STATEMENT OF WORK

1. Objective/Requirements

The National Aeronautics and Space Administration (NASA), Marshall Space Flight Center (MSFC) Damage Tolerance Assessment Branch (EM21) is acquiring a next-generation computed tomography (CT) inspection system to restore and enhance essential nondestructive evaluation capabilities. This investment replaces a 17-year-old legacy system that has encountered considerable reliability challenges, including over 50% downtime in the past 18 months. The new CT platform will offer advanced imaging and analysis capabilities to support ongoing and future initiatives in additive manufacturing development, composite material evaluation—including composite overwrap pressure vessels—and detailed failure investigations. This upgrade will ensure the continuation of mission-critical inspection functions while significantly improving system performance, reliability, and analytical accuracy.

2. Characteristics, Scope, and Specs

a. This document sets forth the minimum requirements for fabrication, testing, delivery and installation of a new computed tomography and digital radiography (CT/DR) system at NASA MSFC in Huntsville, AL.

   i. The CT/DR system shall be capable of inspecting objects in a 60" diameter by 60" height envelope with maximum weight of 3000 pounds.

   ii. The CT/DR system shall be capable of inspecting objects using a digital detector array (DDA) panel and using a linear detector array (LDA).

CT/DR SYSTEM MECHANICAL AND HARDWARE COMPONENTS

The CT/DR system mechanical and hardware subsystem shall be comprised of the following components:

3. X-Ray Source

a. One dual-energy linear accelerator that produces x-rays at peak energies of both 2 MeV and 3 MeV (Varex Linatron M3A dual-energy model, Super Low Leakage, Focal spot size ≤ 2.0 mm) with thermal control unit (TCU), and including the following items:

   i. One imaging control unit to provide interface and synchronization with the 4343HE detector and with the LDA detector, including all required power and signal cables necessary for operation.

   ii. One motorized independent jaw external collimator. The jaws shall open asymmetrically to produce a field size from 1° to 24° in cone beam mode and to produce a fan beam with adjustable horizontal slice width from 1 mm to 6 mm as measured at the isocenter of the turntable.

   iii. One mechanically stowable laser alignment system.

1. The laser wavelength shall be 532 nm, Class II, <1mW.
2. The laser alignment shall be capable of producing a crosshair indicator and a line indicator, each centered on the DDA (crosshair) and the LDA (line) active window/length.

iv. The linear accelerator shall be fitted with one external bracket for tungsten filter plates, co-operable with the external collimator.

v. One set of tungsten filter plates, one each at thicknesses of 0.0625", 0.125", 0.25", 0.5" and 1", shall be included with each of sufficient length and height to fit the filter bracket and completely cover the radiation output cone of the accelerator at its maximum 24° field size.

vi. Two extended spare parts kits for the Linatron M3A shall be included.

vii. Interconnecting cables with sufficient lengths to allow assembly and placement of all components shall be included.

viii. Interconnecting hoses with sufficient lengths to allow assembly and placement of all components shall be included.

ix. An internally mounted single spot laser to align the X-ray beam to an object being radiographed. Laser is 532 nm, Class II, 0.5 mW.

x. A remote customer user interface with cabling to install in control room 136 adjacent to CT cell room 137 shall be included.

xi. Operator manuals, drawings, schematics, and all supporting documentation in printed and electronic forms in English language shall be provided.

4. X-Ray Detectors

a. Two DDA panels designed for high energy x-ray exposure, same make and model with pixel pitch no larger than 139 microns x 139 microns (Varex 4343HE) shall be included.

i. DDA panels shall be fully compliant with the requirements of the latest versions of ASTM specifications E2597, E2698, E2736, E2737 and E3375.

ii. One DDA panel shall be installed in the CT/DR system upon system assembly and the other shall be retained as a spare for installation upon end of serviceable life of the original DDA panel.

iii. The DDA shall be capable of operating in native width, helical and mosaic scan modes.

iv. One shielded enclosure for DDA panel to minimize radiation exposure of detector internal electronics shall be included.

v. All cables, connectors, power supplies and accessories needed for operation in DR and CT modes shall be included.

vi. All cables, connectors and accessories needed to support operation of the detector from control room 136 adjacent to CT cell room 137 shall be included.

