TELEIOS-BATT

Product/category

- Software/Services

Primary submitting organization:
Idaho National Laboratory

Product/services brand name:
TELEIOS-BATT

When product was introduced to the market:
Phase-in of different tools spanning January 2023 to January 2026.

Abstract:
TELEIOS-BATT, developed by Idaho National Laboratory, is an advanced suite of physics-based diagnostic and prognostic tools for batteries. It offers fast, accurate, and efficient monitoring, simulation, and prediction of battery health and aging, helping maximize safety, reliability, and cost-efficiency for modern battery-dependent industries.

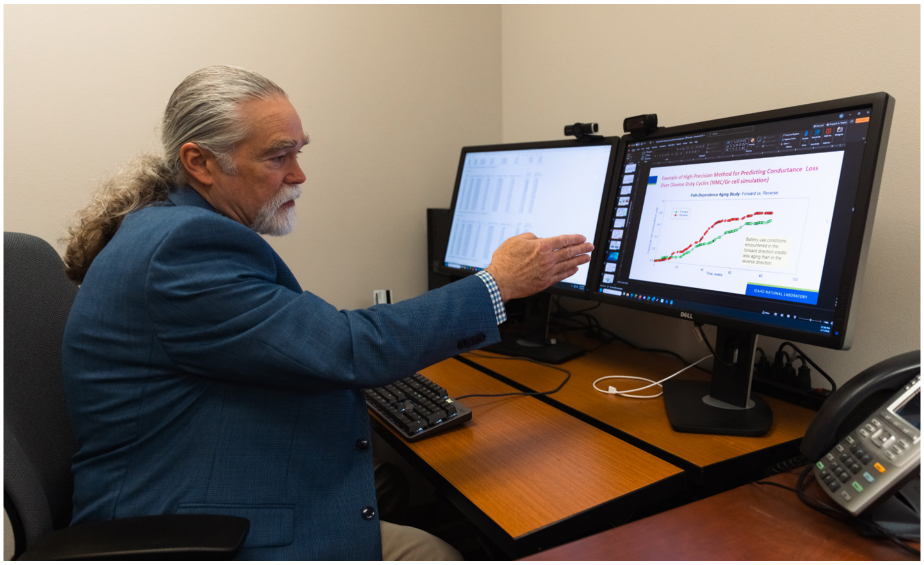

Figure 1: Dr. Kevin Gering explaining the importance of path-dependence of battery aging, using TELEIOS-BATT results for simulations covering changeable, diverse battery use conditions over the timeline.

Executive summary:
In a world that has become increasingly dependent on power from batteries, accurate diagnostics and prognostics (D&P) are absolutely essential to understanding battery performance, safety and profitability. One only has to look at General Motors' 2021 recall of all Chevrolet Bolts due to the risk of the cars' high-voltage battery packs catching fire. The manufacturing giant was hit with significant downtime, as well as financial and reputational damages. GM later confirmed that the Bolt recall was caused by a cell-manufacturing issue.

Intelligent D&P that continuously monitor and predict State of Health (SoH) help identify patterns of stress or misuse that could compromise safety, allowing for proactive intervention. The more accurate these estimations are, the greater the control operators have over battery behavior, reliability, and cost efficiency. Precision in SoH estimation not only extends the operational life of batteries but also maximizes return on investment by reducing downtime and minimizing unexpected failures.

TELEIOS-BATT, a suite of physics-based D&P tools developed by Idaho National Laboratory, offers the most advanced algorithms and simulations for optimizing battery performance, enhancing safety, and ensuring the longevity of battery-powered systems. It quickly transforms raw battery data and materials metadata into meaningful intelligence, enabling smarter decisions and supporting the sustainable, reliable operation demanded by modern industry.

Unlike other technologies, TELEIOS-BATT provides a wide range of tools that go beyond what competitors offer. While some alternatives rely mainly on empirical correlations -- which might result in inaccurate diagnostics -- TELEIOS-BATT is grounded in rigorous physics. Other competitors may have models that require accurate estimates for scores of parameters and take hours to run. Yet, TELEIOS-BATT applies strategic levels of physics needed to quickly answer the questions at hand, whether for battery performance or longevity, with most runs from constituent tools taking only seconds to complete. TELEIOS-BATT also needs far less test data to train its models. Using just a few weeks to a few months of data, TELEIOS-BATT can predict long-term battery aging trends with impressive accuracy -- within 1-2% absolute error and 5-10% relative error -- making lab testing faster and less expensive, while speeding up battery development.

