# STATEMENT OF WORK

**FOR**

# FLARE – CAPACITOR CHARGE DISCHARGE POWER SUPPLY (CCDPS) MANUFACTURING

**UNIQUE PROJECT IDENTIFIER: FLARE-CCDPS-SOW-05**

**Reference Work Planning #: WP1995**

**REVISION 0**

**DATED *April 08, 2016***

PREPARED BY: Frank Hoffmann ______________________
Digitally signed by Frank Hoffmann
Date: 2016.04.11 10:05:39 -04'00'
Cognizant Individual / ATI

REVIEWED BY: Michael Kalish ______________________
Digitally signed by Michael Kalish
DN: cn=Michael Kalish, o=PPPL, ou=Engineering, email=mkalish@pppl.gov, c=US
Date: 2016.04.08 15:17:03 -04'00'
Project Manager

REVIEWED BY: Barry L. Jedic ______________________
Digitally signed by Barry L. Jedic
DN: cn=Barry L. Jedic, o, ou, email=bjedic@pppl.gov, c=US
Date: 2016.04.08 15:26:15 -04'00'
Quality Assurance

APPROVED BY: John C. Lacenere ______________________
Digitally signed by John C. Lacenere
DN: C=US, E=lacenere@pppl.gov, O=AC Power, OU=PPPL, CN=John C. Lacenere
Reason: I am approving this document
Date: 2016.04.11 08:06:48-04'00'
AC Power

APPROVED BY: Hantao Ji ______________________
Digitally signed by Hantao Ji
DN: cn=Hantao Ji, o, ou, email=hji@pppl.gov, c=US
Date: 2016.04.08 14:20:22 -05'00'
RLM

**PRINCETON UNIVERSITY**
**PLASMA PHYSICS LABORATORY**
**P.O. BOX 451**
**PRINCETON, N.J. 08543**
**609-243-2000**

## 1.0 INTRODUCTION & SCOPE

### 1.1. Facility for Laboratory Reconnection Experiments (FLARE)

The Princeton Plasma Physics Laboratory, part of Princeton University (PU), is in the process of designing and constructing the FLARE (Facility for Laboratory Reconnection Experiment) experimental machine. The purpose of FLARE experiment is to study the magnetic reconnection in regimes previously inaccessible. The project is a multi-year project funded by the National Science Foundation and the Department of Energy.

The FLARE experiment incorporates a vacuum vessel with a number of electrical coils that are used to create and contain plasma during short pulses. The coils are powered using capacitor banks that are slowly charged and then very quickly discharged, thereby generating current pulses for the coils.

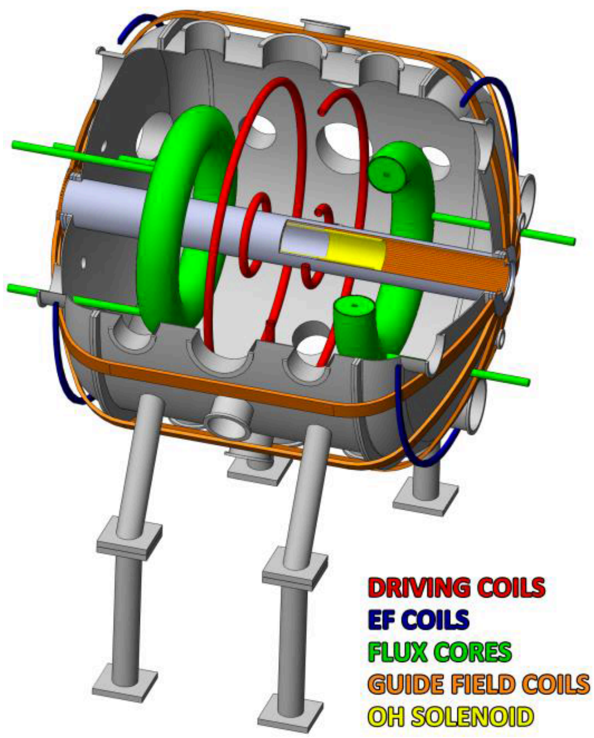


**Figure 1: FLARE Experiment Vessel**

The FLARE machine consists of nine coil systems, hereafter referred to as:

1) OH (Ohmic Heating)
2) EF (External Field)
3) GF (Guide Field)
4) PF-A (Poloidal Field A)
5) PF-B (Poloidal Field B)
6) TF-A (Toroidal Field A)
7) TF-B (Toroidal Field B)
8) DC-I (Inside Driver Coil)
9) DC-O (Outside Driver Coil)

All coils will be pulsed using the Capacitor Charge Discharge Power Supply (CCDPS), which is a set of nine capacitor banks with chargers as well as control and diagnostic system. This Statement Of Work describes the scope of work required for the manufacturing of the CCDPS for this project .The FLARE experiment will be performed in two phases – an initial proof-of-concept phase (day-1 operation) and full experimental phase (full-scale operation). The FLARE machine is the same during these two phases, but the voltage and current required from the power supplies are different. In the initial phase, the current and voltage required is the minimum needed to achieve plasma in the FLARE machine.

