Section 1. Opportunity Description

The Intelligence Advanced Research Projects Activity (IARPA) often selects its research efforts through the Broad Agency Announcement (BAA) process. The use of a BAA solicitation allows a wide range of innovative ideas and concepts. The BAA will appear on https://beta.sam.gov/and will be linked from the IARPA website at https://www.iarpa.gov/. The following information is for those wishing to respond to this Program BAA.

This BAA (IARPA-BAA-20-02) is for the Robust Energy Sources for Intelligence Logistics in Extreme Novel and Challenging Environments (RESILIENCE) program. IARPA is seeking innovative power solutions to support Intelligence Community (IC) applications. RESILIENCE is envisioned to be a 3-year, 9-month effort, beginning approximately January 2021 and extending through October 2024.

Reliable sources of power are a key enabler for many intelligence missions. The IC has some portable power needs that are similar to those of any other large enterprise; for example, to support its mobile workforce by providing power for handheld and other mobile devices. However, the IC also has mission needs for power that are far more challenging than those of the private sector to enable intelligence missions, such as powering unmanned robots or vehicles that keep IC personnel out of harm's way or powering sensors and electronics that are in extreme environments where they must function unattended for long periods of time. For some IC applications, quiet operation and minimal generation of heat are preferred. Collectively, the IC's needs for power present an extremely challenging set of requirements to power solutions experts: unyielding volume and mass limitations, unobtrusive operation, maximum lifetime and reliability, and operation in extreme environments.

Consider, for example, the case of Unmanned Aerial Vehicles (UAVs), which need both maximum flight times and very high power bursts for Vertical Takeoff and Landing (VTOL) and to hover in place. Moreover, their power solutions must meet strict volume and weight constraints. Compared to UAVs for commercial applications such as package delivery, RESILIENCE will focus on powering UAVs that have longer flight ranges, longer flight times, quieter operation, and optimized performance under a wider variety of environmental conditions.

Consider, as a second example, unattended sensors that may lie dormant for many months, but may need to provide occasional bursts of power on demand. Such sensors may be subjected to extreme environmental conditions (temperature and humidity) and must have a calendar life of up to two years.

Developing novel power solutions for these two example applications, UAVs and unattended sensors, is the subject of the RESILIENCE program. Objectives of the RESILIENCE program include power solutions with high energy density, high power density, long calendar life, quiet operation, and robustness to extreme environmental conditions such as large temperature fluctuations, vibration, shock, overcharge and complete discharge. Detailed information about specific goals, objectives, metrics and milestones can be found in this BAA.

The RESILIENCE program will be structured as three phases. Phase 1 will be a 15-month phase culminating in a proof-of-concept power solution that is self-contained, but not necessarily fully packaged. Phase I deliverables will include test articles of the self-contained power solution, as well as design documents and modeling and/or other calculations. Together, these deliverables shall demonstrate that the materials within each delivered power solution, when packaged, can be expected to meet all Phase 1 metrics. Phase 2 will be an 18-month phase culminating in a packaged power solution. “Packaged” means that the mass and volume of any equipment needed for power solution operation (e.g., compression, insulation, or gas conditioning equipment) will be included in the calculation of energy density and power density from measurements of energy output made during testing and evaluation. Phase 3 will be a 12-month phase culminating in a final demonstration of a prototype power solution capable of meeting all the program metrics.

Section II. Technical Approaches

For both the UAV application and the unattended sensor application, suitable power solutions will need to have the following properties:

- High specific energy and energy density;
- Long lifetime; and
- High pulsed power response.

In the case of UAVs, long lifetime means the ability to power a flight of several hours’ duration. In the case of unattended sensors, long lifetime means long calendar life; that is, the power solution must operate for up to two years.

Power solutions that may prove suitable for these two example applications could include batteries (primary or secondary cells), fuel cells, supercapacitors, or other solutions that convert some form of energy to electricity. To achieve the goals and metrics of the program (detailed in Sections III.A and IV of this BAA, respectively), RESILIENCE will leverage recent and emerging technologies in materials science, surface and interface science, component fabrication, and manufacturing to yield power solutions with unprecedented performance.