TELEIOS-BATT tracks leading measures of battery performance and aging throughout a battery's lifecycle, from new to retired or repurposed cells. It continuously monitors key indicators -- capacity, conductance, and power -- to detect critical limits on performance. This helps stakeholders decide when to remove or isolate batteries that no longer meet required standards. With its materials-based TAA/SP component, users can simulate battery aging virtually without any preliminary testing. The Smart Pulse Diagnostic Tool goes even further: with just a single pulse, it can predict detailed information about a battery's power across many cycling conditions and account for temperature changes during operation. These features are a few of many that are exclusive to TELEIOS-BATT.

Additional supporting materials:
[INL technology summaries covering selected CellSage capabilities (a subset of TELEIOS-BATT)]

[Novel Method for Evaluation and Prediction of Capacity Loss Metrics in Li-Ion Electrochemical Cells]

[Accelerated battery life predictions through synergistic combination of physics-based models and machine learning]

Video:
[Link]

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Ridgetop Group, Inc.

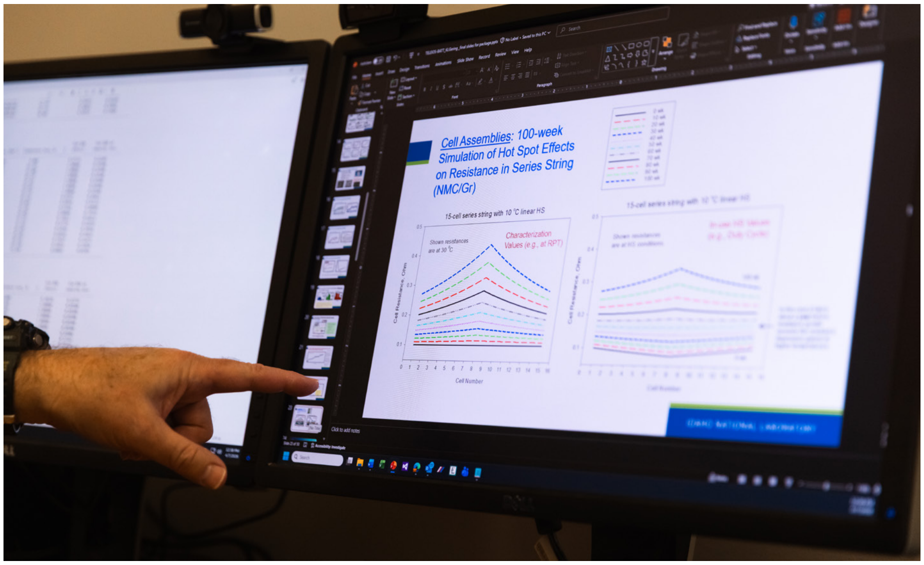

Figure 2: Snapshot of a 100-week aging simulation for a multi-cell string containing a thermal hotspot, showing the combined effects on cell resistance. Such simulations capture the plausible condition of imperfect thermal management in battery assemblies, and how it impacts local aging within the cell string.

"TELEIOS-BATT represents a significant advancement in battery modeling, diagnostics, and lifecycle prediction, offering a fundamentally new approach to understanding and managing battery performance across its full operational life. … (It) is a transformative platform that redefines how battery aging and performance are modeled and managed."

— Wyatt Pena, President & COO, Ridgetop Group

What does this product or technology do?

In today's increasingly electrified world, batteries have become the backbone of countless industries, powering everything from consumer electronics to large-scale energy storage systems. As battery technology advances and costs decline, the success of businesses and organizations relying on batteries hinges on effective management of these critical assets. Central to this is the ability to monitor and assess battery state-of-health (SoH), which has emerged as a vital practice for maximizing performance, safety, and operational efficiency.

Battery state-of-health refers to the overall condition of a battery relative to its original capabilities. SoH will decline as batteries age, but the manner in which they age is a central consideration driven by the type of battery chemistry and the prevalent stress factors over time. By providing accurate SoH data, engineers and operators gain the ability to make informed decisions that protect battery investments, enhance safety protocols, and streamline operations. SoH monitoring enables operators to track the gradual degradation of battery cells, anticipate maintenance needs, and schedule timely replacements before performance falls below acceptable thresholds. This proactive approach minimizes downtime and prevents costly, unexpected failures.

To address the growing need for advanced battery management, Idaho National Laboratory (INL) has developed TELEIOS-BATT — a comprehensive suite of physics-based modeling tools designed to monitor and predict key battery state-of-health metrics throughout the entire lifecycle, from initial deployment to end-of-life. TELEIOS-BATT provides a virtual environment for testing, diagnostics, and prognostics, dramatically reducing the need for extensive physical testing. By quickly surveying battery duty cycle conditions and identifying optimal arrangements, TELEIOS-BATT helps extend battery life and improve reliability.