## 1.2. Capacitor Charge Discharge Power Supply (CCDPS)

The power supply for FLARE consists of a number of capacitor banks, to be switched at high speed, and discharged rapidly into the various coil sets indicated below in this SOW. The typical discharge time is in the range of 0.01-100 msec.

**Table 1: Coil Voltage & Current Requirements**

| | OH | EF | GF | PF-A | PF-B | TF-A | TF-B | DC-I | DC-O |
|---|---|---|---|---|---|---|---|---|---|
| **Voltage Rating** | 20kV | 1.4kV | 20kV | 20kV | 20kV | 20kV | 20kV | 60kV | 60kV |
| **Full System Current** | 180kA | 26kA | 40kA | 540kA | 540kA | 250kA | 250kA | 50kA | 50kA |

The capacitor bank systems will be located in a basement directly underneath the platform and experimental vessel installed in the test cell above. Triax cables will be used to connect the bank output to the coils inside the vessel. Control and diagnostic signals will use optical signaling. Electrical power and cooling water will be provided by the existing facilities. The CCDPS, due to the existing capacitor voltages and pulse currents has to adhere to strict safety rules and will need to interface with the existing systems for access restriction and safe operation.

## 1.3. Scope

The CCDPS has been designed and the specifications for the subsystem that make up the complete CCDPS have already been determined. The design for the CCPDS has taken into account all the functional requirements, as well as the necessity for a modular design that is going to be installed in stages.

This Scope Of Work (SOW) covers the manufacturing of the CCDPS sub systems as they have been designed and specified. This **does** include the procurement of commercially off-the-shelf-components, the procurement (or manufacturing) of custom components, for example metal bus bars, and non-conductive mechanical support structures. This SOW also includes the assembly of the procured components into modules that will be combined to form the capacitor bank systems, as well as testing of these modules before shipment.

This SOW **does not** include substantial re-design for any of the core power electronics of the bank modules, or their mechanical design. Any changes in the design of the CCDPS sub-systems need to be reviewed with and accepted by PU personnel prior to manufacturing.

### 1.3.1. Scope Of Equipment

The equipment manufactured by the supplier during this project phase needs to meet all specifications defined in the separate capacitor bank system specification documents.

### 1.3.2. Tasks and Deliverables

The supplier shall perform the following tasks and submit the resulting deliverables defined in 13.1 and 13.2 below:

1. Evaluate the provided scope of work and design specifications for all capacitor bank systems.
2. Define a plan and schedule to execute the work within the scope.
3. Throughout all tasks have regular meeting or conference calls to discuss issues and provide status updates.
4. Day-1 Deliverables
    a. Procure all commercially available parts for day-1 operation.
    b. Manufacture (or procure from third parties) all custom parts for Day-1 operation.
    c. Assemble the parts into sub modules of the capacitor bank systems as for Day-1 operation.
    d. Test assembled sub modules to verify operation.
    e. Ship all sub modules for all capacitor bank systems for Day-1 operation.
    f. Provide on-site guidance for installation of the sub modules into the capacitor bank systems needed for Day-1 operation.
5. Full-Scale Deliverables
    a. Procure all remaining commercially available parts for full-scale operation.
    b. Manufacture (or procure from third parties) all remaining custom parts for full-scale operation.
    c. Assemble the parts into sub modules of the capacitor bank systems as for full-scale operation.
    d. Test assembled sub modules to verify operation.
    e. Ship all sub modules for all capacitor bank systems for full-scale operation.
    f. Provide on-site guidance for installation of the sub modules into the capacitor bank systems needed for full-scale operation.

## 2.0 APPLICABLE DOCUMENTS

### 2.1. Capacitor Bank Specifications

The specifications for all capacitor bank and general systems are provided together with this document.

### 2.2. Bills of Materials (BOMs)

The BOM for the design is provided together with this document.

### 2.3. Standards

The manufactured systems shall comply with all relevant industrial regulations, practices, standards, safety codes as well as specific performance requirements specified by PU, unless otherwise agreed upon in writing by both parties. The services are subjected but not limited to the following standards:

- ANSI IEEE 18 Shunt Power Capacitors
- ANSI/IEEE 4 Techniques for Dielectric Tests
- ANSI/NEMA ICS 1 Industrial Control and Systems General Requirements

- NFPA 70 The National Electrical Code

## 3.0 APPLICABLE DRAWINGS

### 3.1. Basement Drawing

### 3.2. Overlay of FLARE platform with vessel and basement

## 4.0 RESPONSIBILITIES

### 4.1. PRINCETON PLASMA PHYSICS LABORATORY

PU will provide detailed plans of the installation area as well as any special requirements with respect to gaining access. PU is responsible for providing the work required to separate the area into sections that meet the maximum energy per capacitor bank system module.