vii. The system shall be configured so that the DDA detector can be used with minimum x-ray exposure on the LDA detector.

viii. Operator manuals, drawings, schematics, and all supporting documentation in printed and electronic forms in English language shall be provided.

b. One LDA capable of high energy operation up to the 3 MeV Linatron x-ray output shall be included.

i. The LDA pitch shall be 400 microns.

ii. The LDA shall incorporate cadmium tungstate ($CdWO_4$) or better capability detector crystals.

iii. The LDA shall include a collimator that can support slice thicknesses of 1 mm to 6 mm (as measured at isocenter) in 1 mm increments.

iv. The LDA detection length shall be between 30” and 36” (762 mm and 915 mm).

v. The system shall be configured so that the LDA detector can be used with minimum x-ray exposure on the DDA panel. This requirement can be satisfied by any of three configurations:

1. A shield capable of blocking radiation from the DDA panel during LDA use shall be included; or

2. The DDA housing shall be constructed such that the DDA panel can be easily removed from the system during LDA operations; or

3. Detector mounting system can be constructed so that DDA and LDA can be easily exchanged to allow removal of the inactive detector from the x-ray cell.

vi. The LDA shall be capable of operating in native width, offset, helical and mosaic scan modes.

vii. All cables, connectors, power supplies and accessories needed for operation in DR and CT modes shall be included.

viii. All cables, connectors and accessories needed to support operation of the detector from control room 136 adjacent to CT cell room 137 shall be included.

ix. Operator manuals, drawings, schematics, and all supporting documentation in printed and electronic forms in English language shall be provided.

5. **Mechanical Components**
    a. One turntable to mount inspection articles shall be provided.
        i. Turntable movement motor and associated components capable of sustaining object weight no less than 3000 pounds throughout all ranges of motion shall be provided.
        ii. Turntable diameter shall be 36”.
        iii. Turntable surface shall be scribed across diameters with lines at 45-degree intervals starting at 0°.
        iv. Turntable surface shall be scribed or stamped with degree indication markers at 0°, 90°, 180° and 270° in such manner that the degree marks correspond to the equivalent angle locations in a CT volume or slice produced when the turntable is homed (0°) at the beginning of scan data acquisition.
        v. Threaded inserts (1/4-20) shall be installed in the turntable at 6” intervals along each radial scribe line.
        vi. Bracket mounts, mounting hole threaded inserts, or other mounting mechanism for extension brackets or frames shall be machined into the outer perimeter of the turntable to allow for attachment of customer-fabricated tooling for inspection of parts larger than the turntable diameter.
    b. The motion control system comprising drives, motors, encoders and all other required equipment shall meet the following requirements:
        i. The system shall be capable of acquiring and reconstructing a continuous cylindrical volumetric dataset with a minimum usable volume (CT) of 60 inches in diameter by 60 inches in height at minimum voxel size irrespective of the mechanical motion, scan trajectory, or acquisition method employed by the vendor, using a test article of dimensions 60” height x 60” diameter or width.
        ii. The system shall be capable of acquiring and reconstructing a continuous planar radiographic image with a minimum usable area (DR) of 60 inches in width by 60 inches in height at minimum pixel size irrespective of the mechanical motion, scan trajectory, or acquisition method employed by the vendor.
        iii. Compliance with these requirements shall be demonstrated by the system’s ability to deliver a fully reconstructed, geometrically accurate 60” × 60” cylindrical volume at minimum pixel and voxel size without stitching discontinuities, resolution loss, or artifacts anywhere in the volume, and to deliver a fully reconstructed digital radiograph of a 60” x 60” panel at minimum pixel and voxel size without stitching discontinuities, resolution loss, or artifacts anywhere in the image area.