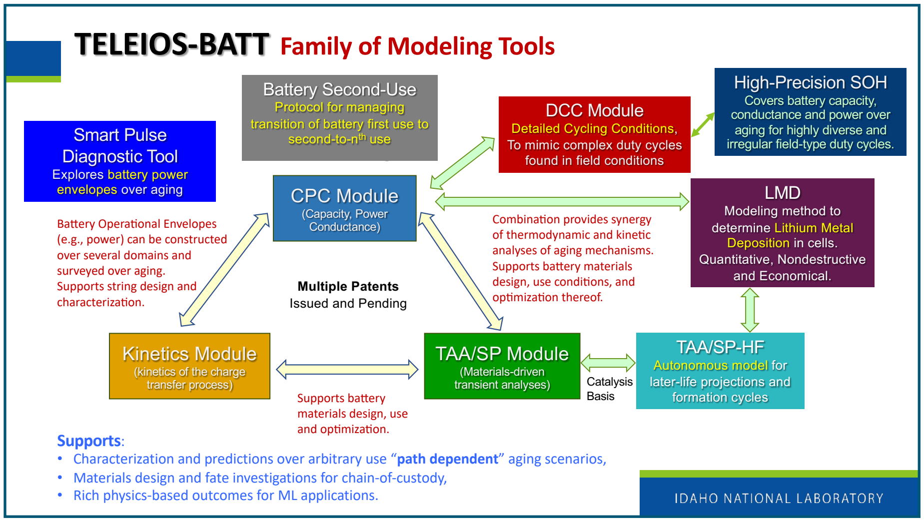

Figure 3: Overview of modeling components that comprise TELEIOS-BATT. Interconnections between modules support multi-physics to be applied to key battery state-of-health topics.

What truly sets TELEIOS-BATT apart is its integration of multi-physics models, covering several scientific disciplines, and incorporation of machine learning (artificial intelligence) where deemed beneficial. These technologies transform raw battery data into actionable intelligence, empowering users to make smarter decisions and supporting the sustainable, reliable operation demanded by modern industry. TELEIOS-BATT's intelligent diagnostics continuously monitor different SoH metrics (capacity, conductance and power), offering quantifiable insights for risk management and helping operators identify patterns of stress or misuse that could compromise safety. With more accurate SoH estimations, operators gain greater control over battery behavior, reliability, and cost efficiency, ultimately maximizing the return on investment. SoH projections enabled by TELEIOS-BATT allow knowledge into battery performance and life far into the future, giving battery operators and end-users a clear lens to plan corrective actions and to see possibilities for matching batteries to diverse applications. TELEIOS-BATT addresses four prime targets:

- Achieve Reliable Diagnostics and Prognostics for Battery Aging Mechanisms,
- Capture Path-dependent Battery Aging, accounting for Changeable Use Conditions,
- Simulate Battery Aging under Complex, Real Field Conditions
- Evaluate Achievable Power along the way.

To achieve these targets TELEIOS-BATT is designed as a multi-technology umbrella, covering critical metrics of battery performance and aging over anticipated service periods, which can extend over years. It tackles the fundamental challenge of predicting battery aging under diverse and realistic field conditions, serving users who develop new battery chemistries, match battery types with real-world applications, and evaluate aging patterns. As a powerful accelerator for benchmarking both new and existing batteries, TELEIOS-BATT enables rapid matching with best-fit applications, benefitting battery developers, end-users, research groups, and those involved with battery second use.

The platform's comprehensive approach includes lifecycle evaluations to verify whether batteries will "fulfill their ultimate purpose" (as per the Greek word TELEIOS) over time for specific applications. TELEIOS-BATT offers a significant advantage in model training: it requires only three to six months of battery life testing to gather sufficient data, compared to the one to two years often needed by conventional predictive tools. This reduction in testing time translates into substantial cost savings and faster deployment of reliable battery solutions.

At the core of TELEIOS-BATT's capabilities is its super-structure of modeling tools, which track essential battery SoH metrics such as the chief quantities of capacity, conductance, and power. These metrics are crucial for understanding both the performance and aging mechanisms of batteries. TELEIOS-BATT's ability to drastically reduce the amount of physical testing required by 50% or more allows users to efficiently benchmark battery use in new or unexplored conditions and quickly identify duty cycles that promote longer battery life.

The TELEIOS-BATT toolset has been validated across a wide range of battery chemistries operating under various duty-cycle conditions. This validation process has demonstrated TELEIOS-BATT's effectiveness in assessing both achievable power and aging mechanisms, providing valuable insights into the relationships between stress factors and aging outcomes for different battery applications.