PU will provide all necessary information about the existing infrastructure providing electrical power, cooling water HVAC, etc. PU will provide all necessary information to allow the connection of the capacitor bank systems control unit(s) to the facility safety systems.

PU will organize as a minimum bi-weekly meetings or conference calls for to discuss the status of the project. At the beginning of the project PU will provide a list of contacts for technical and administrative (financial) issues.

### 4.2. SUPPLIER

#### 4.2.1. General Responsibilities

1. The suppliers, before submitting a bid, must thoroughly familiarize themselves with the existing conditions at the project site, the performance requirements and service restrictions. Should any discrepancies arise between the existing conditions and the plans and specifications, they shall be reported to the Bid Contact prior to submitting the quote/proposal.
2. The Supplier shall perform all services within the schedule that is agreed upon. The supplier shall notify PU immediately in case of delays.
3. The supplier is required to take part in the regular status meetings or conference calls.
4. The supplier is required to actively seek resolution of technical questions with PU if and when they arise.

#### 4.2.2. Quotation / Proposal

All submitted quotations / proposals will be evaluated on their schedule, the technical qualification and related experience of the supplier, and the price. The accepted supplier will be notified electronically.

The following information shall be included in the quotation:

1. Prior related experience of the company and their staff involved in this work.
2. A detailed PERT or GANTT chart showing how work will be executed in terms of sequence, linkage, work hours, resource allocation, and schedule for the project before the contract is awarded.
3. Pricing for the separate work stages and delivery packages as follows:
   a. Cost per capacitor bank system for all systems required for Day-1 operation
   b. Differential Cost per capacitor bank system for all systems to upgrade from day-1 operation to full-scale operation. This breakdown needs to include alternative costs for either delivering parts kits only (for PU personnel to install the kits), or for delivering parts kits and providing on-site support during installation.

   c. For the capacitor bank systems that consist of multiple modules provide the cost per module.
4. All pricings must be split up into costs for parts & material and labor. The labor rates must be categorized per skill level of the personnel involved.
5. A high-level test plan for review

**Note:**
**The hardware for the day-1 operation will be purchased. Within six months of initial operation a decision about the procurement of the additional hardware will be made and a separate PO may be issued. The quotations need to be valid for at least six months.**

#### 4.2.3. Procurement Plans

The supplier shall provide procurement plans for all components and raw materials purchased from other vendors. The plans need to identify for each component the vendor, quoted price, lead times, shipping & delivery dates. The plans need to be updated throughout the project.

#### 4.2.4. Manufacturing Plans

The supplier shall provide manufacturing plans for all manufactured components. The plans need to identify for each component the materials required, the manufacturing steps, the start, and the completion of manufacturing.

#### 4.2.5. Monthly Status Reports

The supplier shall submit via e-mail, to be received by PU by the last working day of each month, a report that includes a schedule of major tasks to be performed under the subcontract, and actual/projected completion dates. The report shall include a narrative explanation of significant schedule delays if those exist. Photos are recommended to support the narrative.

## 5.0 REQUIREMENTS

### 5.1. PERFORMANCE REQUIREMENTS

#### 5.1.1. PERFORMANCE CHARACTERISTICS

The detailed specifications for each of the CCDPS bank systems are presented in their separate specifications. This section will only provide a summary of these performance requirements defined for the CCDPS.

A typical circuit that is similar for each capacitor bank system is shown in Figure 2 below. The capacitor bank is charged using a bipolar power supply (typically two charger in series with a center ground point). During charging the bank is connected to the chargers with two medium voltage relays (NO). A protection circuit between the chargers and the capacitor bank protects the chargers against malfunctions and early firing of the bank.

Each capacitor bank has a dump load into which any energy remaining in the bank can be discharged, either after a pulse has been fired, or if a pulse needs to be terminated. The dump load is engaged using a medium voltage relay (NC). In all cases where the bank isn't powered or operated, this relay is closed. The dump load is distributed across multiple modules if possible and is dimensioned to provide some redundancy.

The capacitors in each bank have bleed resistors across their terminals, as additional safety. These resistors are dimensioned to discharge the capacitors overnight even if no other discharge circuit is used. Each capacitor is fused to provide over-current protection.