A. Materials Science

Solutions may leverage novel materials to maximize the energy density of active material and the efficiency of the reactions that lead to generation of electricity. Innovations in 3D structured materials, self-assembled materials, nanomaterials, nanoporous materials, gels, polymers, solid state electrolytes, coatings, foams, catalysts, adhesives, grain boundary engineering, proton exchange membranes, and other materials technologies may contribute to novel power solutions that will deliver the performance required to meet the RESILIENCE program metrics. Chemical stability and mechanical integrity are also key to robustness under the challenging environments in which RESILIENCE power solutions will operate.

B. Surface and Interface Science

Interactions at surfaces and transport of ions across interfaces are essential to most power solutions, but unwanted surface and interface phenomena and reactions must be avoided. Efficiency of power generation can be reduced by the formation of passivation layers, poisoning of catalysts or nucleation phenomena resulting in dendritic structures, for example. These unwanted surface and interface reactions may contribute to safety problems in power solutions as well. Innovative ways to engineer surfaces to increase diffusion rates, to support anodic and cathodic reactions and decrease the rate of dendrite formation or the formation of passivating films may result in improved power solution designs with a higher energy density and greater longevity under heat stress.

C. Component Engineering and Manufacturing

To meet the size and weight constraints of RESILIENCE power solutions, innovative engineering and manufacturing methods will be required. For example, technical means to maximize interfacial surface areas could be used to enhance ion transfer rates at constant mass of material to deliver higher power density. Likewise, new fabrication techniques to optimize catalyst, or crystalline material orientation on a surface can greatly increase catalyst turnover rates and/or ionic conductivity rates, and therefore power density.

Section III. Program Description and Structure

A. Program Goals

The RESILIENCE program will pursue two research tracks that correspond respectively to the UAV application (Track 1) and the unattended sensor application (Track 2) described above. Offerors may propose to a single track, to both tracks separately, or to both tracks with a single power solution. Performers who propose to both tracks shall be required to submit test articles in the numbers specified in Section III.E. Testing & Evaluation to support separate testing and evaluation (T&E) for each track.

The overall goals of the two tracks are as follows.

Track 1: High Power Density, High Energy Density Power Solutions

Track 1 aims to demonstrate the following improvements in power solutions over state-of-the-art:

1. Substantially higher energy density;
2. Capability to sustain power bursts for up to a minute at both the beginning and near the end of the power solution's discharge profile;
3. Capability to sustain operation on demand over a temperature range from -20°C to +60°C with no advance preparation;

4. Minimal heat generation during operation; and
5. Quiet operation.

Track 2: Long Calendar Life Unattended Power Solutions

Track 2 aims to demonstrate the following power solution improvements over state-of-the-art:

1. Substantially longer calendar life (ability to hold a single charge) during storage at -20 to +60˚C;
2. Capability to sustain ten cycles without significant irreversible capacity loss following storage for up to two years;
3. Substantially higher energy density;
4. Capability to sustain periodic, on-demand high power pulses of five second duration;
5. Minimal heat generation during operation; and
6. Quiet operation.

Both Track 1 and Track 2 power solutions must meet strict mass and volume constraints, as well as other metrics described in Section IV. Program Metrics.

B. Program Structure

The RESILIENCE program will proceed in three phases as follows.

Phase 1 (15 months) Proof of Concept

The objective of Phase 1 is to demonstrate new materials and concepts for power solutions that meet the Track 1 and Track 2 performance metrics shown in Section IV of this BAA. Because they are not required to be packaged, deliverables for Phase 1 need not meet the mass and volume requirements for the Track 1 or Track 2 example applications directly. For Phase 1, demonstration deliverables must be self-contained, with a single positive connection and a single negative connection that will allow IARPA to perform independent testing and evaluation (T&E) to measure performance of each delivered power solution. Examples of appropriate form factors would be coin cells or button cells in the case of batteries, or a breadboard-mounted apparatus in the case of fuel cells or other power solutions. The form factor for the Phase 1 deliverable shall be specified in the Offeror's Proposal.

In addition to delivering power solutions for T&E, Performers must deliver design documents and modeling and/or other calculations to demonstrate that the materials within each delivered power solution, when packaged, can be expected to meet all Phase 1 metrics. As a representative example, if the Offeror has researched a new battery cathode material and electrolyte for Track 1, a successful Phase 1 deliverable could comprise 1) a coin cell, 2) a description of the mass and volume of the cathode, anode and electrolyte contained within, and 3) a mathematical model describing how the new cathode and electrolyte's measured performance would be used in a pouch cell that would meet all of the performance metrics for Phase 1 when packaged.