Ultimately, TELEIOS-BATT addresses the need for intelligent diagnostics that continuously monitor SoH and deliver actionable insights for risk management. By identifying stress or misuse patterns, operators can intervene proactively, enhancing safety and extending operational life. The precision of TELEIOS-BATT's SoH estimation not only increases control over battery reliability and cost efficiency but also ensures that batteries provide maximum value throughout their service life and beyond, for possible second-use applications.

How does the product operate?

Battery health and performance predictions have become increasingly vital as the reliance on energy storage systems grows across industries, from electric vehicles to grid-scale applications. TELEIOS-BATT, a suite of advanced computational modeling tools developed by researchers at Idaho National Laboratory, is at the forefront of this technological evolution, enabling comprehensive battery mission readiness assessments and supporting battery design innovations.

At the core of TELEIOS-BATT's methodology is the employment of a state-of-health "triad" — capacity, conductance, and application power — to evaluate battery aging and performance. These metrics serve as the foundation for understanding how batteries deteriorate over time within their intended applications. TELEIOS-BATT's modeling environment is designed to cover these SOH metrics throughout the battery's lifecycle, thereby providing a holistic, physics-based platform for virtual testing, diagnosis, and prognosis. The simulation suite minimizes reliance on time-consuming and resource-intensive physical testing, using virtual tools to predict battery aging consequences and maintain an aging chain-of-custody.

Central to TELEIOS-BATT's virtual testing capabilities are its materials-driven autonomous models for battery aging, which facilitate improved cell design and rigorous screening and optimization of new materials. The aging simulation framework interprets battery material interactions as catalytic processes at electrode surfaces and as rheological consequences in porous electrode materials. Through materials-driven transient analyses, the TAA/SP Module provides insight into critical physical changes, such as solid-to-electrolyte interphase (SEI) growth and repair, gas formation, changes in porous spaces due to SEI, and particle cracking, for example. This TAA/SP capability also covers the critical "formation" stage, whereupon new electrodes undergo passivation from redox reactions involving the electrolyte.

Figure 4: Lithium Iron Phosphate batteries on test at INL in support of the DOE Rapid Operational Validation Initiative (ROVI). This program seeks to obtain predictions for battery health covering 15 years, based on a single year of testing. This is a perfect target for TELEIOS-BATT tools.

In addition, other modules in the TELEIOS-BATT toolbox help complete its multi-physics holistic mission. The Kinetics Module models the charge transfer process kinetics, thus supporting informed decisions in battery materials design, usage, and operational strategies. The Detailed Cycling Condition (DCC) Module further enhances predictive accuracy by mimicking complex duty cycles encountered in real-world field conditions. The Smart Pulse Diagnostic Tool (SPDT) creates a wealth of information on battery impedance sources and efficiencies due to a wide spectrum of conditions, enabling construction of power envelopes that are seen to shrink with aging. The LMD Module provides a clear path to quantify the amount and coverage of lithium metal deposition that occurs in lithium-ion cells. Lastly, the High-Precision SOH Module covers the critical functions of determining aging path dependence and simulating highly variable duty cycle conditions whose stress factors can change frequently and with arbitrary and diverse time steps. Collectively, these modules enable TELEIOS-BATT to characterize and predict battery performance with the ultimate target of real-world field conditions

The importance of accurate SoH estimation extends beyond mere technical assessment. In practical terms, precise SoH data is crucial for maximizing battery performance, longevity, and safety. Real-time SoH estimation facilitates optimal electrochemical operation, leading to extended service life, improved user satisfaction, and a higher return on investment. Errors in SoH estimation, on the other hand, can result in accelerated degradation, underutilization of available capacity, and increased safety risks. This makes the accuracy and reliability of SoH estimation algorithms indispensable in modern battery management systems.

One of the most immediate benefits of accurate SoH estimation, as enabled by TELEIOS-BATT's modeling tools, is the prevention of overcharging and deep discharging — both of which are significant contributors to rapid battery degradation and safety hazards. Overcharging pushes cell voltage beyond safe limits, risking electrolyte decomposition and thermal runaway, while deep discharging can cause irreversible capacity loss. Achieving SoH with improved accuracy is made possible through SPDT predictions of the polarization impact on voltage that occurs in all battery cells as they operate, but acts to mask their true state of charge (SoC). By providing a physics-based, precise view of available energy over SoC, TELEIOS-BATT's SoH algorithms ensure that charging protocols strictly adhere to safe voltage thresholds and limits. This targeted management extends battery lifespan and minimizes the risk of unexpected failures and safety incidents.