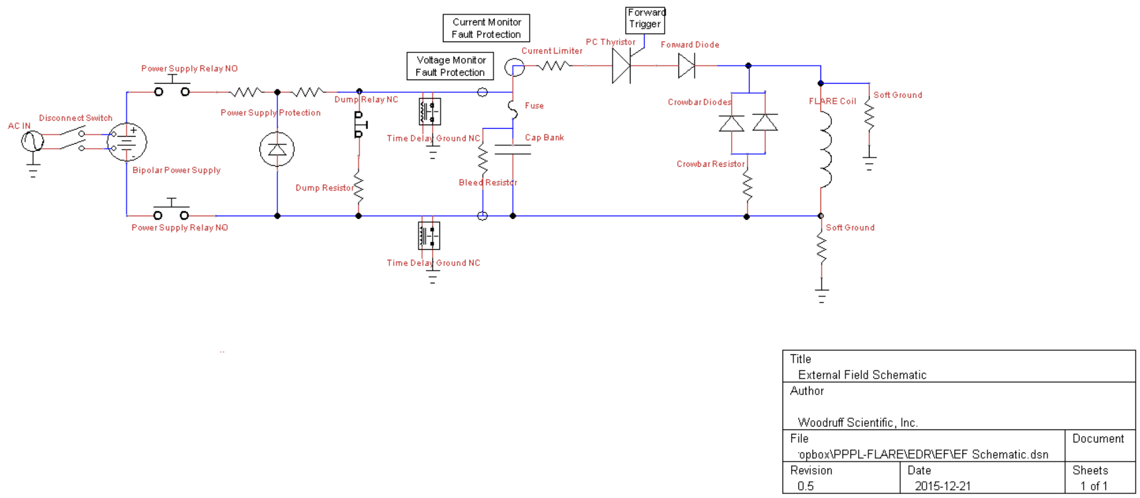


**Figure 2: Typical Capacitor Bank Circuit**

Depending on the pulse characteristics of each bank / coil a forward switch with or without forward diode is used. The forward switches in the most cases are ignitrons, only in one case a thyristor is used. As dependent on the pulse expected characteristics are the crowbar switches. In the simplest case the crowbar switches are stacks of diodes that automatically trigger at the peak of the pulse. When more control is needed the crowbar switches are ignitrons. Depending on the current requirements for the respective bank, multiple switching components (diodes or ignitrons) are used in parallel.

The circuit is monitored and controlled using a LabVIEW based DAQ and control system. Currents are measured for each switching device per bank to allow detection of a single device failure as well as monitoring of the current sharing between devices. The bank voltage is measured on each cap bank module (where a bank consists of multiple modules). The temperature is measured on a number of devices where necessary.

**Table 2: Performance Characteristics Summary**

| Bank / Coil System | Voltage | Peak Current Full-Scale | Peak Current Day-1 | Rise Time |
|---|---|---|---|---|
| OH | 20kV | 180kA | 0% | < 0.45 ms |
| EF | 1.4kV | 26kA | 33% | > 30ms |
| GF | 20kV | 40kA | 20% | < 0.45ms |
| PF-A | 20kV | 540kA | 33% | < 0.11ms |
| PF-B | 20kV | 540kA | 33% | < 0.11ms |
| TF-A | 20kV | 250kA | 33% | < 0.08ms |

| Bank / Coil System | Voltage | Peak Current Full-Scale | Peak Current Day-1 | Rise Time |
|---|---|---|---|---|
| TF-B | 20kV | 250kA | 33% | < 0.08ms |
| DC-I | 60kV | 50kA | 0% | < 0.01ms |
| DC-O | 60kV | 50kA | 0% | < 0.03ms |

### 5.1.2. OPERATING ENVIRONMENT

The CCDPS will be installed in a basement. The allocated space for the CCDPS will be partitioned to limit the energy per capacitor bank module. The basement will be temperature controlled. De-ionized Cooling water will be provided for the components that require water-cooling.

### 5.1.3. DESIGN LIFE

The FLARE experiment is planned for a minimum of ten years operation. The CCDPS has a specified design life of 10 years with a minimum of 100.000 full power charge discharge cycles (shots). The CCDPS systems have been designed to meet these requirements and the supplier must ensure that components and manufacturing techniques used do not jeopardize the design life.

### 5.1.4. MAINTAINABILITY

The CCDPS has been designed to be maintainable with respect to components that might fail on purpose (like fuses) or have a known lifetime and will need to be replaced. The supplier must ensure that the maintainability is not reduced due to manufacturing techniques or components used.

## 5.2. EQUIPMENT DEFINITION

### 5.2.1. SPECIFICATIONS AND STANDARDS

The manufactured systems shall comply with all relevant industrial regulations, practices, standards, safety codes as well as specific performance requirements specified by PU, unless otherwise agreed upon in writing by both parties. The services are subjected but not limited to the following standards:

- ANSI IEEE 18 Shunt Power Capacitors
- ANSI/IEEE 4 Techniques for Dielectric Tests
- ANSI/NEMA ICS 1 Industrial Control and Systems General Requirements
- NFPA 70 The National Electrical Code

### 5.2.2. GENERAL DESIGN FEATURES

The manufacturer must ensure that the specifications as defined in the documents are at least met. The specifications must not be weakened when using materials and components different to the ones specified in the provided BOMs or by the chosen manufacturing techniques.

See the capacitor bank system specifications for details.

### 5.2.3. MATERIALS

See the capacitor bank system specifications for details.