At the conclusion of Phase 1, Performers must also make a compelling argument, supported by data and modeling, that their Phase 1 proof of concept and future design approach will meet Phase 3 metrics by the end of the program.

Phase 2 (18 months) Packaged Power Solution.

In Phase 2, Performers will improve upon materials and design to optimize performance of their power solutions. Deliverables for Phase 2 must be fully packaged. As stated in Section I, "packaged" means that the mass and volume of any equipment needed for power solution operation (e.g., compression, insulation, or gas conditioning equipment) will be included in energy density and power density measurements to demonstrate achievement of metrics. Performers will also deliver a systems evaluation of their design, including a clear description of how the design will scale to the prototype required for Phase 3 of the program.

Phase 3 (12 months) Prototype.

In Phase 3, Performers will refine their power solutions to meet Phase 3 metrics, with additional materials development, improved component assembly, and mitigation of risks of failure over time.

C. Team Expertise

IARPA anticipates that Offeror teams may include, but are not limited to, expertise in the following technical areas. Expertise in all these disciplines is not a selection criterion.

- Materials science or chemistry
- Mechanical engineering
- Condensed matter physics
- Polymer science
- Ceramics
- Process engineering
- 3D printing
- Electrochemistry
- Electrical Engineering
- Corrosion
- Theoretical chemistry and modelling
- Systems Engineering

D. Out-of-Scope Research Areas

The following areas of research are out of scope for the RESILIENCE program:

- Partial solutions that cannot be independently tested and evaluated against program metrics.
- Solutions that employ radioactive materials.
- Research that does not have strong theoretical and experimental foundations or plausible scientific support for the Offeror's claims.
- Approaches that propose, or are likely to result in, only incremental improvements over the current state-of-the-art.
- Approaches that cannot be packaged for safety.
- Approaches that are incompatible with remote, unattended operation.
- Approaches with significant limitations on operating conditions or operational parameters.
- Development of component technology that is not required for the Offeror's approach.
- Solutions that contain arsenic.
- Solutions consisting of internal combustion engines.
- Solutions that cannot be made sufficiently robust for field use.

E. Testing and Evaluation (T&E)

All deliverables will be subjected to independent, objective T&E. T&E will verify progress toward achieving program objectives at defined points during the program. Achievement of program metrics at these defined points may be a condition for continued participation in the RESILIENCE program.

Power solution deliverables will be tested as received and must contain only one positive and one negative connection suitable for attachment to testing equipment. Power solutions must deliver power immediately upon electric load application without any startup time. Performers must provide the estimated maximum capacity (given in Ampere-hours, hereafter referred to as Ah) at either a C/3 Rate (for Track 1, first discharge) or C/4 Rate (for Track 2, for the first tested discharge after pre-conditioning). These estimated capacities should be provided at both 25°C and 0°C. Performers must provide an estimated open circuit voltage (no load potential), nominal operating voltage, and cut-off voltage appropriate for each test article.

There will be a round of T&E in each of Phases 1 and 3 of the RESILIENCE program as shown in the Program Milestone, Deliverables and Testing Schedule in Table 3 in Section V of this BAA. Phase 2 will have two rounds of T&E as described in the schedule.

The following is a notional description of testing protocols planned for the RESILIENCE program. Final testing protocols will be provided at program kickoff. Performers are expected to conduct their own T&E of their power solutions continually throughout the program to measure progress toward achieving program metrics. Proposals shall describe how the Offeror plans to conduct their own T&E in preparation for the independent Government T&E of deliverables described below.

Offerors may expect up to three months of time after power solutions are delivered before independent Government results are available. Performers will be responsible for transportation of deliverables to designated T&E sites in compliance with all applicable laws and regulations.

Track 1 Testing

For Track 1, each Performer shall deliver 15 power solution test articles (hereafter referred to as "test articles") for each round of T&E, for a total of 60 over the three Phases of the program. There will be one round of T&E in Phases 1 and 3, and two rounds of T&E in Phase 2 as shown in the Program Milestone, Deliverables and Testing Schedule in Table 3 in Section V of this BAA.

