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August 28, 2025

Karen Tyler, Executive Director
North Dakota Industrial Commission
State Capitol – 14th floor
600 East Boulevard Avenue, Dept. 405
Bismarck, ND 58505-0840
ndicinfo@nd.gov

Subject: Proposal to the Renewable Energy Program

Dear Ms. Tyler:

On behalf of the University of North Dakota, I am pleased to submit Dr. Xiaodong Hou's proposal on "Empowering the Critical Minerals for Novel Cathode Materials-based Drone Batteries," for consideration by the NDIC's Renewable Energy Program. Dr. Hou is a Research Associate Professor in UND's College of Engineering and Mines and is the Principal Investigator for this project. Dr. Hou is proposing a two-year project with a total requested amount from NDIC of $500,000. Cost share has been committed by Packet Digital ($330,000); Talon Metals ($20,000); and the University of North Dakota ($150,000). The total value of the overall project would thus be $1,000,000. The performance period is planned as 11/01/2025 to 10/31/2027.

Please contact Dr. Hou with any technical questions about the project at (701) 777-6350 or xiaodong.hou@und.edu. If the NDIC selects this proposal for an award, please send any award documents and related communications to Sherry Zeman at sherry.zeman@und.edu for processing on behalf of UND. The $100 application fee is being handled as an electronic payment by UND and should reach your office in a timely manner. Thank you very much for your consideration of this proposal.

Sincerely yours,

DocuSigned by:
Karen Katrinak
DD9BE15BC81D4AA...

Karen Katrinak, Ph.D.
Proposal Lead, Research & Sponsored Program Development
Karen.katrinak@und.edu 701-777-2505

Renewable Energy Program

North Dakota Industrial Commission

Application

Project Title: Empowering the Critical Minerals for Novel Cathode Materials-based Drone Batteries

Applicant: University of North Dakota

Principal Investigator: Xiaodong Hou

Date of Application: August 31, 2025

Amount of Request: $500,000

Total Amount of Proposed Project: $1,000,000

Duration of Project: 2 years

Point of Contact (POC): Xiaodong Hou

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1 ABSTRACT

Objective: The Center for Process Engineering Research (CPER) at the University of North Dakota (UND) College of Engineering & Mines, in collaboration with Packet Digital LLC (PD), will lead the development of advanced cathode materials to enable next-generation Li-ion batteries for drone applications. As part of this effort, UND and PD will also establish a Battery Materials Qualification & Testing Lab to ensure that synthesized cathode materials meet the requirements for PD's new cell manufacturing facility in Fargo. This pilot project will integrate North Dakota's critical mineral resources—nickel and cobalt from Talon Metals, lithium from Wellspring Hydro, and rare earth elements produced by UND—to demonstrate a fully domestic pathway for innovative cathode materials such as lithium cobalt oxide (LCO) and nickel manganese cobalt oxide (NMC).

Expected Results: This project will focus on the development of advanced cathode materials at lab-scale as the foundation for next-generation Li-ion batteries, while also establishing a supporting Battery Materials Qualification & Testing Lab at PD's manufacturing facility. By the end of the project, we expect to deliver battery-grade nickel and cobalt precursors, prototype cathode materials Lithium Nickel Manganese Cobalt Oxide (NMC) ($LiNi_xMn_yCo_zO_2$, where $x+y+z \approx 1$) and Lithium Cobalt Oxide ($LiCoO_2$) and the associated synthetic processes, battery performance testing results in both coin and pouch cells formats, determining their feasibility for PD's drone applications, and a process design for pilot-scale cathode materials production. The successful completion of this effort will position us for the next phase of pilot scale production, supported by techno-economic analysis (TEA), life-cycle assessment (LCA), and a Business Plan. Together, these results will lay the foundation for commercial licensing and the establishment of pilot-scale manufacturing capacity in North Dakota.

Duration: 24 months (Suggested: November 1, 2025 – October 30, 2026)

Total Project Cost: NDIC Share: $500,000 | Total Project: $1,000,000

Participants: UND, Packet Digital LLC, Talon Metals, and WellSpring Hydro.

2 PROJECT DESCRIPTION

2.1 Objectives

Our goal is to establish a closed-loop North Dakota supply chain for advanced drone batteries, eliminating reliance on foreign suppliers while meeting U.S. energy security and urgent defense needs. By integrating lignite-derived rare earth elements, critical minerals, and lithium from produced water with local cell manufacturing, this project links resources extraction, materials innovation, and battery manufacturing into a single regional ecosystem.

The objectives include:

1. Development of a lab-scale separation & purification process that can produce battery-grade nickel and cobalt precursors (iron<10 ppm) from Mixed Hydroxide Precipitate (MHP) feedstock supplied by Talon Metals.
2. Synthesis of advanced cathode materials NMC and LCO with quality superior to commercial counterparts from the purified nickel and cobalt precursors, along with Li precursors (i.e., LiOH or Li_2CO_3) supplied by WellSpring Hydro.
3. Process design for the pilot-scale production of Nickel Cobalt precursors and cathode materials.
4. Development of cell prototypes to evaluate the feasibility of the cathode materials for drone battery application.
5. Building a Battery Materials Qualification & Testing Lab with the key personnel, equipment and facility secure.