Vendor may employ any combination of detector motion, source motion, object manipulation, or other scanning approaches, provided the resulting reconstructed CT volume and DR scan meets the dimensional, geometric, and image-quality requirements in all scan modalities.

iv. All required motion ranges and trajectories necessary to achieve the 60” × 60 in” CT volume and 60” x 60 DR area. shall be provided as part of the vendor’s delivered system configuration.

v. One pendant controller shall be included to allow independent and simultaneous user manipulation of all axes of freedom while inside CT cell room 137, adjacent to the system turntable and incorporating an emergency stop button and a “dead man’s switch” function.

vi. One joystick or pendant controller shall be included to allow independent and simultaneous user manipulation of all axes of freedom while in control room 136 adjacent to CT cell room 137, incorporating an emergency stop button and a “dead man’s switch” function.

c. One gantry frame constructed from steel square/rectangular tubing, capable of supporting all components listed in sections 3 through 5 shall be provided.

d. The frame shall be painted finish with rust-resistant paint, Occupational Safety & Health Administration (OSHA) Safety Blue ASTM-STD-595 #15092.

e. The frame shall be permanently affixed to the floor of x-ray vault with floor anchors rated to support overall system weight.

f. The frame shall include leveling screws and/or feet to adjust alignment and leveling during installation and prior to affixing frame to floor.

g. All cables, cable trays/races and cable management system for use with all components with minimal floor obstruction shall be provided.

h. A motion control system spare parts kit shall be provided consisting of a full set of all motors, drives/drive controllers, belts, motion control card or subsystem, relays, fuses, switches, programmable logic controller (PLC) and any other components to provide for a complete replacement set of all motion control components.

6. Electrical Components

a. Vendor shall calculate all electrical power requirements and provide information to NASA no later than date of design review.

b. Vendor shall connect all system components to customer-provided disconnects.

c. All cables, wiring, connectors and other electrical components shall be labeled for identification and a complete listing shall be provided to identify each item by label.

d. Wiring diagrams shall be keyed to wiring labels.

CT/DR SYSTEM COMPUTER HARDWARE AND SOFTWARE COMPONENTS

7. Computer Hardware Specifications

The CT/DR system computer hardware/software subsystem shall meet or exceed the following specifications:

i. Acquisition PC:

1. CPU: Workstation class, 16 full-performance cores
2. Memory: 64GB DDR5
3. Hard Drive: 2x 4TB NVMe PCIe Gen5 SSD in RAID1
4. GPU: NVIDIA RTX PRO 2000 Blackwell 16GB
5. Network: 100Gbit QSFP28 Fiber
6. Monitor: Minimum 32” 4K display

ii. Image reconstruction and CT/DR inspection workstation PC:

1. CPU: Workstation class, 48 full-performance cores
2. Memory: 512GB DDR5 ECC
3. Hard Drive:
    a. Boot Drive: 2x 2TB NVMe PCIe Gen5 SSD in RAID1
    b. Storage Drive: 4x 16TB NVMe PCIe Gen4 U.2 SSD in RAID5
4. GPU: 4x NVIDIA RTX PRO 6000 Blackwell 96GB
5. Network: 100Gbit QSFP28 Fiber
6. Monitor: 30” ASTM E2698 and E3375-compliant display with calibration hardware; EIZO MX317W or equivalent
    a. Monitor shall be bundled with quality control hardware and supporting quality control software (EIZO Radiforce RadiCS UX2 or equivalent).

8. Computer Software Requirements

a. Acquisition PC, image reconstruction CR/DR inspection workstation PC and all software required for image data acquisition, CT reconstruction and CR/DR data review shall operate on Windows 11 Professional.

b. System software shall support all motion control, data acquisition, and image reconstruction and analysis for CT and DR modes.

c. Image analysis software shall at minimum include the following functions in CT and DR modes:

i. Measurement tools including line measurements, area measurements, histograms and line profiles.

ii. Image processing and filtering options including contrast enhancement and edge enhancement.

iii. Image smoothing and sharpening filters applicable to prefiltering of raw data and postfiltering of reconstructed CT slices or data volume and DR images.

iv. Image analysis tools including contrast to noise, signal to noise and mean/minimum/maximum pixel/voxel values in defined areas.

v. Annotation tools including arrow markers, lines, circles, defect marking and text remarks.

vi. Automated measurements of hole diameters or dimensions, hole spacing (center-to-center), and hole minimum distance between nearest points in CT slices and DR images.

vii. Automated measurements of sizes and areas of regular geometric figures such as circles, squares, rectangles and triangles in CT slices and DR images.

viii. CT artifact reduction capabilities shall, at a minimum, include:

1. Beam hardening correction
2. Ring artifacts reduction
3. Metal artifact reduction
4. Scatter artifact reduction
5. Cone beam artifact reduction
6. Bad pixel/bad cluster mitigation
7. Part movement or settling artifacts
8. Mitigation of artifacts in the reconstructed CT volumes and DR radiographs caused by any of the above conditions

d. All images shall be stored in non-proprietary industry-standard lossless formats such as .TIFF and with Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) compatibility.

e. All system parameters and settings for each inspection shall be saved in a non-proprietary format.

i. System parameters and settings shall be incorporated into a technique information report generated by the software.

f. One license for Volume Graphics (VG) Studio Max Ultimate, latest version, shall be provided.

g. All CT images and volumes shall be directly importable to VG Studio Max Ultimate.

h. All system software updates and patches, e-mail and phone support and remote diagnostic support shall be provided for one year beginning upon completion of NASA acceptance of the system.

    i. All network connections for remote diagnostic support shall be physically separable from the overall system.

9. Supported Computed Tomography Scan Modes

a. Cone Beam Scanning (DDA) mode shall include following capabilities:

    i. Circular (rotate only) at native and enhanced resolutions (with enhanced resolution generated by sub-pixel image data acquisition, shifting detector position in multiple directions in intervals of less than one DDA pixel size).

    ii. Helical (spiral motion) at native and enhanced resolutions.

    iii. Stitching/mosaic (multiple detector positions with overlap) to support inspection envelope of 60” height x 60” diameter at native and enhanced resolutions.

    iv. Pause and resume scan in all scan modes

b. Fan Beam Scanning (LDA) mode shall include following capabilities:

    i. Circular (rotate only) at native and enhanced resolutions (with enhanced resolution generated by sub-pixel image data acquisition, shifting detector position in multiple directions in intervals of less than one LDA pixel size).

    ii. Helical (spiral motion) at native and enhanced resolutions.

    iii. Stitching/mosaic (multiple detector positions with overlap) to support inspection envelope of 60” height x 60” width at native and enhanced resolutions.

    iv. Software support for slice generation in thicknesses of 1 mm to 6 mm (as measured at isocenter) in 1 mm increments.

    v. Software support for aligning x-ray fan beam plane and LDA center horizontal plane at slice location.

    vi. Software support for sequential or interval-spaced slice acquisition.

    vii. Pause and resume scan in all scan modes.

10. Supported Digital Radiography Inspection Modes

a. DR inspection mode shall include following capabilities:

   i. Static DR image with variable frame averaging at native resolution and at enhanced resolution.

   ii. Static DR image with variable frame averaging with image stitching/mosaic function at native resolution and enhanced resolution, up to the full 60” width x 60” height of the inspection envelope.

   iii. Live imaging at native resolution with frame averaging available in active region of DDA panel.

      1. Capability to record live imaging in static or moving detector/part modes using DDA panel.

11. Supported Acquisition Settings Common to CT and DR Modes

a. CT and DR inspection modes shall include following capabilities, as appropriate to detector type(s):

   i. Frame averaging adjustment (DDA).

   ii. Integration time adjustment (LDA).

   iii. Detector calibration.

   iv. Offset, gain and bad pixel maps for each detector.

   v. Imaging system alignment functions:

      1. Alignment/geometry tool for DDA panel using rod and ball phantom or equivalent method

      2. Alignment tools and/or phantoms and software support for alignment of accelerator, turntable and detectors (DDA and LDA) to produce accurate images and meet image quality requirements throughout the entire inspection envelope.

   vi. Alignment of rotational axis and detector with machine center and x-ray beam center spot (where object z-axis lines up with vertical axis of detector active area).

b. Automated support for system performance monitoring meeting the requirements of ASTM E1695, E2597, E2737, E2698, and E3375, including:

   i. Bad Pixel Analysis and Reporting

   ii. Offset Level

   iii. Image Lag

   iv. Spatial Resolution (Duplex Wire Gauge)

   v. Signal to Noise Ratio

   vi. Contrast to Noise Ratio

vii. Signal Level

viii. Contrast Sensitivity

ix. Burn In

x. MTF (Modulation Transfer Function)

xi. CDF (Contrast Discrimination Function)