In each T&E round, the 15 delivered test articles will be divided into three cohorts of five each and tested against the performance metrics listed in Table 1 in Section IV of this BAA. If there are testing considerations specific to an Offeror's solution that may be incompatible with the notional testing protocols described herein, these must be described in the Offeror's proposal. Electrical discharge and temperature will be recorded for each power solution tested. Temperature will be measured by a sensor attached to the test article in a position chosen by the T&E team at their sole discretion. One cohort of five test articles will be used in each of the following tests. Because Phase 1 deliverables are not packaged, for the purposes of Phase 1 power solution testing Performers must supply a model that includes equations into which measured discharge data shall be input to demonstrate that the power and energy metrics for Phase 1 will be met. Further description concerning Phase 1 metrics calculation may be found in Section III.B. Program Structure.

Test 1.1: Specific Energy and Energy Density at 25˚C. To determine the power solution's specific energy and energy density, each test article will be weighed, and its volume will be determined. Then, the test article will be stored at 25˚C until it reaches thermal equilibrium. Each test article will be discharged at a current calculated from its Performer-estimated maximum capacity (given in Ah) at 25˚C when the test article is discharged at its C/3 Rate. The test will conclude when the test article discharge current can no longer be reached for 5 seconds or the Performer-estimated cut-off voltage is not maintained for 5 seconds. Specific energy and energy density will be calculated based upon each test article's discharge current and voltage integrated over time, and its mass or volume. The median result of these tests will be compared against target values in Table 1 in Section IV of this BAA.

Test 1.2: Specific Energy and Energy Density at 0˚C. To determine the power solution's specific energy and energy density, Test 1.1 will be repeated, except that a testing temperature of 0˚C and Performer-estimated capacities at 0˚C will be used. The median specific energy and energy density result of these tests will be compared against target values in Table 1 in Section IV of this BAA.

<u>Test 1.3:</u> Pulsed Power. To determine the power solution's ability to discharge pulses of power at different capacities, each test article will be weighed, and its volume will be determined. Then, the test article will be stored at 25°C until it reaches thermal equilibrium. Each test article will be discharged at a current calculated from its Performer-estimated maximum capacity (given in Ah) at 25°C when the test article is discharged at its C/3 Rate. When the power solution reaches 99% and then 20% of its maximum capacity, the discharge will be increased to a 5/3C Rate for ten seconds (for Phase 1) or one minute (for Phases 2 and 3). At all other times, discharge current will be at its C/3 Rate. The test will conclude when the test article discharge current can no longer be reached for 5 seconds or the Performer-estimated cut-off voltage is not maintained for 5 seconds. Specific power and power density will be calculated continuously for each test article's measured mass, volume, current and voltage and compared with target metrics for specific power and power density at the C/3 and 5/3C discharge Rates provided in Table 1 in Section IV of this BAA). Test article specific energy and energy density will also be calculated using data measured during the full discharge profile. There are no specified target metrics for specific energy and energy density to be calculated from data collected during this test. Consistent with the overall goal of the program, high specific energy and energy density are objectives.

Track 2 Testing

For Track 2, each Performer shall deliver 20 power solution test articles for each round of T&E, for a total of 80 over the three Phases of the program. There will be one round of T&E in each of Phases 1 and 3, and two rounds of T&E in Phase 2 as shown in the Program Schedule in Table 3 in Section V of this BAA.

Track 2 testing will involve a "pre-conditioning" step prior to testing. Upon receipt, each test article will be weighed, and its volume will be determined. Then, the test article will be stored at 25°C until it reaches thermal equilibrium. Proposals must include a suggested protocol for recharging or refueling, for the purposes of determination of appropriate T&E pre-conditioning and cycle testing procedures. Generally, each power source will be cycled three times, with a pause at the completion of each cycle to assure that the power solution reaches thermal equilibrium before commencing the next cycle. Discharge current for each pre-conditioning cycle will be based upon its Performer-estimated maximum capacity (given in Ah) at 25°C at its C/4 Rate. A power source will be considered depleted during each cycle when the discharge current can no longer be reached for 5 seconds or the Performer-estimated cut-off voltage is not maintained for 5 seconds. The pre-conditioning step will conclude by energizing test articles to their maximum capacity.