The achievement of these objectives leverages the following key components:

1) Talon Metals and its partners (University of Columbia and Argonne National Laboratories) ‘s ongoing R&D projects aiming to produce Nickel MHP from Talon Metals’ Nickel concentrates.
2) UND’s expertise and facility in the Rare Earth Element (REE) extraction from lignite feedstock, a hydrometallurgical process highly synergistic to the proposed purification of MHP.
3) Local Li precursor sources supplied by WellSpring Hydro, which has developed a Direct Lithium Extraction technology from ND’s produced water with its partner Volt Lithium.
4) UND’s 10+ years’ experience in battery materials R&D, including cathode and anode materials synthesis and characterization facility, battery fabrication and testing equipment, and intelligent modeling capability based on COMSOL’s battery design module.
5) PD’s industry-leading smart battery manufacturing technology and over 20 years’ drone battery manufacturing experience.
6) PD’s DoD clients’ extremely strong support, including a recent $17M contract by Navy to appeal PD to secure domestic supply chain for the military use drone battery.

The proposed project will address key technical gaps identified from prior technology development efforts. Specific objectives related to addressing these gaps and targeting specific improvements to the baseline performance and their technical performance are listed in **Table 1.** The baseline for most of the technical objectives is based on the commercial counterparts currently used in drone batteries.

Table1. Target Level of Performance

Objective/Goal	**Metric**	**Min Target**	**Baseline Performance**
Nickel Precursor	Purity as $NiSO_4 \cdot 6H_2O$ or $Ni(OH)_2$	>99.0%	Commercial sources
Cobalt Precursor	Purity as $CoSO_4 \cdot 7H_2O$ or $Co(OH)_2$	>99.0%	Commercial sources
Fe impurities	Iron impurities in precursors	<50ppm	Commercial sources
Fe impurities	Iron Impurities in Cathode Materials	<50ppm	Commercial NMC811 and LCO
NMC cathode materials	Specific capacity (mAh/g)	>170	Commercial NMC811
	Initial Columbic Efficiency (ICE)	85%	
LCO cathode materials	Specific capacity (mAh/g)	>140	Commercial LCO
	Initial Columbic Efficiency (ICE)	90%	

2.2 Methodology

A high-level summary of the proposed technology is provided below (see **Appendix 2** for full confidential details). As shown in **Figure 1**, the process starts with Talon Metals extracting nickel concentrates (~10%

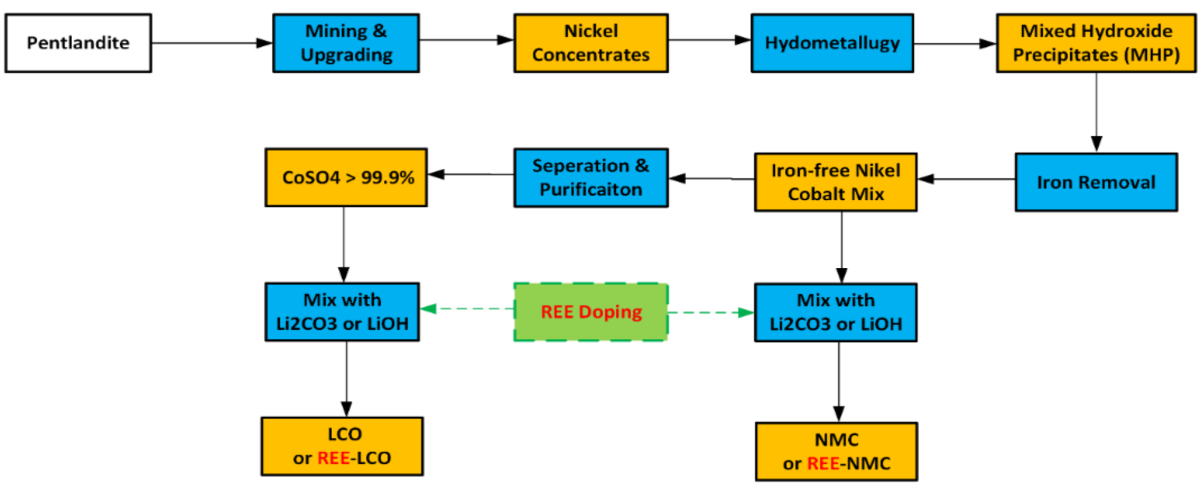


Figure 1. Flow Chart of the Advanced Cathode Materials Synthesis Process

Nickel) from pentlandite ore via advanced mining and beneficiation techniques. These concentrates undergo hydrometallurgical processing by the University of Columbia and Argonne National Laboratories, yielding mixed hydroxide precipitates (MHP, ~50% Nickel). Subsequently, UND executes iron removal from the MHP, followed by precise separation & purification protocols to isolate a high-purity iron-free nickel-cobalt mixture, or further separate cobalt from Nickel to yield cobalt sulfate with a purity exceeding 99.9%. This refined Ni-Co mixture (or cobalt sulfate) is then blended with lithium carbonate (Li_2CO_3) or lithium hydroxide (LiOH) supplied by WellSpring Hydro to form precursor solutions for synthesizing cathode materials NMC (or LCO). UND will not only produce state-of-the-art LCO and NMC, but also develop next-generation cathode materials through the strategic incorporation of rare earth element (REE) doping to enhance battery performance.