Extreme temperatures, high or low, negatively affect battery performance, capacity, and safety. All batteries experience some level of heating as they operate, and so will have an increase in temperature. Battery thermal management (BTM) sees marked improvement with reliable SoH data, since real-time or predicted battery conductance attributes can advise BTM actions. Insufficient cooling leads to elevated temperatures that promote an accelerated rate of reactivity between the electrolyte and electrode surfaces, resulting in increased aging which reduces usable capacity and heightens the risk of thermal runaway events. Likewise, battery operation at low temperatures creates its own set of problems in terms of greater inefficiency caused by resistance heating, and charging conditions that are more likely to cause lithium metal deposition. The answer to these issues is found in the TELEIOS-BATT SPDT module, which determines the heat evolution and related temperature profile over time as a cell undergoes each specific power condition. This is key information for the BTM to act quickly, effectively, and proactively to maintain the correct parameters for thermal management. Since SPDT also covers the aging impact on heat generation and temperature, then the BTM actions can have a strong proactive foundation. Thus, TELEIOS-BATT's virtual environment will enable the Battery Management System

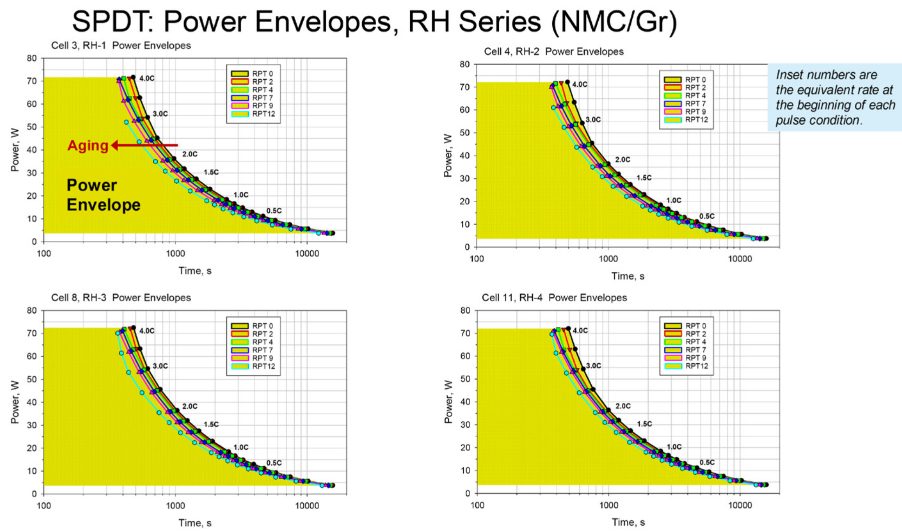

Figure 5: Example of Power Envelopes predicted by the TELEIOS-BATT Smart Pulse Diagnostic Tool (SPDT). Power envelopes shrink over battery aging, and are a critical part of evaluating battery health and performance over time.

(BMS) and its BTM to closely monitor thermal controls based on actual state of charge and load profiles, thereby reducing thermal stress and mitigating risks associated with hot spots and unsafe temperature fluctuations.

Perhaps most notably, these advanced modeling and SoH estimation techniques support predictive maintenance — a proactive approach that leverages real-time degradation data to forecast when a battery or cell may underperform or fail. TELEIOS-BATT's autonomous aging models and simulation modules allow for continuous monitoring of capacity fade and resistance increases. Early anomaly detection (say, in voltage or resistance) facilitates targeted interventions, reducing both system downtime and unnecessary component replacements. By preventing catastrophic failures and minimizing waste, predictive maintenance provides substantial operational and economic benefits.

TELEIOS-BATT employs three complementary approaches for battery performance and life predictions. Chemical physics allows for detailed duty-cycle inputs and immediate diagnostics of aging mechanisms, while chemical physics enhanced with artificial intelligence reduces the need for extensive time-series lab data. The materials-driven autonomous model (TAA/SP) utilizes metadata for cell materials, providing rich outputs for correlating multiple materials factors to battery degradation over multi-year simulations. These strategies collectively result in decreased lifetime testing time, reduced battery pack costs by avoiding over-designed packs, and sophisticated multi-metric SOH diagnostics. With its refined approach, TELEIOS-BATT offers strategies to reduce battery aging by at least 10 to 25% per application, and reduce battery life testing by at least 50%, empowering users with rich diagnostics and actionable insights for battery management and maintenance. Lastly, within the toolset of TELEIOS-BATT is a methodology to help batteries undergo a transition from their first life application to secondary use, further extending battery valuation.

How does the product improve upon competitive products or technologies?

TELEIOS-BATT is built upon the pillars of multi-physics from several disciplines, materials metadata, and the infrastructure to cover detailed battery use conditions unique to each test or application. Multi-physics ensures that the right set of physics-based models are employed to quickly answer specific questions on battery performance and aging outcomes. Battery life predictions often span several years, with extended cases typically covering 5-10 years or more.