Following pre-conditioning in each T&E round, the 20 delivered test articles will be divided into four cohorts of five test articles each and tested against the performance metrics shown in Table 2 in Section IV of this BAA. Cycling data and temperature will be measured for each delivered test article during each test. Temperature will be measured by a sensor attached to the test article in a position chosen by the T&E team in their sole discretion.

One cohort will be assigned to each of the four tests below. For all four tests, the test articles will be cycled ten (10) times as described in tests 2.1-2.4. Because Phase 1 deliverables are not packaged, for the purposes of Phase 1 testing, Performers must supply a model that includes equations into which measured discharge data shall be input to demonstrate that the power and energy metrics for Phase 1 will be met. Further description concerning Phase 1 metrics calculation may be found in Section III.B. Program Structure.

<u>Test 2.1</u>: Specific Energy and Energy Density at 25˚C. To determine the power solution's specific energy and energy densities, each test article will be weighed, and its volume will be determined. Then, the test article will be stored at 25˚C until it reaches thermal equilibrium. Each test article will be discharged at a current based upon its Performer-estimated maximum capacity (given in Ah) at 25˚C at its C/4 Rate.[1] The bottom of each tested cycle will conclude when the test article discharge current can no longer be reached for 5 seconds or the Performer-estimated cut-off voltage is not maintained for 5 seconds. Test article specific energy and energy density will be calculated using its measured discharge current and voltage integrated over time, and its measured mass or volume. The median specific energy and energy density values will be compared with the targets in Table 2 in Section IV of this BAA. All test articles will be cycled a total of times using this procedure, and their specific energy and energy density will be calculated for each cycle. There are no specified target metrics for specific energy or energy density calculated from the final nine test cycles. Consistent with the overall goal of the program, low capacity fade is an objective.

<u>Test 2.2</u>: Specific Energy and Energy Density at 25˚C following high temperature storage. Following storage at up to 60˚C for up to three months, Test 2.1 procedures will be conducted at 25˚C. The specific energy and energy densities of the five test articles here will be calculated. The median specific energy and energy densities calculated during the first discharge in Test 2.1 will be compared against those from this test to calculate the percent capacity loss after storage. This percent capacity loss will be compared against the target values in Table 2 in Section IV of this BAA. There are no specified target metrics for specific energy or energy density calculated from the final nine test cycles. Consistent with the overall goal of the program, low capacity fade is an objective.

<u>Test 2.3</u>: Pulsed Power. To determine the power solution's ability to discharge pulses of power at different capacities after storage at high temperature, each test article will be weighed, its volume will be determined, and test articles will be stored at up to 60˚C for up to three months. Following storage, each test article will be brought to thermal equilibrium at 25˚C, and then discharged at the

[1] The T&E partner may change the discharge current for the test if the Performer-estimated maximum capacity for any given test article and the measured maximum capacity from its pre-conditioning step are dissimilar.

current calculated from its Performer-estimated maximum capacity (given in Ah) at 25˚C at its C/4 Rate.[1] When each test article reaches 90, 80, 70, 60, 50, 40, 30, 20 and 10% of its maximum capacity, it will be discharged for five seconds at an elevated current matching its 1C Rate. For all other points during discharge, the current calculated at its C/4 Rate will be used. Discharge testing will conclude for each cycle when the test article has completed its elevated discharge at 10% capacity and can no longer discharge at the current calculated at its C/4 Rate for 5 seconds or the Performer-estimated cut-off voltage is not maintained for 5 seconds. Maximum capacity for each test article will be estimated using the median specific energy result from Test 2.2. Specific power and power density will be calculated continuously from the test article's current, voltage and mass or volume and compared with the target metrics listed in Table 2 in Section IV of this BAA. Test articles will be cycled nine more times using the same procedure, and their specific power and power density will be calculated continuously throughout each discharge. Specific energy and energy density for the full discharge profile will also be calculated as a part of the test. There are no specified target metrics for the final nine test cycles, but consistent with the program goal, the ability to maintain specific power and power density at both discharge rates, and low capacity fade over all 10 tested cycles are objectives.

<u>Test 2.4</u>: Specific energy and energy density at 0˚C following high temperature storage. Following storage at up to 60˚C for up to three months, Test 2.1 procedures will be conducted at 0˚C. The median specific energy and energy density result calculated from these test articles will be compared against the target values in Table 2 in Section IV of this BAA. There are no specified target metrics for specific energy and energy densities calculated from the final nine cycles of this test, but consistent with the program goal, low capacity fade over the 10 tested cycles is an objective.