Advantages of the Proposed Technology Over Competing Ones

1) *Integrated supply chain*. Unlike competitors that rely on imported precursors, this project leverages North Dakota resources (Ni/Co, Li, REEs) to create a fully domestic, closed-loop supply chain.
2) *Superior purity*. Delivers battery-grade Ni-Co precursors at >99.9% purity with Fe <10 ppm, exceeding typical outputs from competing hydrometallurgical processes.
3) *Reduced processing complexity*. Selective iron removal and optimized separation minimize the need for repeated pH adjustments, precipitation, and other solution-preparation steps, lowering costs and simplifying operations compared to standard leach-and-refine routes.
4) *Next-generation innovation*. Goes beyond baseline NMC and LCO synthesis by incorporating REE doping to enhance battery performance, directly supporting PD's need for higher-energy, higher-power and higher-safety cathode materials for drone batteries—a capability rarely available through conventional supply chains.
5) *Synergy with REE processes*. Leverages UND's established rare earth element extraction expertise and infrastructure, lowering development costs and accelerating scale-up compared to standalone technologies

Work Plan

We propose the following set of tasks to achieve the project objectives.

Task 1 – Project Management

UND will perform all project management work necessary to manage the project's scope, schedule and budget (see Sections 5, 6, & 7). UND CPER will lead the effort in collaboration with PD, Talon Metals and Wellspring through bi-weekly meetings, with milestone reviews every quarter. UND will be responsible for communication with NDIC Renewable Energy Program in terms of financial status and technical progress reports.

Task 2 Development of A Lab-Scale Separation & Purification Process

This task aims to produce battery-grade nickel and cobalt precursors such as $NiSO_4 \cdot 6H_2O$ and $CoSO_4 \cdot 7H_2O$

with iron less than 10 ppm from nickel Mixed Hydroxide Precipitate (MHP) feedstock supplied by Talon Metals.

Subtask 2.1 – Feedstock Procurement and Characterization: Nickel and cobalt-containing feedstock Mixed Hydroxide Precipitate (MHP) will be supplied by Talon Metals. The chemical composition of the MHP feedstock will be analyzed to determine the impurities' type and concentrations using an inductively coupled plasma atomic emission spectrometer (ICP-AES). The chemical analytical resutls will enable us to identify the optiaml seperation & prufication strategies in the following tasks.

Subtask 2.2 – Removal of Iron from MHP: This subtask focuses on efficiently removing iron impurities from mixed hydroxide precipitate (MHP) to improve the purity of the target nickel and cobalt stream. The plan involves evaluating chemical and/or physical separation methods, optimizing process parameters such as pH, temperature, and reagent concentration, and performing lab-scale experiments to quantify iron removal efficiency. Results will guide the selection of the most effective approach for integration into subsequent nickel/cobalt separation and purification steps.

Subtask 2.3 – Separation of Cobalt and Nickel: This subtask focuses on the separation and purification of cobalt and nickel from the refined MHP. Process conditions, including feed rate, pH, temperature, and time will be optimized to maximize yield and purity. The structure and composition of the resulting cobalt and nickel precursors will be characterized using X-ray-diffractomer (XRD), Scanning Electron Microscope (SEM) and ICP-AES. The results will be compared with commercial reference materials and the objectives defined in **Table 1**.

<u>Task 3 – Syntheses of Cathode Materials</u>

Subtask 3.1 – Syntheses of State-Of-The-Art Cathode Materials. This subtask aims to produce state-of-the-art cathode materials (LCO and NMC) for PD's drone batteries using the nickel and cobalt precursors produced in Task 2, along with lithium carbonate Li_2CO_3 (or Lithium hydroxide LiOH) supplied by WellSpring Hydro. The cathode materials' phase purity and yield as a functional of synthetic process parameters such as precursors feeding ratio, reaction time and temperature, atmospheric will be systematically investigated. The power samples need to be further size classified to achieve desired particle size distributions. The characterization methods used in Subtask 2.3 will be applied to measure the chemical composition of the cathode materials. Particle size and specific surface areas will be measured by using a BET surface area analyzer. The results will be compared with PD's current commercial cathode materials and the performance targets defined in **Table 1**.

Subtask 3.2 – Syntheses of Next-Generation Cathode Materials. This subtask aims to prepare next-generation LCO and NMC cathode materials through doping strategies with the goal of improving the rate capability, cycling life and thermal stability of PD's next-gen drone batteries. The basic process is like the Subtask 3.1 except for the addition of a few % of REE and other dopants. The impact of dopant's type and concentration on the battery performance in particular the rate capabilities will be systematically studied.

All the characterization approached used in Subtask 3.1 will be applied in this Subtask. The doping concentration in the final cathode materials will be analyzed by ICP-OES. The battery performance including rate capability, cycling life and thermal stability will be tested by PD in the form of coin cells.

Task 4 – Process Design for the Pilot-Scale Production.

