7 production supervisors and 350+ production personnel. He managed manufacturing build plans to meet financial commitments and demand requirements for 134 SKUs, including developing production capacity, growth, and expansion plans to meet customer demand. He was responsible for ensuring his production team met demand while providing products that meet stringent FDA standards.

2016 – 2017 Sr. Product Engineer, Medtronic – Minimally Invasive Technology Group. Alex Benson lead commercialization activities for new product launches related to manufacturing build plans, engineering line design and validation to meet FDA quality requirements, and

production personnel training. He implemented process improvements of new manufacturing lines to improve output, yield, and efficiency, using statistical analysis and six sigma tools.

2015 – 2016 Sr. Manufacturing Engineer, Medtronic Energy and Component Center. Alex Benson was responsible for providing 24-hour engineering support of lithium ion battery manufacturing lines. He managed a cross-functional team through the commercialization of new lithium ion battery manufacturing lines, leading yield and efficiency improvements through product design and equipment improvement projects.

2012 – 2015 Manufacturing Engineer, American Medical Systems. Alex Benson oversaw multiple medical device manufacturing lines, managing yield, efficiency, and other process improvement projects. He was a member of a team to develop and commercialize a novel antimicrobial coating process for implantable medical devices.

Selected Publications and Presentations

Steven Benson, Shuchita Patwardhan, David Stadem, James Langfeld, Alex Benson, and Travis Desell, "Application of Condition Based Monitoring and Neural Networks to Predict the Impact of Ash Deposition on Plant Performance," Accepted for publication, Conference postponed to 2021.

Patents/Applications

Benson A, Benson S, Fuka M, Kolb E., inventors. Microbeam Technologies Inc., assignee. System And Method For Predicting Abundance Of Rare Earth Elements With Handheld X-Ray Fluorescence. United States of America 63/148,292. 2021 February 11.

Synergistic Activities

Continued Education (CE)/Professional Development Hour (PDH) Classes Completed:

- Combined Cycle Power Plant Fundamentals (EUCI)
- Heat Recovery Steam Generator (HRSG) Fundamentals (EUCI)
- A Comparison of the New SEC Regulation S-K 1300 on Modernization of Property Disclosures for Mining Registrants to Canadian National Instrument 43-101 (SME)

ERIC KOLB

Education and Training:

University of North Dakota	Mechanical Engineering	B.S. 2020

Research and Professional Experience:

2020 – Present Associate Research Engineer, Microbeam Technologies Incorporated. Eric Kolb's role is primarily focused on the design and construction of a rare earth element processing pilot plant. He also provides experience in computer equipment modeling, data interpretation from SEM analysis, and preparing and conducting laboratory experiments.

2019 – 2020 Research Engineer Intern (part-time), Microbeam Technologies Incorporated. Eric Kolb worked on various projects with respect to power systems and gasification technology. He conducted laboratory experiments for projects and conducted data interpretation for reporting purposes. Eric also operated and maintained a laboratory and scanning electron microscope.

Selected Publications and Presentations

Benson A, Benson S, Fuka M, Kolb E. Development of Low-Cost Rare Earth Element Analysis and Sorting Methods. [revised 2021 January]. [Print]. 2017 July. Other: Contract No. FY18LXXXIII-213

Patents/Applications

Benson A, Benson S, Fuka M, Kolb E., inventors. Microbeam Technologies Inc., assignee. System And Method For Predicting Abundance Of Rare Earth Elements With Handheld X-Ray Fluorescence. United States of America 63/148,292. 2021 February 11.

Synergistic Activities

- "Rare Earth Element Extraction and Concentration at Pilot-Scale from North Dakota Coal-Related Feedstocks"(DE-FE0031835). Subcontract to the University of North Dakota.
- "Conceptual Design of a One Ton Per Day Rare Earth Oxide Extraction and Concentration Plant from Low-Rank Coal Resources" (89243320RFE000032). Subcontract to University of North Dakota.

- "Development of of Low-Cost Rare Earth Element Analysis and Sorting Method" - North Dakota Industrial Commission funded research project. Developing an REE predictive algorithm to be used with pXRF and PGNAA to assist in the exploration, identification, and sorting of REE in coal.