Section IV. Program Metrics

IARPA research programs include rigorous evaluations using carefully designed technical performance metrics. Performance against the metrics is used to inform decision-making in IARPA research programs; for example, the exercise of options to continue performance under research contracts may be based in large part on achievement of program metrics. IARPA has defined program metrics to evaluate effectiveness of the proposed solutions in achieving the stated program goal and objectives, and to determine whether satisfactory progress is being made to warrant continued funding of the Performers. The metrics described in this BAA are shared with the intent to bound the scope of the effort, while affording Offerors maximum flexibility, creativity, and innovation in proposing solutions to the stated problem. Proposals with a plan to exceed the defined metrics in one or more categories are desirable, provided that all of the other metrics are met, and that the proposals provide clear justification as to why the proposed approach will be able to meet or exceed the enhanced metric(s). Program metrics may be refined during the various phases of the RESILIENCE program; if metrics change, revised metrics will be communicated to Performers as quickly as possible.

Track 1: High Power Density, High Energy Density Power Solutions

Metrics for Track 1 are shown in Table 1. While Track 1 is aimed at powering VTOL UAVs, the metrics have not been set with any particular aircraft in mind. Rather, the metrics represent aggressive performance objectives applicable to multiple mission-critical power requirements. In addition to energy and power performance characteristics, the metrics include a cost target in order to drive Offerors to propose solutions that will be accessible broadly for government and commercial applications.

Table 1: Technical metrics for Track 1. High Power Density, High Energy Density Power Solutions.

Performance Parameter Track 1	Phase 1: Proof-of-Concept Power Solution[2]	Phase 2: Packaged Power Solution	Phase 3: Prototype Power Solution
Specific Energy and Energy Density when discharged at the C/3 Rate Tested at 25°C	600 Wh/kg 1080 Wh/L	650 Wh/kg 1170 Wh/L	750 Wh/kg 1350 Wh/L
Specific Power and Power Density when discharged at the C/3 Rate Tested at 25°C	200 W/kg 360 W/L	220 W/kg 390 W/L	250 W/kg 450 W/L
Specific Power and Power Density at 99% and 20% capacity when	1000 W/kg,10 sec. 1800 W/L,10 sec.	1080 W/kg for 1min 1950 W/L for 1 min	1250 W/kg for 1 min 2250 W/L for 1 min

[2] Target performance parameters for Phase 1 will be calculated from measured parameters. See the explanation provided in Section III.B Testing and Evaluation.

Performance Parameter Track 1	Phase 1: Proof-of-Concept Power Solution[2]	Phase 2: Packaged Power Solution	Phase 3: Prototype Power Solution
discharged at the 5/3C Rate Tested at 25˚C			
Specific Energy and Energy Density when discharged at the C/3 Rate Tested at 0˚C	420 Wh/kg 755 Wh/L	455 Wh/kg 820 Wh/L	525 Wh/kg 945 Wh/L
Specific Power and Power Density when discharged at the C/3 Rate Tested at 0˚C	140 W/kg 250 W/L	150 W/kg 270 W/L	175 W/kg 315 W/L
Maximum Mass and Volume	N/A	5kg and 2.5L, respectively	
Maximum Unit Temp during operation	120˚C		
Cost	<$20,000/kWh Stored		

Track 2: Long Calendar Life Unattended Power Solutions

Metrics for Track 2 are shown in Table 2. While Track 2 is aimed at powering unattended sensors, the metrics have not been set with any particular sensor or deployment environment in mind. Rather, the metrics represent aggressive performance objectives, achievement of which will satisfy multiple sensors and environments. In addition to energy and power performance characteristics, the metrics include a cost target in order to drive Offerors to propose solutions that will be accessible broadly for government and commercial applications.

Table 2: Technical metrics* for Track 2. Long Calendar Life Unattended Power Solutions.