This task aims to design a pilot-scale process for the production of cathode materials, building on the lab-scale processes developed in Tasks 2 and 3. The design encompasses feedstock procurement, separation and purification of nickel and cobalt, cathode materials synthesis, and post-treatment, aiming for a reproducible and efficient operation at a scale of about 25 tons/year. The process design will identify critical process parameters, select appropriate equipment, and establish robust process control strategies to ensure product quality, operational safety, and scalability for future commercial production. While this project focuses solely on process design without executing scale-up testing, it leverages the existing bench and pilot-scale units at UND's REE Pilot Plant to inform design decisions with scale-relevant data, minimizing risks and enhancing feasibility for future pilot-scale implementation.

Task 5 – Establishing a Battery Materials Qualification & Testing Lab.

This task aims to establish a battery materials qualification and testing lab at PD's facility to support evaluation of cathode materials developed in the previous tasks, with a primary focus on performance testing. The lab will provide shared capabilities for verifying material quality, conducting critical electrochemical testing, and ensuring compatibility with PD's in-house manufacturing requirements. Importantly, this lab fills a critical gap not addressed by UND's existing battery R&D infrastructure, serving as a dedicated resource for on-site material qualification. It will cover cell design and prototyping activities, strengthen collaboration among project partners, and contribute to a more resilient domestic battery supply chain. The lab building was completed as a part of the construction of PD's new cell factory. Some of the key equipment and facility in the lab, including the coin-cell and pouch cell assembly line and testing instruments, have been procured. The main effort of this task will be calibration and testing of those existing equipment, and procurement of necessary new equipment, and make the lab fully functional. Key equipment to be installed and calibrated includes slurry mixers, precision electrode coaters, calendaring machines, electrode punching and slitting tools, electrode drying ovens, glove boxes, coin and pouch cell assembly lines, electrolyte filling systems, formation and cycling testers, and advanced analytical instrumentation for electrochemical and materials characterization. Three new equipment to be procurement include a particle size analyzer, BET surface area analyzer and moisture content analyzer. PD will lead this task.

Task 6 – Battery Performance Testing.

This task aims to evaluate the battery performance of the synthesized LCO and NMC cathode materials in small coin-cells to see if they meet the performance targets defined in **Table 1** and determine the feasibility of being used in PD's battery fabrication when scaled up in the next phase. CR2032 coin-type cells will be prepared using lithium metal as the counter electrode. Electrochemical performance testing, including initial charge-discharge capacity, ICE, and anode cycle life, will be conducted on a TOB CT-4008 battery testing system, Cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) tests will also be conducted on a Gamry potentiostat. This task including three subtasks below is to be accomplished in the newly established battery research lab in Task 5.

Subtask 6.1 – Optimization of Cathode Electrode Formula. This subtask aims to tailor the cathode electrode formula for high power and high energy density UAS applications, by optimizing the ratio of cathode material, electric conductive and binder inside the cathode electrode.

Subtask 6.2 – Optimization of Cathode Electrode Slurry Mixing. This subtask aims to study electrode preparation techniques (mixing, coating, and calendaring) to optimize electronic conductivity networks.

Subtask 6.3 – Optimization of Electrolyte Formula. This subtask aims to optimize electrolyte by blending high temperature Li salt, low freezing point solvent and selected additives to form stable CEI protective layers on cathode electrode surfaces, with the goal of long cycle life, high-rate capability and wide temperature range cell performance.

<u>Task 7 – Fabrication and Evaluation of Prototype Pouch Cells.</u>

This task aims to evaluate the battery performance of the synthesized LCO and NMC cathode materials in large pouch-cells, using the optimized formulations developed in Task 6. This objective is to assess their feasibility for integration into PD's battery fabrication process and potential deployment in customer applications. Pouch cells with capacities >1Ah will be fabricated, employing commercial synthetic graphite as the anode electrode. The same advanced testing protocols and analytical methods established in Task 6 will be applied to characterize cycle life, rate capability, and overall performance, providing critical validation of the materials' scalability and practical application.

2.3 Anticipated Results

The primary outcome of this project will be the development and proof-of-concept demonstration of advanced cathode materials that combine superior technical performance with cost competitiveness. Supporting this effort, a dedicated battery materials qualification and testing lab will be established at PD's facility to ensure synthesized materials meet target requirements. The expected results include: The expected results of this project include: **1)** Purification and production of 20–50 grams of battery-grade nickel and cobalt precursors with impurity levels (Fe <10 ppm) suitable for cathode synthesis; **2)** Fabrication of a minimum of 10 grams of high-quality cathode materials (NMC and LCO) meeting battery-grade standards; **3)** Assembly and testing of >10 coin-type half-cells pairing the synthesized cathodes with lithium metal anodes, demonstrating electrochemical performance superior to commercial reference materials; **4)** Development of 3–5 full NMC or LCO pouch cells achieving ≥260 Wh/kg specific energy, targeting high-power drone applications, and **5)** Completion of a process design for pilot-scale cathode material production (25 tons/year) that validates the technical and economic performance of our innovative process; **6)**. Establishment of a fully functional Battery Materials Qualification & Testing Lab at PD's factory in Fargo.