12. Imaging Performance Requirements

a. Minimum pixel/voxel native size of reconstructed (CT) volumes and captured (DR) radiographs shall be no larger, in any circumstance, than the pixel pitch of the DDA panel (139 microns) and detector element pitch of the LDA (400 microns).

b. All geometric parameters affecting voxel/pixel sizing (SID, SOD, focal spot size) and derived parameters (magnification and geometric unsharpness) shall be configured to meet the required dimensions of CT volumes and DR radiographs as listed in Section 9 and 10.

c. Geometric magnification shall be supported to produce as much voxel/pixel dimension reduction as achievable considering system geometry and total image unsharpness limits.

   i. Geometric magnification value shall be 1.05x or greater.

   ii. Voxel/pixel dimensions of CT/DR images using geometric magnification shall be 133 microns (DDA) or smaller, and 382 microns (LDA) or smaller.

   iii. CT and DR sub-pixel modes shall be available for use in the full 60” x 60” inspection envelope.

      1. Sub-pixel (enhanced resolution) modes shall be capable of producing effective voxel/pixel dimensions of 70% of native detector element width/pitch or smaller.

      2. Sub-pixel mode shall be usable in combination with DDA pixel binning mode.

d. Imaging performance for CT mode shall be baselined and monitored using standard ASTM E1695 test articles as well as custom test phantoms, both to be provided by vendor.

   i. Output of the performance test shall be expressed as either microns resolved or as line pairs/mm per the methods of ASTM E1695.

e. Imaging performance for DR mode shall be baselined and monitored using standard ASTM E2737 test articles as well as custom test phantoms, both provided by vendor. Output of the performance test shall be expressed as either microns resolved or as line pairs/mm per the methods of ASTM E2737.

13. Safety System Requirements

a. All safety circuits in motion control and linear accelerator shall be integrated into a master safety circuit at the x-ray cell, to include warning lights (internal and external), audible alarms, emergency stop buttons and cell door interlock switches.

b. Vendor shall provide and install all components of safety system and circuits.

c. All components of the system shall be properly labeled with warning signs for each hazard type (radiation hazard, crush hazard, laser hazard, electrical hazard etc.)

d. X-ray production and gantry motion shall both stop operations immediately upon opening of any interlock door switch or engagement of any emergency stop button.

e. Limit switches that prevent movement of any component axis beyond safe operating range shall be provided and installed.

    i. Each limit switch shall be independently capable of instantly stopping all motion of moving gantry components.

f. A wired video surveillance system shall be provided consisting of at least six cameras capable of operating in high radiation environments and a display that is to be installed in the user control room 136.

    i. Camera resolution shall be 2160p or better.

    ii. Cameras shall be independently controllable from room 136.

    iii. Cameras shall have full pan, tilt and zoom capabilities.

    iv. Cameras shall have optical zoom capability of at least 10X.

    v. Display monitor resolution shall be 2160p or better, matching camera resolution.

    vi. Display monitor diagonal size shall be at a minimum 32”

    vii. Surveillance system shall be capable of recording all camera inputs at 2160p resolution and 15 frames per second or better.

    viii. Recording capacity shall be 8TB or better.

g. Emergency stop buttons shall be installed at multiple locations on the gantry such that at least one emergency stop button is accessible within six feet from any point on all sides of the gantry.

h. At least one wall-mounted emergency stop button shall be installed in room 137, mounted near the personnel door.

i. At least one wall-mounted or table-mounted emergency stop button shall be installed in room 136.

j. At least 8 emergency stop buttons (at least 2 on south primary beam wall, and at least 3 each on east and west walls) shall be installed and interfaced with the safety system circuit.

k. All emergency stop buttons shall instantly immobilize all moving gantry elements.

l. Engaging any emergency stop button shall unlock all movement axes to either prevent or relieve crushing hazards.

m. All emergency stop buttons shall instantly stop radiation production from the Linatron.

n. All emergency stop buttons shall interface with system safety circuitry.

o. Interlock switches shall be installed on each door (one personnel door and two large bay doors).

p. Interlock switches shall stop all radiation production when any door is opened.

q. Interlock switches shall be integrated into the safety system circuit.

r. Warning lights shall be installed by vendor at customer-designated locations inside the cell, outside the cell (internal to building) and exterior of cell.

    i. Light configuration is as follows:

        1. One red light inside the x-ray cell, constantly illuminated when system is in “ready” state (all safety controls ready for x-ray generation) and while x-rays are generated.