Nolan L. Theaker

Education and Training:

University of Louisville	Chemical Engineering	B.S. 2016
University of Louisville	Chemical Engineering	M.Eng. 2017
University of North Dakota	Chemical Engineering	Pursuing PhD

Research and Professional Experience:

2017-Present Research Engineer, UND Institute for Energy Studies. Responsibilities include high-level innovative research and development of novel concepts for submission of funding proposals. Coordinated and led efforts associated with downstream rare earth element concentration operations that have resulted in the development of final process flow diagrams. Key contributor to multiple proposals involving REE extraction and/or concentration from multiple feedstocks. Proposed efforts associated with coal conversion and value improvement using chemical/thermal methods. Key contributor on proposals and projects for CO2 capture and/or utilization from coal combustion flue gases. Currently co-PI on pilot-scale REE work (DE-FE31835), and leading day-to-day research activities on the project.

2016-2017 Research Assistant, University of Louisville Conn Center. Research involved design and operation of multi-stage electrochemical reactor scheme for efficient production of fuels from CO2. Developed nano-functionalized electrocatalysts for improvements in activity and selectivity for targeted reactions in two phase reaction systems.

2014-2015 Co-op Engineer, University of Kentucky CAER. Research involved improvement and operation of a DOE bench-scale CO2 capture unit in multiple reaction conditions. Evaluation and comparison of catalyst performance in a holistic view for CO2 capture was conducted, including novel organic and enzymatic catalysts.

Publications/Presentations:

1. Theaker, N., Strain, J. M., Kumar, B., Brian, J. P., Kumari, S., & Spurgeon, J. M. (2018). Heterogeneously Catalyzed Two-Ctep Cascade Electrochemical Reduction of CO2 to Ethanol. Electrochimica Acta, 274, 1-8. doi:10.1016/j.electacta.
2. Park, D., Middleton, A., Smith, R., Laudal, D., Theaker, N., Hsu-Kim, H., Jiao, Y. A Biosorption-based approach for the selective extraction of REEs from coal byproducts. Separation and Purification Technology. 2020.
3. Mann, M; Theaker, N; Benson, S; Palo, D. "Investigation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks – Final Report". Submitted March 31, 2020.
4. Theaker, N., Rew, B., Laudal, D., Mann, M. Investigation of rare earth element extraction from North Dakota Coal-Related Feed Stocks. 2019 NETL Annual Crosscutting Projects Review Meeting. April 9th, 2019. Pittsburgh, PA.
5. Zygarlicke, C; Folkedahl, B; Feole, I; Kurz, B; Theaker, N; Benson, S; Hower, J; Eble, C. "Rare-Earth Elements (REEs) in U.S. Coal-Based Resources: Sampling, Characterization, and Round-Robin Interlaboratory Study – Final Report". Submitted September 30th, 2019.

Patents/Applications:

- Theaker, Nolan; Laudal, Dan. 2020. Method for Leaching Rare Earth Elements and Critical Minerals from Organically Associated Materials. USA. 63/112,846A, filed Nov. 12, 2020.
- Theaker, Nolan; Laudal, Dan; Lucky, Christine. 2020. Generation of Rare Earth Elements from Organically-Associated Leach Solutions. USA. 63/112,842A, filed Nov. 12, 2020.

Synergistic Activities:

Mr. Theaker's principal area of research interest includes energy, fuels, and alternative critical material research. These include developing alternative uses and sources of fuels and valuable materials, both carbon and mineral based.

Dennis R. James

Education and Training:

Youngstown State University	Geology	B.S. 1975
Purdue University	Geochemistry	M.S. 1977
University of Mary	Management	M.A. 2001
University of Mary	Business Administration	M.B.A. 2002

Research and Professional Experience:

2021 – Present	President, Dennis James Consulting LLC
2011 – 2020	Director – New Technology (retired), The North American Coal Corporation
2007 – 2011	Manager of Technology, The North American Coal Corporation
2002 – 2007	Fuel Quality Administrator, The North American Coal Corporation
1997 – 2007	Staff Geologist, The Falkirk Mining Company and The Coteau Properties Company (North American Coal subsidiaries)
1989 – 1997	Senior Geologist, The Falkirk Mining Company (North American Coal subsidiary)
1987 – 1989	Senior Geologist – Special Projects, The North American Coal Corporation
1986 – 1987	Senior Geologist – Exploration, The North American Coal Corporation
1983 – 1986	Senior Mine Geologist, The Coteau Properties Company (North American Coal subsidiary)
1981 – 1983	Mine Geologist, The Coteau Properties Company (North American Coal subsidiary)
1977 – 1981	Geologist, The B&M Coal Corporation
1975 – 1977	Trainee – Purdue University, The National Science Foundation Energy – Related (Coal)
1974 – 1975	Salesman, The Adamas Lapidary & Gem Shop
1973 – 1974	Teaching Assistant, Youngstown State University

Awards

Oct. 2009	American Institute of Professional Geologists (AIPG) Presidential Award of Merit, for work on the AIPG Energy Policy (Coal Chairman)

Oct. 2005 North Dakota Lignite Energy Council Distinguished Service Award, R&D, for work developing technologies to remove mercury from lignite-fired emissions

Oct. 2002 North Dakota Lignite Energy Council Distinguished Service Award, Government Affairs, for work with EPA on Mercury MACT issues

Professional Memberships & Certifications

- National Coal Council, Department of Energy (2016 – Present)
- American Institute of Professional Geologists
    - Member and Certified Professional Geological Scientist (CPGS #4970)
    - Vice President of the North Dakota Section (1996)
    - President of the North Dakota Section (1997-2004)
- American Association of Petroleum Geologists
    - Member (#18262-6)
    - Energy Minerals Division Member
    - Certified Coal Geologist (CCG #08)
- State of Indiana – Certified Professional Geologist (CPG #72)
- Society for Mining, Metallurgical, and Exploration – Member (#1583100)
- American Geological Institute – Member (#42419)

Patents/Applications:

Method of Enhancing the Quality of High-Moisture Materials Using System Heat Sources:

- United States (Serial No. 11/107,152 filed on April 15, 2005. Issued as U.S. Patent No. 7,275,644).
- Also filed: Pakistan, PCT, Europe, Canada, Australia, South Africa, China, Japan, India, Indonesia, and Russia

CARROLL L. DEWING
Vice President – Operations

Telephone: 701-323-3392
E-Mail: carroll.dewing@nacoal.com

February 23, 2021

Dr. Steven Benson
President
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Production of Germanium and Gallium Concentrates for Industrial Processes" Submitted in response to DOE funding opportunity announcement (FOA) DE-FOA-0002404 "Advanced Processing of Rare Earth Elements and Critical Minerals for Industrial and Manufacturing Applications," Area of Interest (AOI-2) Production of Critical Minerals (CM) Excluding Rare Earth Elements (REE) from Coal-Based and Alternate Resources.

Dear Dr. Benson:

North American Coal Corporation (NACC) is pleased to support the proposal from the Microbeam and the University of North Dakota proposal team to recover germanium and gallium from the University of North Dakota (UND) rare earth element recovery process from lignite coals that are rich in germanium and gallium. We are excited to be part of the team with Microbeam who brings expertise on germanium recovery technologies and UND who is currently constructing a pilot-scale demonstration of a REE extraction and recovery technology.

We understand this proposed project is Phase I of a multiphase program that is aimed at the development of an advanced midstream concept for the production of Ge and Ga from the UND REE process that is compatible with downstream industrial processes that utilize these elements. If the Phase I concept shows promise, a Phase II effort will be proposed. In Phase II proof of concept testing will be performed in laboratory- or bench-scale facilities to determine the potential viability of advanced innovative processes to produce Ge and Ga (90% pure as oxides, salts, or metals).

The work in Phase I will involve the following: 1) identify and analyze potential feedstocks rich in Ge and Ga., 2) perform literature review and identify industrial applications, 3) develop process flow diagrams for the production of Ge/Ga materials in existing pilot-scale facilities, and 4) determine the quantity of resource needed to produce quantities of refined product if scaled to a pilot project.