Performance Parameter Track 2	Phase 1: Proof of Concept Power Solution[2]	Phase 2: Packaged Power Solution	Phase 3: Prototype Power Solution
Capacity loss following storage Tested at 25°C (simulated)	<4% / month	<1% / month	<0.5% / month
Required number of discharge/recharge cycles	3 Conditioning cycles, followed by 10 Tested Cycles		
Specific Energy and Energy Density when discharged at the C/4 Rate Tested at 25˚C	400 Wh/kg 720 Wh/L	450 Wh/kg 810 Wh/L	500 Wh/kg 900 Wh/L
Specific Power and Power Density, when discharged at the C/4 Rate Tested at 25˚C	100 W/kg 180 W/L	115 W/kg 200 W/L	125 W/kg 225 W/L
Specific Power and Power Density, when discharged at the 1C Rate Tested for 5 Seconds at 25˚C	400 W/kg 720 W/L	450 W/kg 810 W/L	500 W/kg 900 W/L
Specific Energy and Energy Density when	280 Wh/kg 500 Wh/L	315 Wh/kg 570 Wh/L	350 Wh/kg 630 Wh/L

Performance Parameter Track 2	Phase 1: Proof of Concept Power Solution[2]	Phase 2: Packaged Power Solution	Phase 3: Prototype Power Solution
discharged at the C/4 Rate Tested at 0°C			
Specific Power and Power Density, when discharged at C/4 Rate Tested at 0°C	70 W/kg 125 W/L	80 W/kg 140 W/L	90 W/kg 160 W/L
Maximum Mass and Volume	N/A	50g and 30mL, respectively	
Maximum Temp during operation	120°C		
Cost	<$80,000/kWh Stored		

* All listed metrics in this table will be measured during the first discharge cycle out of the 10 tested cycles.

Section V. Program Schedule and Deliverables

This section describes the program schedule, including Waypoints, Deliverables and Milestones.

A. Waypoints

Waypoints are Government- and Offeror-defined, task-driven intermediate steps toward achieving the program objectives. Waypoints are measurable accomplishments reflected in the work plan and depicted on the schedule. They are typically traceable to the metrics. Waypoints provide additional insight into the development of the key aspects of the proposed research beyond the measurement of deliverable performance metrics. They assist the program management team to provide guidance and assistance to Performer teams. The waypoints will also be used by the Program Manager (PM) to assess the need for any course correction during the program. Program waypoints may be refined during the various Phases of the program; if waypoints and milestones change, these will be communicated to Performers as quickly as possible.

Offeror's proposed technical and programmatic waypoints shall be included in the Offeror's proposal. For each proposed waypoint, the proposal shall describe the waypoint, its relationship to program tasks(s) and metrics, criteria for successful achievement of the waypoint, and the date by which the waypoint shall have been achieved. It is preferred that this waypoint information be conveyed in tabular format.

B. Deliverables

A description of the program deliverables follows.

Power Solution Test Article Deliverables

Performers shall provide power solution test article deliverables as described in Section III.E. Testing & Evaluation (T&E) and shown in the program schedule in Table 3 in Section V.C. Program Milestone, Deliverables and Testing Timeline. Performers shall also provide documentation to the Government proving the safe shipment of their test articles to the T&E site.

Power Solution Model Deliverables

Performers shall provide design documents and modeling and/or other calculations to demonstrate that their power solutions can be expected to meet the program metrics for the Phase in which they are due. Models shall also support the Performer's ability to meet Phase 3 metrics by the end of the program.

Technical Reporting

Performers shall provide monthly technical reports no later than 10 days after the first of each month. The technical reports shall include data presented at monthly technical review meetings and will serve as background material for discussion at subsequent meetings. Both the results presented at technical review meetings and technical reports will serve as an official record of progress. Technical reports shall include the results of internal performance tests as follows. Performers are expected to evaluate their power solutions continually throughout the program to measure progress toward achieving program metrics. Internal performance testing shall be a subset of the test protocols described in Section III.D. The results of internal performance testing shall be included in the Monthly Technical Reports, as internal performance testing is completed, no less frequently than every six months throughout program performance. The first Monthly Technical Report shall contain a description of the Performer's testing methodology for internal performance testing. The Performer and the PM shall agree on the Performer's testing methodology not later than the 3rd month after program kickoff, with the first internal testing to be completed not later than the 6th month of the program.

Technical Review Meetings

Performers shall support monthly technical review meetings in person at the Performer's site (see Site Visits below) or remotely (e.g., by means of telephone, Skype, WebEx, video conference or otherwise, at the discretion of the PM). During these monthly technical review meetings, Performers will present their results, describe their progress toward waypoints and achievement of performance metrics, and identify any issues that may affect their ability to meet metrics, milestones, or overall program objectives.