#### 5.2.4. ELECTROMAGNETIC INTERFERENCE AND SUSCEPTIBILITY

See the capacitor bank system specifications for details.

#### 5.2.5. IDENTIFICATION AND MARKING

All capacitor banks shall have a nameplate with a unique name/identifier, their rated voltage, maximum pulse current, and stored energy when fully charged. For systems consisting of multiple modules, each module shall have a nameplate with a unique identifier, voltage rating, maximum pulse current, and stored energy per module.

#### 5.2.6. WORKMANSHIP

The supplier shall apply generally accepted industry practices throughout their work.

## 6.0 TEST & INSPECTION REQUIREMENTS

### 6.1. PERFORMANCE TESTS

The supplier is required to verify performance of the manufactured capacitor bank systems or their respective modules. The tests must be carried out and documented before the equipment is shipped. Any tests must ensure that equipment cannot be damaged throughout the tests. The tests are expected to include the following sections. The details for each sections need to be defined as part of the Manufacturing / Inspection / Test (MIT) Plan (see 9.4).

#### 6.1.1. Hi-Pot Tests

The capacitor bank systems must be hi-pot tested to meet a requirement of '2E+1kV', meaning twice the rated capacitor voltage plus 1 kV.

#### 6.1.2. Resistance Measurements of HV Busses

The resistance of the busses connecting the capacitors to the cable endpoints shall be verified to match the values used during the design of the systems. The values for expected bus resistance are specified in the simulations of each bank system. The additional bus resistor value for short circuit protection in each bank is specified in the simulations as well. The values are summarized in the table below.

**Table 3: HV Bus Resistances**

| | OH | EF | GF | PF-A | PF-B | TF-A | TF-B | DC-I | DC-O |
|---|---|---|---|---|---|---|---|---|---|
| **Bus Resistance** | 10uΩ | 10uΩ | 10uΩ | 10uΩ | 10uΩ | 10uΩ | 10uΩ | 10uΩ | 10uΩ |
| **Short Circuit Resistance** | 1mΩ | 1mΩ | 1mΩ | 1mΩ | 1mΩ | 1mΩ | 1mΩ | 1mΩ | 1mΩ |

#### 6.1.3. Testing of Monitoring & Control Signals

All monitoring and control signals shall be tested for correct connectivity and functionality. Transducers for measured voltages, currents, and temperatures must be demonstrated to report correctly scaled values. On/Off signals – for example for relays – must be demonstrated to correctly change the state of the controlled equipment. Control signals for setpoints – for example the voltage setting of power supplies for charging the capacitor banks – must be demonstrated to correctly set the controlled equipment setpoints.

#### 6.1.4. Charge / Discharge Tests of Capacitor Banks Without Using Ignitrons

No test procedures to verify functionality shall jeopardize manufacture's warranties or component life times unless absolutely necessary. In such cases, the contractor must discuss with PPPL before proceeding. This applies in particular to all active switching and rectifying devices.

### 6.2. ACCEPTANCE TESTS

PU will perform a series of acceptance tests after the modules have been installed to verify the functionality. The tests will be conducted after installation of the equipment for Day-1 operation and will be repeated after the incremental installation for full-scale operation.

#### 6.2.1. HiPot Testing

#### 6.2.2. Resistance Measurements of HV Busses

#### 6.2.3. Testing of Monitoring & Control Signals

#### 6.2.4. Charge/Discharge Tests for all Banks (Increasing Voltage, Dump Load only)

#### 6.2.5. Firing of Coil Shots Below Maximum Voltage

### 6.3. SUPPLIER HOLD POINTS

The hold points are defined the in list of deliverables (see 13.0).

### 6.4. QUALITY CONTROL RECEIPT INSPECTIONS

Princeton University will inspect delivered parts for damage during transport. Functional verification tests will be performed within 30 days of arrival at Princeton before acceptance.

## 7.0 QUALIFICATIONS

Not applicable.

## 8.0 ENVIRONMENT, SAFETY, AND HEALTH

Not applicable.

## 9.0 QUALITY ASSURANCE REQUIREMENTS

### 9.1. Inspection / Surveillance / Audit By Princeton University

Authorized representatives of Princeton and the U. S. Government shall have the right at all reasonable times to visit the supplier's premises and those of supplier's suppliers during the performance of the procurement for the purposes of inspection, surveillance, audit and/or obtaining any required information as may be necessary to assure that items or services are being furnished in accordance with specified requirements. Such visits shall be coordinated with the supplier's personnel to minimize interference with the normal operations of said premises. The supplier shall make available records and documentation necessary for this function and shall provide all reasonable facilities and assistance for the safety and convenience of Princeton and/or U. S. Government representatives in the performance of their duties. Princeton and the U. S. Government recognize the supplier's right to withhold information concerning proprietary processes. The supplier agrees to insert the paragraph above in each lower tier procurement issued hereunder.