Competitive technologies include other modeling tools and extended testing. Competitive modeling technologies do not offer the broad diversity of tools found in TELEIOS-BATT, and some are based more on empirical correlations (rather than rigorous physics) which can lead to non-physical diagnostics and out-of-bounds predictions. In other cases, competitors may have over-parameterized models that require accurate estimates for scores of parameters and take hours to run. Yet, TELEIOS-BATT applies strategic levels of physics needed to quickly answer the complex questions at hand, whether for battery performance or longevity, with most runs from constituent tools taking only seconds to complete. Extended testing as an alternative is expensive and requires a prolonged commitment of hardware and man-hours, whose outcomes would lag far behind TELEIOS-BATT high-fidelity predictions.

Owing to this unique architecture of diagnostic and predictive multi-physics tools, impact of TELEIOS-BATT is found in the drastic reduction of physical testing needed to benchmark battery use within new or unexplored conditions, and to quickly survey a large number of battery duty cycle conditions to find optimal arrangements that yield longer battery life. TELEIOS-BATT requires a minimum of test data to train models while other conventional methods can require many times as much (e.g., 2X-6X). In some cases, we demonstrate that with as little as three weeks of data, TELEIOS-BATT tools can forecast long-term battery capacity aging trends within 1-2% absolute and 5-10% relative error, reducing lengthy lab testing and speeding development. In other cases where multiple, complex battery aging mechanisms are at play, only 3-6 months of battery life testing is required under TELEIOS-BATT, whereas conventional predictive tools can require 12-24+ months.

TELEIOS-BATT covers the premier metrics of battery performance and aging, spanning battery use from new to retired/repurposed. The state-of-health triad of capacity, conductance, and power are tracked over life so that critical performance limitations are identified, which can enable battery stakeholders to take appropriate actions to remove or isolate batteries that no longer meet performance specifications. Using the materials-driven TAA/SP component, all-virtual simulations can be done for battery aging without the need for upfront testing. Likewise, the Smart Pulse Diagnostic Tool takes a single simple pulse, then predicts a rich depth of information on achievable power over a large range of cycling conditions, all the while accounting for complex temperature effects as the batteries undergo ohmic heating. Further, battery aging at arbitrary field conditions, possibly comprising thousands of steps with distinct conditions, can be investigated under the purview of aging path dependence using the High-Precision State-of-Health (SOH) module. These tools are among those unique to TELEIOS-BATT.

Another point of distinction is that the TELEIOS-BATT toolset applies equally to many battery systems, where validation has been achieved over numerous battery chemistries, such as lithium-ion chemistries (NCA, NMC, LFP, LMO, LTO) and sodium-ion cells, operating at various duty-cycle conditions. Added to this is the ability to evaluate aging among interconnected strings of cells, such as when a hot spot accelerates local aging within a series string of lithium-ion cells.

Other considerations:

Physics-Based Accuracy with Patented Modeling. Currently, TELEIOS-BATT is comprised of seven issued patents and five patents pending, with more in the pipeline. This portfolio of intellectual property speaks to the commitment of INL and inventor Dr. Kevin Gering to support industry with battery-relevant tools that create advantages toward planning and managing the battery lifecycle.

Commercial Partnering for Professional-grade Software. INL is partnered with Ridgetop Group Inc. to commercialize selected TELEIOS-BATT scientific software tools invented at INL. This has produced a growing set of software offerings that maintain professional standards of usability.

Provide a matrix demonstrating how key features compare to other products:

Metric	TELEIOS-BATT	Conventional battery lifetime / simulation tools(example: NREL BLAST; MathWorks/ Simulink SOH workflows)	Cloud battery analytics platforms(example: TWAICE, ACCURE)	Electrochemical Impedance Spectroscopy (EIS)	Extended lab / field testing	TELEIOS-BATT advantage
Core approach	Multi-physics, materials-informed, path-dependent battery aging and performance modeling across capacity, conductance, and power; includes modules for detailed cycling, power/ impedance, lithium plating, thermal effects, and high-precision SOH.	Useful model-based workflows exist, but are typically narrower in scope: BLAST focuses on lifetime simulation; MathWorks examples emphasize SOH estimation blocks/filters and resistance/capacity estimation. (NREL)	Primarily operational analytics built on existing BMS/fleet data for safety, degradation, availability, and performance monitoring. (Accure)	Diagnostic measurement technique based on impedance response; rich but usually point-in-time rather than full life simulation by itself. (ScienceDirect)	Ground truth from real hardware under real duty cycles.	TELEIOS-BATT combines diagnostics + prognostics + virtual testing + materials-informed aging physics in one umbrella toolset rather than relying on only estimation, only analytics, or only measurements.
Physical testing burden	Low to medium. TELEIOS-BATT enables up to 50%+ reduction in physical testing and, in some cases, only 3 weeks or 3–6 months of data for useful forecasts depending on complexity.	Medium. Model-based tools still generally require parameterization, calibration, or scenario-specific setup; vendor docs do not show the same breadth of minimal-data claims. (NREL)	Low new lab testing burden, but they depend heavily on deployed BMS/field data being available and sufficiently rich. (Accure)	Medium to high. EIS can be non-destructive, but still requires measurement workflows, instrumentation, and interpretation. (MDPI)	High. Lifetime testing under realistic conditions often takes months to years. (ScienceDirect)	TELEIOS-BATT's value proposition is strongest when long validation campaigns would otherwise dominate time and cost.
Speed to insight	High. Most constituent-tool runs take seconds, enabling rapid scenario sweeps.	Medium. Useful, but often focused on particular estimators or scenario studies rather than fast multi-module diagnostics across many arbitrary duty cycles. (NREL)	High once deployed, but dependent on access to operational data streams and platform integration. (Accure)	Medium. Measurement itself can be fast (minutes to hours), but interpretation and scaling across use cases can be complex. (ScienceDirect)	Low. Real-life or accelerated cycling still takes substantial calendar time. (ScienceDirect)	TELEIOS-BATT is positioned for rapid virtual screening before full hardware campaigns are complete.
Ability to model arbitrary, path-dependent duty cycles	High. Explicitly designed to capture changeable use conditions, thousands of variable steps, and path-dependent aging.	Medium. BLAST supports lifetime simulation and application-specific models; MathWorks supports estimator workflows, but public materials do not show the same emphasis on arbitrary path-dependent field-aging diagnostics. (NREL)	Medium to high. Strong on actual fleet/field behavior already being observed, weaker for fully virtual exploration of new conditions before deployment. (twaice.com)	Low. EIS is informative, but not by itself a broad mission-profile simulator. (ScienceDirect)	Medium. Real duty cycles can be tested, but only slowly and at high cost.	TELEIOS-BATT appears stronger for "what-if" mission design before or alongside field deployment.
SOH coverage	High. Tracks the SOH triad: capacity, conductance, and application power.	Medium. MathWorks examples focus on internal resistance and capacity/ SOH estimation; BLAST focuses on lifetime behavior. (MathWorks)	Medium to high. Platforms track safety, degradation, availability, efficiency, imbalance, and SOH-related KPIs from field data. (Accure)	Medium. Very strong on impedance-related insights; weaker as a standalone full-lifecycle SOH/prognostics stack. (ScienceDirect)	Medium. Strong empirical truth, but usually periodic and not inherently predictive.	TELEIOS-BATT's triad-based framing is broader than single-metric SOH approaches.
Mechanistic aging diagnostics	High. Includes SEI growth/ repair, gas formation, pore-space changes, particle cracking, lithium deposition, thermal behavior, and kinetics.	Medium. Published literature show modeling/estimation capability, but less evidence of the same breadth of mechanistic outputs in a unified suite. (NREL)	Low to medium. Excellent operational analytics, but typically not presented as deep materials-level mechanistic modeling platforms. (Accure)	Medium. Can reveal rich electrochemical signatures, but interpretation is indirect and often expert-dependent. (MDPI)	Medium. Can be combined with teardown/post-mortem work, but at high cost and time.	TELEIOS-BATT is strongest where customers need actionable mechanism-level explanation, not just health flags.
Thermal-management / pack-design support	High. Explicitly positioned to support thermal-management decisions, heat generation, temperature profiles, and hotspot / string effects.	Medium. BLAST includes electrical and thermal performance models for cells, packs, and systems. (NREL)	Medium. Can support operations and alerts, but less clearly aimed at early-stage pack-design optimization. (Accure)	Low. Not a complete design-space exploration tool.	Medium. Possible, but expensive to cover the full design space experimentally.	TELEIOS-BATT is differentiated for design-space exploration under aging-aware thermal constraints.