Site Visits

Once or twice per calendar year, the RESILIENCE program management team and invited representatives of Government agencies will visit each Performer at their work site to conduct an in-depth review of progress toward program objectives and to meet with team members. Performers shall host these site visits at the sites where research for the RESILIENCE program is being performed. During site visits, Performers will show their physical capabilities, and introduce the researchers working on the program to the program management team and invited Government representatives. The site visit shall be concurrent with the technical review meeting to be held in the same month.

Kickoff and Program Wide Review Meetings

Kickoff and program wide review meetings shall be held at a location to be determined by the PM, typically in the Washington, D.C. metropolitan area, where Performers shall share non-proprietary information and/or updates with the other Performers. Typically program-wide review meetings, also known as Principal Investigator (PI) Meetings, will also include breakout sessions for each team to meet individually with the PM, the program management team and the T&E team. At these breakout sessions, any results the Performers assert are proprietary shall be discussed. Performers shall plan to send no more than 2-3 key technical personal to the program wide review meetings, unless otherwise agreed with the PM. Unless otherwise specified in the program schedule or by the PM, kickoff and program wide review meetings are in addition to the monthly technical review meetings.

Financial Reporting

Performers shall provide monthly status reports (MSRs) not later than ten days after the first of each month. The MSRs shall summarize budget and spending and identify any financial issues that may affect the program or put achievement of program objectives at risk.

C. Program Milestone, Deliverables and Testing Timeline

The RESILIENCE program will follow the timeline in Table 3. Table 3 shows milestones, deliverables dates, testing dates, and dates for program review meetings, including site visits.

Table 3: Program Milestone, Deliverables and Testing Schedule.

Event	Months after Kick-off			Deliverables
	Phase I	Phase II	Phase III	
Kickoff Meeting (Beginning of each Phase)	1	16	34	Read-ahead package due from Performers to the Government 7 days before meeting. If required by the PM, updates after the meeting are due 15 days after the meeting date.
Program Wide Review Meeting	12	27	41	Read-ahead package due from Performers to the Government 7 days before meeting. If required by the PM, updates after the meeting are due 15 days the meeting date.
Technical Review Meetings	Monthly	Monthly	Monthly	Read-ahead package due from Performer to the Government 2 days before meeting. If required by the PM, updates after the meeting are due 15 days after the meeting date.
Site Visits	3, 9	19, 24, 30	37, 45	Site visits (to be held concurrently with Technical Review Meetings)
Power Solution Test Article Deliverables	12	21, 30	42	Power solutions delivered by Performer for T&E. Deliverable shall be received at the T&E site specified by the Government no later than the final day of the listed month. Performers shall also provide documentation to the Government proving the safe shipment of their deliverables to the T&E site.
Power Solution Model Deliverables	14	23, 32	44	Power solutions model delivered by Performer for T&E. Deliverable shall be received at the T&E site by the Government no later than the final day of the listed month.

Event	Months after Kick-off			Deliverables
	Phase I	Phase II	Phase III	
Independent T&E	12-15	21-24, 30-33	42-45	Upon receipt of the Performer Test Article Deliverables, T&E will be conducted. Performers may expect test results within three months of test article submission, but no later than the last day of the listed range of months.
Financial and Technical Reports	Monthly	Monthly	Monthly	Monthly financial and technical reports are due by the 10th day of the following month.
End of Phase	15	33	45	Phase Period of Performance Ends

D. Meeting and Travel Requirements

Performers are expected to assume responsibility for administration of their projects and to comply with contractual and program requirements for reporting, delivery of power solutions for testing, and attendance at program meetings, either at their research facility or at another location to be determined by the PM. Table 3 describes expectations for meetings and travel for the RESILIENCE program. Section V.B. Deliverables describes locations where meetings are to be held as well as the contemplated frequency and locations of such meetings. In addition to ensuring that all required deliverables are made on time, each Performer will be required to be available to the T&E team for questions and troubleshooting during monthly status meetings.

E. Place of Performance

Performance will be conducted at the Performers' sites.

F. Period of Performance

The RESILIENCE Program is envisioned as a 45-month effort that is intended to begin January 1, 2021. Phase 1 will last 15 months; Phase 2 will last 18 months; and Phase 3 will last 12 months.