This technology is of specific interest to NACC since high levels of these elements (up to 160 ppm Ge (dry coal basis)) have been found in some of the coal currently mined. NACC currently has surface mining operations in North Dakota, Mississippi, Texas and Louisiana, and also provides dragline mining services for independently owned limerock quarries in Florida. North Dakota

operations, where testing of this technology would be conducted, include Falkirk, Coteau, and Coyote Creek mines with a total annual production of over 25 million tons annually in North Dakota. The technology could provide NACC with the ability to provide a high value feedstock to a critical mineral recovery facility.

NACC will work closely with the project team to identify regions within existing mines that have high levels of Ge and Ga. NACC will also provide samples collected through sampling efforts in the mine for critical mineral analysis including Ge and Ga. NACC is willing to provide $20,000 in in-kind support in the form of samples and time for the project that can be used as cost share.

We believe that, if successful, this project can significantly contribute to the development of an alternative and low-cost domestic production of critical elements (Ge and Ga) and will reduce foreign dependence. It will also help the coal mines to find new markets for coal-related products and we wish Microbeam and its team success in their effort.

If you have questions and require additional information, please contact me or Gerard Goven at 701 250-2604.

Very truly yours,
THE NORTH AMERICAN COAL CORPORATION

Carroll L. Dewing
Vice President – Operations

UNIVERSITY OF UND NORTH DAKOTA

OFFICE OF THE DEAN
COLLEGE OF ENGINEERING AND MINES
UPSON II ROOM 165
243 CENTENNIAL DRIVE – STOP 8155
GRAND FORKS, NORTH DAKOTA 58202-8155
PHONE (701) 777-3411 FAX (701) 777-4838
www.engineering.und.edu

March 9, 2021

Dr. Steven A. Benson
Microbeam Technologies Inc.
4200 James Ray Drive, Ste. 193
Grand Forks, ND

RE: Support of proposal entitled "Production of Germanium and Gallium Concentrates for Industrial Processes" submitted under DOE NETL FOA 2404 – Advanced Processing of Rare Earth Elements and Critical Minerals for Industrial and Manufacturing Applications – AOI 2.

Dear Dr. Benson:

We are pleased to team with Microbeam on this proposal application to develop novel separation processes for the critical minerals contained within the UND REE concentrates expected to be produced from the ongoing pilot efforts. This effort is expected to dovetail with ongoing efforts at development and validation of low-cost, environmentally friendly extraction and separation efforts for ND lignite resources, a key interest within the Institute for Energy Studies' goals. The following scope of work outlines the anticipated UND work within the project:

- **Task 1 – Project Management and Reporting** – UND will support efforts in management and reporting associated with attendance at all project meetings, development of report sections associated with UND activity, and reviewing of reporting documents prior to submission to funding agency.

- **Task 2 – Feedstock Identification and Characterization** – UND will leverage significant analysis databases of various lignites for identification of a suitable feedstock for sizeable production of Ge and Ga concentrates in Phase 2 work. UND will be assisting MTI in this task, and will also assist in characterization efforts as necessary. UND will also provide sample concentrates from the REE extraction pilot facility for evaluation purposes in Phase 1.

- **Task 3 – Literature Review and Industrial Partner Identification** – UND will assist task lead MTI in this task in literature review, development of process flow diagrams and preliminary mass/energy balances for existing technologies, as well as identification of the minimum salable grade of Ge and Ga materials for use in general markets.

- **Task 4 – Process Flow Diagram Development** – UND will lead this task in process flowsheet development, assisted by MTI, and utilize ASPEN Plus and other process modeling software to identify the anticipated flows and equipment sizing for an equivalent bench-scale size (for Phase 2 applications) and a commercial option to match a similar sizing of the REE extraction plant.

The cost of the proposed effort is $40,000, with a budget breakdown summarized in the attached budget form. The anticipated period of performance is September 1st, 2021 to May 31st, 2022. Nolan Theaker will serve as UND's Principal Investigator for this project and can be reached at (701) 777-6298.