New chemistry onboarding	High. Data import functionality allows addition of new chemistries to model; validated across multiple Li-ion chemistries and sodium-ion, with relevance to emerging chemistries.	Medium. Possible, but usually needs chemistry-specific model setup and validation. (NREL)	Low to medium. Best after real assets are operating and streaming data.	Low to medium. Requires new measurement campaigns and interpretation.	Low. New chemistry qualification is test-intensive and slow.	TELEIOS-BATT looks especially strong for early-stage R&D and benchmarking of emerging chemistries.
Use before hardware exists / early design phase	High. Supports virtual testing and "all-virtual" materials-driven simulations in some workflows.	Medium to high. BLAST can be used pre-deployment for research questions and scenario analysis. (NREL)	Low. Requires real deployed data. (Accure)	Low. Requires physical cells/hardware.	Low. Requires physical hardware and elapsed time.	TELEIOS-BATT is favorable when customers need to decide before committing to lengthy builds/tests.
Operational safety / predictive maintenance	High. Explicitly positioned for proactive intervention, predictive maintenance, misuse/stress detection, and safety improvement.	Medium. Helpful, but public examples are more estimator/model oriented than fleet-operations workflow oriented. (MathWorks)	High. This is a core strength of ACCURE and TWAICE. (Accure)	Medium. Useful input to diagnostics, not a full operating platform by itself. (jecst.org)	Medium. Can reveal issues, but often too slow or periodic for continuous foresight.	TELEIOS-BATT competes well here, though cloud analytics vendors are strong operational comparators once fleets are deployed.
Relative cost to execute insights	Low to medium total cost by reducing test time/ hardware burden.	Medium. Tool licenses and engineering setup are real, but still often cheaper than exhaustive testing; public pricing generally not available in a comparable way. (NREL)	Medium to high enterprise cost is likely, but vendor pricing is not public; integration and fleet-data readiness matter. (Accure)	Medium. Instrumentation + expert interpretation add cost. (MDPI)	High. Long campaigns, hardware, cyclers, labor, and calendar time. (ScienceDirect)	Best message: TELEIOS-BATT reduces total cost of learning.
Connection to Artificial Intelligence (AI)	High. Outputs from various modules provide a rich source of synthetic data for AI. Extensive list of physical parameters contribute to battery evaluations. Physics basis of modules keeps AI within physical boundaries to avoid nonvalid outcomes.	Medium. Constrained by the range of arbitrary conditions used for simulations. Limited by the modest number of physical parameters that describe battery performance and aging.	Medium to High. Cloud environment would help facilitate accessibility of data by AI tools, yet data volumes may be sparse and incomplete for full AI capabilities.	Low. Typically no direct connectivity to AI. EIS users would need to build data conduits to transfer data into AI architectures.	Medium. Constrained by the speed and volume of data generation, which is directly related to cost.	TELEIOS-BATT is a quick and inexpensive route to generate synthetic data for AI architectures.
Best fit	Battery developers, BMS/ BTM teams, integrators, second-life evaluators, and organizations needing mechanistic prediction under realistic use scenarios.	Teams wanting established modeling/simulation environments or estimator blocks. (NREL)	Operators/OEMs with deployed fleets or BESS assets needing continuous monitoring and alerts. (twaice.com)	Labs needing rich diagnostic signatures. (jecst.org)	Final validation, certification, warranty substantiation, and ground-truthing.	TELEIOS-BATT's sweet spot is bridging R&D, design, diagnostics, and life prediction in one framework.

What are the limitations of the product/service?

While TELEIOS-BATT represents a significant advancement in battery health and performance prediction, it is not without limitations. An architecture of accurate physical models depends on accurate physical inputs, so the quality and granularity of the material metadata, operational profiles, and historical aging data are important considerations. If these inputs do not fully capture the diversity of real-world conditions or material behaviors, the resulting simulations may not accurately reflect actual battery performance or degradation pathways. If there are uncertainties in key inputs, then multiple sources are sought to arrive at a consensus, and multiple simulations can be performed that span the range of parameters for later comparisons.

Another limitation may arise in the context of secondary use and battery repurposing. While TELEIOS-BATT offers methodologies to support transitions from first life to secondary applications, the heterogeneity in aging histories and the unpredictable nature of second-life usage can challenge the model's assumptions and forecast accuracy. For transition from first-to-second battery life, the TELEIOS-BATT architecture needs reasonable accounting for the first life conditions of duty cycle protocols and environmental conditions. This helps to set the battery state of health at the end of first life and beginning of second life. Additionally, the suite's dependence on autonomous aging models and AI-enhanced diagnostics means that rare failure modes or emerging chemistries may not be fully captured without ongoing updates and retraining of algorithms. As battery materials and related technology evolves, TELEIOS-BATT will require updated training to remain applicable and accurate, an anticipated consequence.

Finally, while TELEIOS-BATT minimizes the need for time-consuming physical testing, it does not fully eliminate the necessity for periodic validation. As is currently done, simulation results are corroborated with real-world measurements (when available) to ensure continued fidelity and relevance, particularly as new materials and cell designs are encountered. The advantage of TELEIOS-BATT is that less data is needed for this training and validation process (as seen in the Smart Pulse Diagnostic Tool). Thus, the effectiveness of TELEIOS-BATT is linked to the quality of its metadata inputs, rendering of operational profiles (duty cycles), and retuning to new materials and empirical data as they become available. These are seen as routine and acceptable conditions for application of physics-based models to new targets.