In the next phase, we will conduct a full techno-economic analysis (TEA) and life-cycle assessment (LCA) to evaluate the scalability and environmental impact of the process. A Manufacturing Transition Plan (MTP) will be developed to define the required steps toward commercial manufacturing. Upon project completion, we will be positioned to pursue licensing opportunities and advance toward establishing commercial-scale cathode production in North Dakota.

2.4 Facilities & Resources

UND has world-class facilities and resources that will be leveraged in this project, including: 1) wet-chemistry labs , 2) advanced materials characterization laboratories, 3) bench-scale and pilot-scale facilities associated with UND's development of lignite-based REE technologies, which can be used in the separation and purification of nickel and cobalt from Mixed Hydroxide Precipitate with minimal additional equipment additions, 4) various furnace types and sizes that can be used for production of cathode materials, and 6) commercial license to AspenPlus process simulation software and license for SimaPro LCA software.

Packet Digital LLC operates two well-equipped facilities in Fargo, North Dakota, for power electronics and battery pack design, development, and manufacturing. The headquarters spans 11,161 square feet, featuring offices, collaborative spaces, and a 4,000-square-foot lab with ESD-safe flooring. The production facility covers 25,000 square feet, with 20,000 square feet dedicated to production activities including PCB assembly, battery welding, testing, and final product assembly. Both facilities have advanced security measures. Additionally, Packet Digital recently acquired an 80,000-square-foot warehouse in Fargo, to be converted into a cell manufacturing plant, designed to support and expand their production capabilities.

The project will also leverage the facilities of our industry partners. **Talon Metals** will supply mixed hydroxide precipitates feedstock through their partner the University of Columbia. **WellSpring Hydro** will supply battery-grade lithium carbonate (Li_2CO_3) or lithium hydroxide (LiOH) from their facility at Williston, ND. **Appendix** 7 provides additional details about UND's facilities and resources and PD's proposed Battery Materials Qualification & Testing Lab.

2.5 Techniques to Be Used, Their Availability and Capability

A high-level summary of the techniques for the seperation and purificaiton of nickle and cobalt, and synthesis of cathode materials were described in Section 2.2 Methodology, more details are inlcuded in the confidentials (**Appendix 2**). These separation and purification techniques are somewhat synergetic with UND's patented REE extraction techniques (U.S. Patent No. US10669610B2, US20220145421A1, and US20220144660A1). The majority of the required techniques and the associated bench-scale and pilot-scale facilities are directly available at UND's REE plant at Grand Forks, with minimal amendment and additional equipment needed. Key techniques for synthesizing cathode materials NMC and LCO are also confidential included in the **Appendix** 2. UND team has intensive experience and patented technologies (U.S. Patent No. 17/558,080**)** in the synthesis of Li-ion battery cathode materials $LiFePO_4$, which was funded by the Renewable Energy Program (R-035-044). The key steps like precursor blending and following solid-phase calcination can be easily adopted to the proposed cathode materials NMC and LCO. All the lab and bench-scale equipment and facilities for this project are directly available without modification.

2.6 Environmental and Economic Impacts while Project is Underway

The proposed work will involve negligible environmental impacts, as the work involves research-scale demonstrations and desktop engineering work. We will follow all UND permits and procedures for effluent management. Economic impacts during the project will primarily involve employment opportunities for UND faculty, staff and students and the workforce development/ training associated therewith. The Battery materials R&D platform establishment at PD's facility will have minimal environmental impact, limited to standard construction, and will comply with all applicable state and federal regulations.

2.7 Ultimate Technological and Economic Impacts

Successful commercialization will have broader technological and economic impacts: **1)** Strengthen PD's capabilities in securing domestic battery supply chain, positioning it as a leader in next-generation Li-ion batteries for UAS applications; **2)** Expand market opportunities for Talon Metals and WellSpring Hydro by creating new customers their feedstocks. **3)** Transform North Dakota's rich critical minerals and renewable energy assets into high-value products, driving national technological leadership. **4)** Stimulate investment, create highly skilled jobs, and foster regional economic development through critical minerals mining, advanced manufacturing, and energy innovation.

2.8 Why the Project is Needed

North Dakota is uniquely positioned to lead in critical minerals, with in-state resources of nickel, cobalt, lithium, and rare earth elements, all . However, the state currently lacks the R&D infrastructure needed to transform these raw materials into battery-grade components that directly support domestic manufacturing. At the same time, Packet Digital's Department of Defense (DoD) clients face urgent requirements for secure and fully domestic supply chains for critical battery materials. Without a local source of those critical materials, PD's new cell manufacturing facility in Fargo must depend on foreign suppliers, creating risk for defense and drone applications. This project will bridge the gap between North Dakota's mineral resources and PD's manufacturing needs, ensuring that the economic and strategic value of these resources is captured in-state. This effort will also develop a skilled workforce, strengthen regional supply chains, and lay the groundwork for pilot-scale production in North Dakota, directly advancing both state economic diversification and national security priorities.