### 9.2. Supplier's Responsibility For Conformance

Princeton's review and/or approval of supplier's documents nor Princeton's inspection of supplier's items or services shall not relieve the supplier of responsibility for full compliance with requirements of the purchase order/contract. The supplier is responsible for assuring that all requirements and restrictions are imposed on any sub-tier suppliers.

### 9.3. Changes To Documents Approved By Princeton University

Revisions or changes by the supplier to documents approved by Princeton shall be reviewed and approved by Princeton prior to use.

### 9.4. Manufacturing / Inspection / Test (MIT) Plan

The Manufacturing, Inspection, Test and Quality Assurance Plan (MIT/QA Plan) is required for PU review and approval prior to start of fabrication. All inspections and tests must be addressed in the MIT/QA Plan. From the plan, PU may designate selected operations as mandatory "witness" points. supplier shall provide PU with a minimum of five (5) working days' notice in advance of these witness points. Such witness points shall be mutually planned to minimize delays. The MIT/QA shall include as a minimum the following:

1. Outline of the sequence of operations
2. Identify inspections, examinations, and tests (Receipt, In-process, and Final)
3. Identify the documentation to be provided.
4. Approvals for each critical area must be included as these areas are completed.
5. Areas to record the required tests, inspections, etc. must be included.

***Deviations from the MIT/QA Plan, other than simple, minor sequence changes, require written PU approval prior to implementation. All deviations shall be***

### 9.5. Witness/Hold Points and Notification of Princeton in Advance

Princeton reserves the right to designate selected manufacturing, inspection and/or test operations as mandatory Witness or Hold points. Supplier shall provide Princeton with five (5) working days notice in advance of such points.

### 9.6. Inspection and Test Control

Inspections and tests shall be performed in accordance with written procedures referencing criteria for acceptance or rejection. Adequate records shall be maintained and available for Princeton's review.

### 9.7. Nonconformance & Corrective Actions And Notifications Of Princeton

Nonconforming items or services shall be positively identified, and, where possible, segregated to prevent use. The supplier shall document each nonconformance. The written approval of Princeton is required prior to the use of the nonconforming item or service. The supplier's system shall provide not only for timely resolution of non-conformances but also for analysis of non-conformances to determine root causes and to implement appropriate and effective corrective actions.

### 9.8. Measuring And Test Equipment

Inspections and tests shall be performed using properly calibrated measuring and test equipment. Calibration standards shall be traceable to the National Institute for Standards and Technology (NIST) or equivalent. Where such standards do not exist, the basis used for calibration shall be documented. Standards used for calibration shall not be used for shop inspections, but instead shall be protected against damage or degradation.

### 9.9. Submittal Of Equipment Manuals

Supplier shall provide, prior to or with delivery, Princeton with copies of supplier's documents describing equipment installation, operation, maintenance, repair, etc., of the type, format and number of copies as required by Princeton.

### 9.10. Submittal of Drawings

The supplier shall submit any used or generated mechanical drawings of each delivered item. Drawings may be submitted in pdf format. The Supplier shall submit as-built electrical drawings reflecting the final system configurations in terms of power electronics, control, and monitoring circuitry.

### 9.11. Submittal of Material Certifications

The supplier shall submit the manufacturer's Material Test Reports showing actual relevant chemical, mechanical, and electrical properties of materials used and providing traceability to the actual material. One copy is to be submitted to PU upon supplier acceptance for use.

Note: For specialty materials, typically non-metals, where test reports are not readily available from the manufacturer, their certificate of analysis or certificate of grade, as appropriate, may suffice, subject to PU concurrence. For example CMTRs for high strength fasteners must be provided, if such fasteners are used.

### 9.12. Submittal of Completed Inspection & Test Reports

Reports of all required inspections and tests, showing actual values, properly validated by authorized personnel must be provided before shipment.

### 9.13. Completed Release For Shipment Form

Supplier shall not ship (full or partial) without a "Product Quality Certification and Shipping Release" Form (Attachment 1) signed by Princeton's Representative. Manufacturer shall complete and sign the certification section, deliver the form to Princeton's Quality Assurance (QA) Representative, and hold shipment until Princeton signs and returns the form, authorizing shipment. A copy of the fully executed form shall accompany each full or partial shipment.

### 9.14. Princeton Receiving / Inspection

Princeton will perform Receiving Inspection on items or services supplied by the supplier, using either a sampling plan or 100% inspection. Discrepant items or services will be rejected and returned to the supplier or reworked by Princeton.

### 9.15. High Strength Fasteners

High strength fasteners shall only be used if absolutely necessary. If high strength fasteners are utilized for this job, the supplier shall provide high strength fasteners (tensile strength equal to or greater than 100 ksi) in accordance with the Fastener Quality Act. Fasteners shall exhibit grade marks and the manufacturer's identification symbol ('headmark') as specified in the referenced Material Specification. Fasteners having a headmark shown on the suspect fastener list will not be accepted. Certified Material Test Reports (CMTR), showing actual material composition and physical properties and traceable to the actual fasteners, are required for each lot supplied. Results must be on the original letterhead of the entity performing the tests and not transferred to alternate letterhead.