Sincerely,

Michael D. Mann

Michael D. Mann, Ph.D.
Executive Director
Institute for Energy Studies

Karen Katrinak

Karen Katrinak, Ph.D.
Proposal Development Officer
Research & Sponsored Program Development

Dennis James Consulting LLC

Office: (972) 908-2730
Mobile: (214) 914-5778
1806 Longwood Court
Allen, TX 75013
Email: djamesconsulting@att.net

March 9, 2021

Dr. Steven Benson
President
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Production of Germanium and Gallium Concentrates for Industrial Processes". Submitted in response to DOE funding opportunity announcement (FOA) DE-FOA-0002404 "Advanced Processing of Rare Earth Elements and Critical Minerals for Industrial and Manufacturing Applications," Area of Interest (AOI-2) Production of Critical Minerals (CM) Excluding Rare Earth Elements (REE) from Coal-Based and Alternate Resources.

Dear Dr. Benson:

I am pleased to commit to working with the Microbeam and the University of North Dakota proposal team to recover germanium and gallium from the University of North Dakota (UND) rare earth element recovery process extracted from lignite coals. I am excited to be part of the team with Microbeam, who brings expertise on germanium recovery technologies and UND, who is currently constructing a pilot-scale demonstration of a REE extraction and recovery technology.

The scope of work for Phase 1 involves the development of an environmentally benign concept to produce Ge and Ga from a midstream REE concentrate that is fully integrated with downstream uses.

Task 2. Feedstock Identification and Characterization

I will work with North Dakota coal mines to identify feedstocks that have the potential to be rich in Ge and Ga. Samples of coals will be collected and analyzed to determine the abundance of Ge and Ga; along with the determination of modes of occurrence that can be used to ascertain extractability in REE recovery and concentrating processes.

Task 3. Literature Review and Identify Industrial Applications

I will work with the project team to develop a detailed literature review of technologies utilized to separate, concentrate, and refine Ge and Ga from conventional and non-conventional feedstocks. In addition, I will work with the project team to identify specific industrial applications for the Ge and Ga.

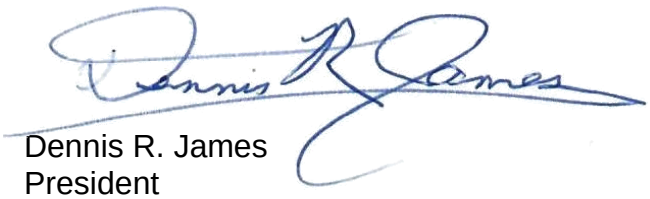
Task 4. Development of Process Flow Diagrams

I will review Process flow diagrams (PFDs) developed to produce Ge and Ga in forms that are required to produce end products from the feedstock materials used in this project. The production of > 90% purity Ge and Ga concentrated are expected from the process.

The level of effort for the work to assist the Microbeam team totals $20,000. I plan on spending 100 hours of time at a rate of $200/hour providing consulting services.

If you have questions and require additional information, please contact me.

Sincerely,
Dennis James Consulting LLC



Dennis R. James
President

resourceful. naturally.
engineering and environmental consultants

BARR

March 10, 2021

Dr. Steven Benson
President
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "*Production of Germanium and Gallium Concentrates for Industrial Processes*" Submitted in response to DOE funding opportunity announcement (FOA) DE-FOA-0002404 "*Advanced Processing of Rare Earth Elements and Critical Minerals for Industrial and Manufacturing Applications*," Area of Interest (AOI-2) Production of Critical Minerals (CM) Excluding Rare Earth Elements (REE) from Coal-Based and Alternate Resources.

Dear Dr. Benson:

Barr Engineering is pleased to support the subject proposal from Microbeam Technologies and the University of North Dakota (UND) team to recover germanium and gallium via UND's rare earth element recovery process from lignite coal. We are excited to support the team with Microbeam who brings expertise on germanium recovery technologies and UND who is currently constructing a pilot-scale demonstration of a REE extraction and recovery technology.

Barr is an 800-person, employee-owned engineering design and environmental consulting firm based in Minneapolis, Minnesota, with focus on mining, energy, fuels, and natural resource management. This technology is of specific interest to Barr Engineering since we worked with the project team on past Critical Material recovery projects.

We understand this proposed project is Phase 1 of a multiphase program that is aimed at the development of an advanced midstream concept for the production of Ge and Ga from the UND REE process that is compatible with downstream industrial processes that utilize these elements. If the Phase 1 concept shows promise, a Phase 2 effort will be proposed. In Phase 2, proof of concept testing will be performed in laboratory- or bench-scale facilities to determine the potential viability of advanced innovative processes to produce Ge and Ga (90% pure as oxides, salts, or metals).