3 STANDARDS OF SUCCESS

The success of this project will be evaluated by following measurable metrics: **1) Precursor Production**: Purification of Ni/Co precursors from Talon's MHP with Fe <10 ppm at 20–50 g scale; **2) Cathode Synthesis:** Production of ≥10 g of high-purity NMC and LCO meeting target specs (NMC ≥170 mAh/g, ICE ≥85%; LCO ≥140 mAh/g, ICE ≥90%); **3) Cell Validation**: Fabrication/testing of ≥10 coin cells and 3–5 pouch cells with pouch prototypes achieving ≥260 Wh/kg; **4) Process Design**: Completion of a pilot-scale cathode production process design (25 tons/year capacity), and **5) Lab Establishment**: Installation of a fully functional Battery Materials Qualification & Testing Lab at PD's cell manufacturing facility Fargo.

4 BACKGROUND/QUALIFICIATIONS

4.1 Project Team

The project will be managed through **UND's Center for Process Engineering Research (CPER)**, a team of 100% research focused faculty and staff researchers. Core capabilities include: **1**) technology development and scale-up: through TRL 6-7; **2**) research equipment design and fabrication; **3**) advanced materials characterization; **4**) techno-economic analysis: AACE Class 5 through AACE Class 3; **5**) environmental lifecycle analysis: SimaPro and GREET; **6**) Process engineering simulation, modeling and design: Aspen Plus (commercial license), HSC Chemistry; and **7**) computational fluid dynamics modeling.

The CPER team will be led by the PI, Dr. Xiaodong Hou, research associate professor. Dr. Hou is a materials chemist with 20 years of experience synthesizing and characterizing advanced materials. He has over 54 peer-reviewed publications in chemistry materials and holds eight patents. Dr. Hou has led multiple projects directly related to developing advanced materials from lignite for LIBs, including the DOE sponsored projects DE-FE0026825, DE-FE0031984, and DE-FE0032139. Dr. Hou will also be supported by UND CPER's REE technology development team, including **Nolan Theaker,** who will lead the Ni/Co purification work leveraging his expertise in REE and CM processing from secondary sources.

Packet Digital, based in Fargo, ND, is a leading manufacturer of Li-ion batteries and power systems with a strong focus on Unmanned Aerial System (UAS) applications. As the primary business partner in this project, Packet Digital is committed to securing a fully domestic supply chain for its drone batteries to meet urgent DoD requirements. The company's objectives align closely with the project's mission to develop supply-chain-secure, high-performance cathode materials. The PD team will be led by Andrew Paulsen, Chief Technology Officer. Andrew Paulsen has extensive research, testing, and product development expertise in high performance batteries and battery systems, including group 3 eVTOLs, power algorithms and power electronics, including air and ground based solar powered vehicles, and other technologies enabling electrification and autonomy. Packet Digital will lead the effort in testing the synthesized cathode materials in coin and pouch cell formats and in establishing the Battery Materials Qualification & Quality Lab at its manufacturing facility.

Talon Metals, is advancing development of domestic nickel and cobalt resources and will supply Mixed Hydroxide Precipitate (MHP) feedstock for this project. The feedstock will be sourced from the technology developers behind Talon Metals' Beulah Minerals Processing Facility in Mercer County, North Dakota, which is funded by a $114 million grant from DOE.

Wellspring Hydro, is pioneering Direct Lithium Extraction (DLE) technology from North Dakota's produced water and will provide battery-grade lithium carbonate and lithium hydroxide.

4.2 Technology Development History

This project mainly leverages UND's REE/CM extraction technologies, cathode materials development expertise, and PD's Cell manufacturing capability.

4.2.1 Talon Metal's Nickel Concentrates and MHP

Talon Metals has advanced critical mineral processing through its Tamarack Nickel Project, producing nickel concentrates (10% Ni, 20–30% Fe, 0.2–0.5% Co, 1–2% Cu) from pentlandite ore (1.94% Ni, 1.84% Cu, 0.44% Co) via froth flotation and electrochemical refinement.[12] In 2023, Talon received a $114 million DOE award to support the development of a battery minerals (i.e., Nickel) processing facility. Since 2023, Talon has collaborated with Columbia University and Argonne National Laboratories under the DOE's ARPA-E MINER program to develop sustainable methods for mixed hydroxide precipitate (MHP) production from nickel concentrates. Led by Alan West, the MINER project employs high-pressure acid leaching (HPAL) and electrochemical techniques to remove impurities and precipitate high-purity Ni-Co hydroxides, achieving 50–52% Ni, <0.6% Fe, no Cu, and 1–2% Co. UND will use this MHP as feedstock to produce battery-grade nickel and cobalt precursors for cathode material synthesis in the proposed project.