        2. One red light inside the control room, adjacent to the personnel door, constantly illuminated when system is in “ready” state (all safety controls ready for x-ray generation) and while x-rays are generated.

        3. One red light outside the x-ray cell and interior to the building, mounted above the large double bay doors on the north wall, constantly illuminated when system is in “ready” state (all safety controls ready for x-ray generation) and while x-rays are generated.

        4. Five sets of one each amber strobe light and one each red strobe light, with sets mounted in the following locations:

            a. Interior to building, mounted above the large double bay doors on the north wall

            b. Exterior of x-ray cell office area, west wall

            c. Exterior of x-ray cell, south wall

d. Exterior of x-ray cell, east wall

e. Exterior of x-ray cell, roof

5. Amber/red strobe set operation shall indicate the following states:

a. Both off: system is deactivated by open interlock switch, depressed e-stop button, or power failure/de-energization of the safety circuit or the linear accelerator.

b. Amber flashing: while system is in "ready" state but x-rays are not being produced.

c. Red flashing: while x-rays are being produced.

d. Amber/red light strobes shall be of sufficient brightness to be clearly discernable during full daylight.

s. One audible buzzer alarm shall be installed inside the x-ray cell.

i. The buzzer alarm shall sound for ten seconds when all doors are closed upon operator exit from cell and all interlocks and e-stop buttons are in "ready" state.

t. All safety system components (warning lamps and strobes, audible alarm, e-stop buttons, interlock switches, relays, fuses and other electrical components) shall be commercial off-the-shelf (COTS) items for user purchase and replacement as needed.

u. Vendor shall provide safety system spare parts kit consisting of:

i. Three red lights and fixtures.

ii. Five sets of amber/red strobes and fixtures.

iii. Three interlock switches.

iv. Four e-stop buttons.

v. One audible alarm buzzer.

v. Vendor shall provide drawings, specifications, wiring diagrams and repair procedures for all components of the safety system.

14. Design Review

a. Vendor shall plan, schedule and perform one on-site visit at the NASA MSFC CT facility (Bldg. 4631) to inspect the CT cell (Rm 137) and adjacent control room (Rm 136), collect any measurements needed for system design, and exchange other information as required to proceed to design review.

b. Vendor shall plan, schedule and perform at least one design review prior to starting construction of CT system.

c. Vendor shall demonstrate or provide detailed explanations of any proposed changes to the initial design from the accepted configuration as established in response to the Request for Quote, provided that such change(s) do not negatively impact any system performance or safety requirements.

d. Vendor shall make any modifications to design documents as directed by NASA that are for the purpose of meeting the requirements set forth in this document.

e. Vendor shall not begin construction of CT/DR system until NASA has approved all design drawings, specifications and component selections, indicated by NASA and vendor signatures accepting design and the contracting officer issuing an authority to proceed.

15. Factory Acceptance Test (FAT)

a. Upon completing construction and internal testing of the CT/DR system, the vendor shall plan, schedule and perform a FAT at the vendor's facility.

   i. Requirements and conditions shall be established by NASA.

   ii. FAT testing shall include inspection of:

      1. Test article(s) provided by NASA.

      2. Vendor provided test article that is 60" height by 60" diameter (or width). Vendor provided test article shall be delivered to NASA after successful FAT testing to provide performance comparison data during the onsite acceptance test.

   iii. FAT testing shall include the demonstration of technical performance requirements set forth in sections 8, 9, 10, 11 and 12 as follows:

      1. Successful demonstration of all software functions listed in section 8 of this document.

      2. CT inspection of 60" x 60" test article in standard acquisition mode, mosaic (stitching) mode, helical acquisition mode and subpixel acquisition mode.

      3. DR inspection of 60" x 60" test article in standard acquisition mode, mosaic (stitching mode) mode, helical acquisition mode and subpixel acquisition mode.

   iv. A checklist containing every requirement of the FAT test shall be produced and provided by NASA one month prior to the scheduled FAT test.

   v. FAT testing shall include inspection of one or more test article(s) provided by NASA and inspected with optimum technique settings selected by vendor to provide performance comparison data for onsite acceptance test (OSAT).

vi. FAT testing shall include system performance measurements using test articles and phantoms in compliance with ASTM Standards E1695, E2737, E2698 and E3375 to provide comparison data for onsite acceptance test (OSAT).