### 9.16. Electrical Items

Commercial electrical Items shall exhibit manufacturer's labels and identification as specified in the referenced specification or in the body of this purchase order/subcontract. No mixed manufacturer's production lots within a single shipment will be accepted. Princeton's receipt inspection activities may include, but are not limited to: (1) dimensional inspection, (2) functional and operational testing,(3) comparison of the manufacturer's test reports to applicable specification requirements, and (4) visual inspection for evidence of used or reworked components, parts, or materials.

### 9.17. Mechanical Items

Mechanical Items shall exhibit manufacturer's labels and identification as specified in the referenced specification or in the body of this purchase order/subcontract. No mixed manufacturer's production lots within a single shipment will be accepted. Princeton's receipt inspection activities may include, but are not limited to: (1) dimensional inspection, (2) functional and operational testing,(3) comparison of the manufacturer's test reports to applicable specification requirements, and (4) visual inspection for evidence of used or reworked components, parts, or materials.

## 10.0 SHIPPING STORAGE AND HANDLING

The capacitor bank systems shall be shipped on the palettes used as mounting base for the modules. Protective material shall be used to protect the assembled modules from damage during transport. The palettes shall be labeled with a unique identifier and description, such that they can be identified and staged for installation without having to remove packing material. The label shall include the weight of the module. Mandatory items on the label:

- "FLARE CCDPS"
- Bank Name,
- Module n of m
- Weight [lbs]

## 11.0 WARRANTY

Not applicable.

## 12.0 ATTACHMENTS

### 12.1. CCDPS Specifications

Princeton Plasma Physics Lab. (2015). *Statement of Work (SOW) for Design of Capacitor Charge Discharge Power Supply (CCDPS) for FLARE* . Engineering. Princeton: PPPL.

Woodruff Scientific. (2016). *FLARE - Specification for CCDPS Charge Supplies, Rev.3.* Seattle: WSI.

Woodruff Scientific. (2016). *FLARE - Specification for CCDPS DAQ/Control, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specifiaction for EF Bank Module - Day1, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for DC Bank Module, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for EF Bank Module, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for GF Bank Module Day-1, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for GF Bank Module, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for OH Bank Module, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for PF Bank Module Day-1, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for PF Bank Module, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for TF Bank Module Day-1, Rev.3.* Seattle: WSI.

Woodruff Scientific Inc. (2016). *FLARE - Specification for TF Bank Module, Rev.3.* Seattle: WSI.

### 12.2. CCDPS Bill of Materials

See documents provided with this SOW: CCDPS BOM - no prices.xlsx.

### 12.3. Shipping Release Form

See documents provided with this SOW: Shipping Release_R1.pdf

### 12.4. High Strength Fasteners Headmark List

See documents provided with this SOW: Headmark List.doc

## 13.0 DOCUMENTATION & DELIVERABLES

**Deliverables List**

### 13.1. Physical Deliverables

PO / Subcontract / BOA / BPA #:_____________________________________________

**Note: Item 2 in the list below will require a separate PO using the quotation delivered at the beginning of this phase!**

| # | Physical Deliverables Required | When Deliverable Is Required | Deliverable Received (✓) |
|---|---|---|---|
| 1 | Manufactured CCDPS modules for Day-1 operation:<br>- EF Day-1 (see *FLARE - Specification for EF Bank Module – Day1, Rev.3 and BOM*)<br>- GF Day-1 (see *FLARE - Specification for GF Bank Module – Day1, Rev.3 and BOM*)<br>- PF-A, PF-B combined Day-1 (see *FLARE - Specification for PF Bank Module – Day1, Rev.3 and BOM*)<br>- TF-A Day-1 (see *FLARE - Specification for TF Bank Module – Day1, Rev.3 and BOM*)<br>- TF-B Day-1 (see *FLARE - Specification for TF Bank Module – Day1, Rev.3 and BOM*)<br>- Charger System Full Scale (see *FLARE - Specification for CCDPS Charge Supplies, Rev.3 and BOM*)<br>- Data Acquisition & Control Full Scale (see *FLARE - Specification for CCDPS DAQ/Control, Rev.3 and BOM*) | Following the procure-ment and manu-facturing schedules | |
| Holdpoint A2 | | | |
| 2 | Manufactured CCDPS bank systems for full scale operation<br>- OH Full-Scale (see *FLARE - Specification for OH Bank Module, Rev.3 and BOM*)<br>- DC-I full scale (see *FLARE - Specification for DC Bank Module, Rev.3 and BOM*)<br>- DC-O full scale (see *FLARE - Specification for DC Bank Module, Rev.3 and BOM*) | | |