4.2.2 UND's expertise in REE/CM recovery technologies

UND CPER is among the top research groups involved in developing REE and critical minerals (REE/CM) technologies for unconventional resources, such as coal and coal byproducts. We have an operational pilot-scale plant (DE-FE0031835) (TRL 6) and have completed a front-end engineering and design and business planning study (DE-FE0032295), and are actively developing commercial offerings for the technology package. <u>Although this proposed project is lab testing only, the outcoming processes will be</u>

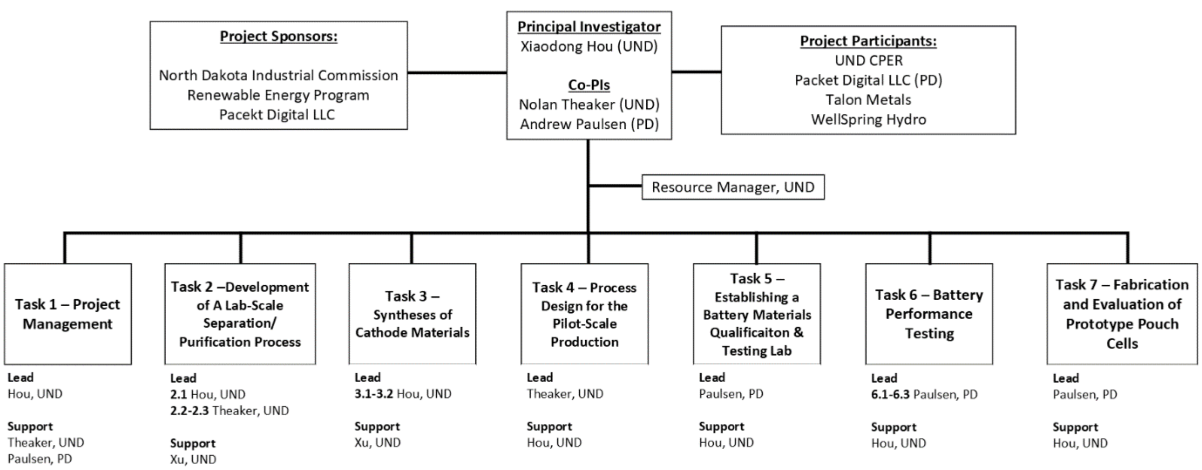
deployed in the REE/CM facility in the next phase of production for rapid time-to-market.

4.2.3 UND's Li-ion battery cathode materials synthetic technology development

UND team was funded by Research ND Venture Grant - Phase I/II (**17-02-J12-166**) in 2016 to develop "a low-cost and reproducible synthetic procedure for mass production of lithium iron phosphate (LFP) cathode materials for Li-ion Batteries". We achieved high purity (>99%) of LFP cathode materials with a capacity (142 mAh/g) greater than the commercial references by 15%. Later, UND team was funded by the NDIC Renewable Energy Program in 2018 to prepare graphene-coated lithium iron phosphate cathode materials (LFP/G) for LIBs (**R-035-44**) at 10 kg/batch in-situ (TRL 5). Major achievements during this project (2018-2020) included the development of a low-cost procedure that can produce high-purity (>99%) and low ash content (~1%) humic acid from Leonardite. We successfully demonstrated production of LFP/G at 20 kg/day, with a cost reduction of 69% compared to adding external graphene into LFP. The UND-owned patent based on the above technology "Battery Materials and Fabrication Methods. (U.S. Patent Application No. 62/706,191, August 4, 2020)" was recently granted.

5 MANAGEMENT

Figure 2. Project organization



Project organization: The project is organized into seven tasks, with key personnel leads and key support personnel identified for each task (**Figure 2**). The project's PI, Dr. Hou will be responsible for the overall project management. Co-PIs Nolan Theaker (UND) and Andrew Paulsen (PD) will be responsible for directing technical efforts. The task leads will be responsible for managing the activities within their respective tasks and closely coordinating with the PI. See **Appendix 6** for resumes of proposed key personnel.

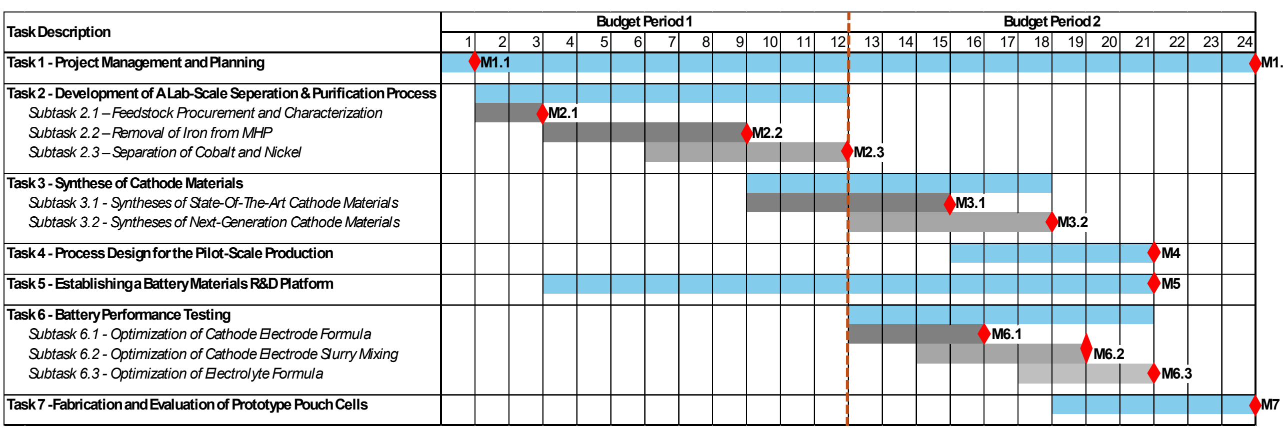
UND is the applicant and overall project lead, responsible for overseeing project execution, and will be the point of contact for project sponsors and partners. UND will lead efforts associated with feedstock selection and characterization, Ni and Co purification, cathode materials synthesis, and process design.