1. Vendor shall provide the test articles and phantoms for use during the FAT and OSAT testing.
2. Test articles shall become the property of NASA upon final system acceptance.
3. Specific articles to be used in system performance measurements shall include:
    a. Two cylinder phantoms fabricated to the requirements of ASTM E1695 Section 5, one in acrylic or similar material and one in aluminum.
    b. Two duplex phantoms with line pair gauges fabricated to the requirements of ASTM E2737 Section 9, one each in aluminum and Inconel.

vii. FAT testing shall include the testing of all elements of the safety system (each e-stop button, each interlock switch, warning lights, and audible alarms).

viii. Vendor shall fulfill all requirements of the FAT test.

ix. Once the FAT test has been completed and results approved by NASA, the contracting officer shall issue an authority to proceed for delivery to MSFC.

16. Delivery

a. The CT/DR system shall be packaged/crated and shipped to NASA via vendor or commercial carrier at vendor expense.

    i. The entire CT/DR system and all components thereof shall be fully insured and indemnified against loss, damage, theft, or any other circumstance that causes a failure to deliver the system in its full working capacity once installed.

b. The system shall be delivered to NASA's Central Receiving station at NASA/Marshall Space Flight Center, Central Receiving Facility Building 4631, MSFC, AL 35812 for initial property documentation and processing.

    i. The system shall remain onboard the shipping vehicle during this process.

c. Upon completion of property receipt documentation and processing, the shipping vehicle shall deliver the system to MSFC Building 4707, Apollo Road, MSFC, AL 35812 and offloaded by NASA rigging service into the large hallway adjacent to the CT cell Room 137 in that building.

17. Installation

a. The vendor shall completely install the CT/DR system in building 4707, rooms 136 (control room) and 137 (CT cell).

    i. Vendor shall provide all tools, fasteners, shop aids, accessories and other items required to complete the system installation.

b. The CT/DR system's frame, towers, turntable and detector shall be operable in the CT cell's dimensions of 50 feet clear length, 19 feet clear width and 14 feet clear vertical space.

c. All sub-components of the CT/DR system must be able to clear a bay door height of 13 feet clear and 10 feet width clear.

d. All components shall be moved into rough installation location by NASA rigging service.

e. System shall be installed such that one side of the long axis footprint provides clearance to maneuver a 50" wide, 135" long (blade tip to back end) forklift for placement and removal of test objects on the system turntable.

f. Assembled system and components shall be aligned along all axes per vendor's processes.

g. Vendor shall perform an initial comprehensive radiation survey of all occupied areas adjacent to CT Cell room 137 as well as the roof and shall provide a copy of the completed survey to NASA.

h. Vendor shall provide a complete set of mechanical drawings, wiring diagrams, alignment and maintenance procedures for the as-built system in printed and digital formats.

18. Onsite Acceptance Test (OSAT)

a. Upon completion of installation, the vendor shall perform an OSAT that is identical in content to the FAT test.

    i. Vendor shall fulfill all requirements of the OSAT.

    ii. OSAT testing shall be conducted on the same test articles from the FAT utilizing the same technique settings as used in the FAT testing.

    iii. Performance of the delivered and installed system in OSAT must meet or exceed all performance results collected during FAT testing.

        1. OSAT failure to meet or exceed performance results of FAT testing shall be corrected by vendor as part of successful completion of OSAT test.

    iv. OSAT test shall include testing of the entire safety system installed by vendor.

19. Warranty

a. All components of the CT/DR system shall be warranted against any failure for a period of one year (12 months) beginning upon NASA acceptance of the installed and onsite tested system.

b. User replacement of any user-serviceable part with same make and model part shall not void any warranty terms.

    i. Lights, strobes, interlock switches, e-stop buttons and alarm buzzer shall be considered user-serviceable parts.

c. All costs for parts, labor, travel, lodging and per diem expenses and any other costs required to fulfill warranty obligations during the warranty period shall be paid by the vendor.