| # | **Physical Deliverables Required** | **When Deliverable Is Required** | **Deliverable Received (✓)** |
|---|---|---|---|
| 3 | Manufactured *additional* CCDPS modules / *incremental* parts kits for full scale operation (or a subset to be defined)<br>**Note: The 'additional modules / incremental parts kits' are understood to be all components that are required for the Full-Scale operation minus the components that were already delivered as part of item #1.**<br>- EF increment to Full-Scale (see *FLARE - Specification for EF Bank Module, Rev.3 and BOM*)<br>- GF increment to Full-Scale (see *FLARE - Specification for GF Bank Module, Rev.3 and BOM*)<br>- PF-A increment to Full-Scale (see *FLARE - Specification for PF Bank Module, Rev.3 and BOM*)<br>- PF-B increment to Full-Scale (see *FLARE - Specification for PF Bank Module, Rev.3 and BOM*)<br>- TF-A increment to Full-Scale (see *FLARE - Specification for TF Bank Module, Rev.3 and BOM*)<br>- TF-B increment to Full-Scale (see *FLARE - Specification for TF Bank Module, Rev.3 and BOM*)<br>- | Following the procure-ment and manu-facturing schedules | |
| Holdpoint B2 | | | |
| | | | |
| **Exceptions (Add justification for any missing physical deliverables that will not be received):** | | | |

### 13.2. Document Deliverables

PO / Subcontract / BOA / BPA #:__________________________________________________

**Note: Items 13-21 in the list below will require a separate PO using the quotation delivered at the beginning of this phase!**

| # | Document Deliverables Required | When Deliverable Is Required | Deliverable format (paper, electronic etc.) | Storage Location for Deliverable | Deliverable Received (✓) |
|---|---|---|---|---|---|
| 1 | Quotation for Day-1 and Incremental Costs for Full-Scale implementation | With proposal | Electronic (PDF) | | |
| 2 | Project Schedule for Day-1 and Incremental Costs for Full-Scale implementation | With proposal | Electronic | | |
| 3 | Related Experience / Team Profile | With proposal | Electronic (PDF) | | |
| 4 | High-Level Test plan (see 4.2.2) | With proposal | Electronic PDF | | |
| Contract Awarded | | | | | |
| 5 | Detailed Procurement Schedule Day-1 (see 4.2.3) | Prior to procurement | Electronic | | |
| 6 | Detailed Manufacturing Schedule Day-1 (see 4.2.4) | Prior to manufacturing | Electronic | | |
| 7 | Manufacturing and Inspection Test Plan (MIT Plan), which includes definition of testing and inspection for Day-1 system. (see 9.4) | Prior to manufacturing | Electronic | | |
| Holdpoint A1 | | | | | |
| 8 | Mechanical Drawings for all parts as built Day-1 (see 9.10) | Prior to shipping | Electronic | | |
| 9 | Electrical Drawings for all systems as built Day-1 (see 9.10) | Prior to shipping | Electronic | | |
| 10 | Manuals and datasheets for all systems as built Day-1 (see 9.9) | Prior to shipping | Electronic | | |
| 11 | Reports for MIT Results | Prior to shipping | Electronic | | |
| 12 | Material Certifications if applicable. | Prior to shipping | Electronic | | |
| 13 | Shipping release (see 9.13) | Prior to shipping | Electronic | | |
| Holdpoint A2 | | | | | |
| 14 | Detailed Procurement Schedule to Full-Scale (see 4.2.3) | Prior to procure-ment | Electronic | | |
| 15 | Detailed Manufacturing Schedule to Full-Scale (see 4.2.4) | Prior to manufactu-ring | Electronic | | |

| # | Document Deliverables Required | When Deliverable Is Required | Deliverable format (paper, electronic etc.) | Storage Location for Deliverable | Deliverable Received (✓) |
|---|---|---|---|---|---|
| 16 | Manufacturing and Inspection Test Plan (MIT Plan), which includes definition of testing and inspection for the incremental work to complete the full scale system. (see 9.4) | Prior to manufactu-ring | Electronic | | |
| Holdpoint B1 | | | | | |
| 17 | Mechanical Drawings for all parts as built to Full-Scale (see 9.10) | Prior to shipping | Electronic | | |
| 18 | Electrical Drawings for all systems as built to Full-Scale (see 9.10) | Prior to shipping | Electronic | | |
| 19 | Manuals and datasheets for all systems as built to Full-Scale (see 9.9) | Prior to shipping | Electronic | | |
| 20 | Reports for MIT Results | Prior to shipping | Electronic | | |
| 21 | Material Certifications if applicable. | Prior to shipping | Electronic | | |
| 22 | Shipping release (see 9.13) | Prior to shipping | Electronic | | |
| | | | | | |
| **Exceptions (Add justification for any missing document deliverables that will not be received):** | | | | | |

Princeton Technical Representative/COG:____________________________________________

*(Sign-off and provide to the Operations Center when job is completed and deliverables are dispositioned and placed/filed in Operations Center (or other Project, Department or Division designated file center)*