Packet Digital (PD) is an industry partner and the primary beneficiary, providing $350,000 in cost share support. Co-PI Andrew Paulsen will lead the PD's efforts in Task 5-7**. Talon Metals** will provide Ni/Co feedstock (MHP) and technical support for Task 2 as cost-share in value of $20,000, and **WellSpring Hydro** will provide battery-grade Li_2CO_3 (or LiOH) for cathode materials syntheses in Task 3, as indicated in their support letters. **NDIC Renewable Energy Program** is the primary project sponsor, providing cash support $500,000 and technical and regulatory guidance for the development of renewable energy technologies.

Risk management: A key risk is that Columbia University or Argonne National Lab may be unable to supply kilogram-scale quantities of mixed hydroxide precipitate (MHP). To mitigate this, (a) we can reduce sample size for laboratory process development, since the project's primary objective is to validate process feasibility, and (b) we can directly work on Talon's nickel concentrates, which are available in sufficient quantity for testing, and the technology for this alternative route is also included in the confidential **(Appendix 2)** . In the event milestones slip, a formal decision structure will be followed: risks will be reviewed in the bi-weekly meeting, escalation will go to the project PI and PD's technical lead within one week, and a joint action plan will be adopted to reallocate resources or adjust scope to keep the project on track.

6 TIMETABLE

The proposed project timeline is 24 months, with an expected start date of November 1, 2025. A simple Gantt chart and milestones table are provided below.



Task No.	Milestone Description	Milestone Verification Process	Date (Month)
1.1	Project kick-off meeting	Meeting held	2
1.2	Final Report	Submit to NDIC REP	24
2.1	Feedstock analytical report completed	Quarterly Report	3
2.2	Iron removal (<10 ppm) process identified	Quarterly Report	9

2.3	Cobalt and Nickel precursors (>10g) produced	Quarterly Report	12
3.1	LCO and NMC cathode materials produced	Quarterly Report	15
3.2	REE-doped cathode materials produced	Quarterly Report	18
4	Process design report completed	Quarterly Report	21
5	Battery materials R&D platform establishment report	Quarterly Report	21
6.1	Cathode electrode formula optimized	Quarterly Report	16
6.2	Cathode electrode slurry mixing formula optimized	Quarterly Report	19
6.3	Electrolyte formula optimized	Quarterly Report	21
7	Prototype pouch-cell testing completed	Quarterly Report	24

7 BUDGET

Cost Share Source	**Amount**	**% of Total Project**
Packet Digital	350,000	70%
University of North Dakota	150,000	30%
TOTAL PROJECT	**500, 000**	**100%**

Project Associated Expense	**NDIC's Share**	**Applicant's Share (Cash)**	**Applicant's Share (in-kind)**	**Industry Partners' Share**
Personnel	130,745	55,790	-	
Fringe Benefits	36,521	20,642	-	28,901
Travel	-	-	-	2,518
Equipment	-	-	-	38,427
Supplies	5,250	-	-	
Subcontracts	225,000	-	-	-
Other Direct Costs	16,785	42,230	-	20,000
Indirect Costs	85,699	31,337	-	260,154
Total	500,000	150,000	-	350,000

The NDIC share will support UND personnel costs, including associated fringe benefits, supplies, a subcontract to Packet Digital, lab fees, tuition, and facilities & administrative costs. UND's cost share will take the form of PI time and partial tuition support (waivers) for graduate students working on the project, totaling $150,000. Two industry partners will be supporting the project via in-kind and cash cost share, totaling $350,000. Talon Metals will provide cost share of $20,000 through technical aid time, project materials, and shipping costs. Packet Digital will provide cost share of $330,000 through fringe benefits, travel, equipment purchases, and indirect costs. Budget notes are in **Appendix 4**.

8 TAX LIABILITY

The University of North Dakota has no outstanding tax liabilities (see **Appendix 8**).

9 CONFIDENTIAL INFORMATION

The confidential information is attached as an appendix (**Appendix 2**).

10 PATENTS AND RIGHTS TO TECHNICAL DATA

The technology for REE extraction from lignite (U.S. Patent No. US10669610B2, US20220145421A1, and US20220144660A1), and $LiFePO_4$ cathode materials synthesis for LIBs (U.S. Patent Application No. 62/706,191) are currently protected under patents solely owned by UND. The additional innovations developed through the proposed work will be considered for patent protection. As we advance our fabrication and testing efforts, any novel devices, procedures or operational designs that emerge will be evaluated for patentability, and we will file domestic and international patent applications as appropriate. In cases involving IP sharing and technology transfer/ licensing, UND will negotiate a comprehensive IP agreement with the participants, in accordance with the university's existing policies.

11 STATE PROGRAMS AND INCENTIVES

UND, as a state-controlled institution of higher education, has been involved in state programs or incentives in the past 5 years, including previous and ongoing research awards through the NDIC grant programs.