The work in Phase 1 will involve the following: 1) identify and analyze potential feedstocks rich in Ge and Ga, 2) perform literature review and identify industrial applications, 3) develop process flow diagrams for the production of Ge/Ga materials in existing pilot-scale facilities, and 4) determine the quantity of resource needed to produce quantities of refined product if scaled to a pilot project.

During Phase 1 Barr Engineering will provide review of conceptual plant design, and in the Phase 2 effort we will provide a technical and economic assessment of the technology.

We believe that, if successful, this project can significantly contribute to the development of alternative and low-cost domestic production of critical elements (Ge and Ga), reducing US foreign dependence on these materials. This technology will also help domestic coal mines to find new markets for coal-related products, and we wish Microbeam and its team great success in their effort.

If you have questions or require additional information, please contact me at 801.333.8421 or dpalo@barr.com.

Sincerely,

Dr. Daniel R. Palo, PhD, PE
Vice President and Senior Process Engineer

August 3, 2021

SENT VIA ELECTRONIC MAIL

Ms. Roxanne Benson
Microbeam Technologies Inc.
rbenson@microbeam.com

SUBJECT: Selection of Application for Negotiation Under Funding Opportunity Announcement Number **DE-FOA-0002404 Advanced Processing of Rare Earth Elements and Critical Minerals for Industrial and Manufacturing Applications**

Dear Ms. Benson:

We are pleased to provide this update on your application. The Office of Fossil Energy within the Department of Energy (DOE) has completed its evaluation of your application submitted in response to the subject Funding Opportunity Announcement (FOA). The application below has been recommended for negotiation of a financial assistance award.

Application: "Production of Germanium and Gallium Concentrates for Industrial Processes" / Dr. Steven A. Benson / Application #13350985

Receipt of this letter does not authorize the applicant to commence with performance of the project. DOE makes no commitment to issue an award and assumes no financial obligation with the issuance of this letter. Applicants do not receive an award until award negotiations are complete and the Contracting Officer executes the funding agreement. Only an award document signed by the Contracting Officer obligates DOE to support a project.

The award negotiation process may take up to 90 days. The applicant must be responsive during award negotiations (i.e., provide requested documentation) and meet the stated negotiation deadlines. Failure to submit the requested information and forms by the stated due date, or any failure to conduct award negotiations in a timely and responsive manner, may cause DOE to cancel award negotiations and rescind this selection. DOE reserves the right to terminate award negotiations at any time for any reason.

Please complete the following items and submit to DOE no later than two weeks from the date of this letter:

- Pre-Award Information Sheet (attached)
- Updates (if applicable) to the Environmental Questionnaire form provided as part of your original application

You are reminded that if your organization proposed a foreign national (in any capacity) on the project, your organization is required to complete NETL F142.1-1A "Request for Unclassified Foreign National Access (Short Form)" for each foreign national. A copy of NETL F 142.1-1A is located at https://www.netl.doe.gov/business/business-forms/financial-assistance under Post Selection Forms/Information. You will then send an email directly to the Contract Specialist notifying them that you are ready to submit a request. The email should identify the award number, the Recipient's name, the name of the proposed foreign national, as well as his/her

country of citizenship and employer. This email should not include the NETL F 142.1-1A, any of the required supporting documents, or any other personal identifiable information (PII). You will be contacted with instructions on how to proceed with submitting the foreign national information after emailing the Contract Specialist.

A Contract Specialist from the Acquisition group will be assigned for the process of negotiating an award. In the meantime, please provide the requested documents to Sue Miltenberger, Contract Specialist, who can be reached at susan.miltenberger@netl.doe.gov or 304-285-4083. Charles Miller is the NETL Project Manager from the Project Management Division handling the technical portion of your application and can be reached at 412-386-5745 or Charles.Miller@netl.doe.gov.

Sincerely,

Keith L. Carrington

Keith L. Carrington
Contracting Officer
Finance and Acquisition Center

Enclosures

cc: FOA File
sbenson@microbeam.com
Charles.Miller@netl.doe.gov
Susan.Miltenberger@netl.doe.gov