



**CONTINUATION SHEET****Reference No. of Document Being Continued**

Page 2 of 17

PIIN/SIIN DAAE07-01-C-L075

MOD/AMD P00006

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

## SECTION A - SUPPLEMENTAL INFORMATION

CONTRACT FOR: Fracture Studies

PRIOR AMOUNT OBLIGATED: \$622,000.00

AMOUNT OBLIGATED THIS ACTION: \$ 0.00

TOTAL AMOUNT OBLIGATED: \$622,000.00

1. This is a bilateral, no-cost modification.
2. The purpose of this modification is to extend the entire contract by 60 days, including the completion dates for the individual CLINs.
3. The contract is being extended due to delays by MSU in completing several sub-tasks, due to the need to order and wait for necessary equipment.
4. To implement the changes listed in Paragraph 2 above the following parts of the contract are revised:
  - a) SubCLIN 0007AA in Section B is revised to list a new completion date of 15 Jul 04 (it was 15 May 04).
  - b) SubCLIN 0008AA in Section B is revised to list a new completion date of 15 Jul 04 (it was 15 May 04).
  - c) SubCLIN 0009AA in Section B is revised to list a new completion date of 15 Jul 04 (it was 15 May 04).
  - d) SubCLIN 0010AA in Section B is revised to list a new completion date of 15 Jul 05 (it was 15 May 05).
  - e) SubCLIN 0012AA in Section B is revised to list a new completion date of 15 Jul 04 (it was 15 May 04).
  - f) SubCLIN 0013AA in Section B is revised to list a new completion date of 15 Jul 05 (it was 15 May 05).
  - g) Provision C.6.3 is revised to list the new completion date of 15 Jul 04 for Task 1, SubCLIN 0007AA.
  - h) Provision C.6.5 is revised to list the new completion date of 15 Jul 04 for Task 1, SubCLIN 0007AA and to change the due date for the draft Final Report to 15 Jun 04, with the due date for the Final Report changed to 15 Jul 04.
  - i) Provision C.6.7 is revised to list the deliverables due date under SubCLIN 0007AA as now due by 15 Jul 04.
  - j) Provision C.7.3 is revised to list the new completion date of 15 Jul 04 for Option 3, SubCLIN 0009AA.
  - k) Provision C.7.5 is revised to list the new completion date of 15 Jun 04 for submission of the draft Final Report and 15 Jul 04 for submission of the Final Report under Option 3, SubCLIN 0009AA.
  - l) Provision C.8.3 is revised to list the start date of 16 Jul 04 for Option 4, SubCLIN 00010AA and the new completion date of 15 Jul 05.
  - m) Provision C.8.5 is revised to list the new due dates for the draft Final Report for SubCLIN 0010AA as being 15 Jun 05 and for submission of the Final Report of 15 Jul 05.
  - n) Provision C.8.7 is revised to list the new due date for the deployable nondestructive inspection device as being due by 15 Jul 05 (was due 15 May 05) unless Option 5 is exercised, in which case this device would be due by 15 Jul 06 instead.
  - o) Provision C.8.8 is revised to list the new due date for the computer-aided design (CAD) procedure as being due by 15 Jul 05 (was 15 May 05), unless Option 5 is exercised in which case it would be due by 15 Jul 06.
  - p) Provision C.9.2 is revised to change the final date for the possible exercise of Option 5 to 15 Jul 05 (it was 15 May 05).
  - q) Provision C.9.3 is revised to list the new performance period for Option 5, if that option is exercised, as being from 16 Jul 05 to 15 Jul 06.
  - r) Provision C.9.5 is revised to list the new due date for the draft Final Report under Option 5, if Option 5 is exercised, as being 15 Jun 06 (was 15 Apr 06) and the Final Report by 15 Jul 06 (was 15 May 06).
  - s) Provision C.9.7 is revised to list the new delivery date of 15 Jul 06 (was 15 May 06), if Option 5 is exercised.
  - t) Provision C.9.8 is revised to list a new due date for a CD\_ROM which incorporates the CAD procedure by 15 Jul 06 (it was 15 May 06), if Option 5 is exercised.
  - u) Provision C.10.3 is revised to list the new due date of 15 Jul 04 for the basic effort under Task 2 in SubCLIN 0008AA (it was 15 May 04).
  - v) Provision C.10.5 is revised to list the new due date of 15 Jun 04 (was 15 Apr 04) for submission of the draft Final Report due under SubCLIN 0008AA and to list the new due date of 15 Jul 04 for the Final Report submitted under SubCLIN 0008AA (it was 15 May 04).
  - w) Provision C.11.3 is revised to list the new due date of 15 Jun 04 for submission of the draft Final Report under SubCLIN 0012AA (it was 15 Apr 04) and to list the new due date of 15 Jul 04 for submission of the Final Report due under SubCLIN 0012AA (it was 15 May 04).
  - x) Provision C.12.3 is revised to list the new performance period for Option 7 under SubCLIN 0013AA of 16 Jul 04 to 15 Jul 05 (it was 16 May 04 to 15 May 05).
  - y) Provision C.12.5 is revised to list the new due date of 15 Jun 05 for submission of the draft Final Report under SubCLIN 0013AA (it was 15 Apr 05) and to list the new due date for submission of the Final Report under SubCLIN 0013AA of 15 Jul 05 (it was 15 May 05).
  - z) Provision C.12.7 is revised to list the new due date for delivery of a CD-ROM for new CAD design for thick section composites of 15 Jul 05, if Option 8 is not exercised, and a new due date of 15 Jul 06, if Option 8 is exercised.
  - aa) Provision C.13.2 is revised to change the end of the option exercise period for Option 8 to 15 Jul 05 (it was 15 May 05).

**CONTINUATION SHEET****Reference No. of Document Being Continued****Page 3 of 17**

PIIN/SIIN DAAE07-01-C-L075

MOD/AMD P00006

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

- bb) Provision C.13.3. is revised to list the new performance completion date of 15 Jul 06 for Option 8, if Option 8 is exercised (it was 15 May 06).
- cc) Provision C.13.5 is revised to list the new due date for submission of the draft Final Report due under Option 8 of 15 Jun 06 (it was 15 Apr 06), if Option 8 is exercised, and to list the new due date of 15 Jul 06 for submission of the Final Report (it was 15 May 06) if Option 8 is exercised.
- dd) Provision F.3.3 is revised to list the new due dates for the Option 4 deliverables of 15 Jul 05 (it was 15 May 05).
- ee) Provision F.3.4 is revised to list a new due date of 15 Jul 06 (it was 15 May 06) for deliverables due under Option 5, if Option 5 is exercised.
- ff) Provision F.3.5 is revised to list a new due date of 15 Jul 05 (it was 15 May 05) for deliverables due under Option 7, if Option 8 is not exercised.
- gg) Provision F.3.6 is revised to list a new due date of 15 Jul 06 (it was 15 May 06) for deliverables due under Option 8, if Option 8 is exercised.
- hh) Provision F.4 is revised to change the current contract completion date to 15 Jul 05 (it was 15 May 05).
- ii) Provision H.16.3.2 is revised to list the new performance period for Option 3 which extends to 15 Jul 04 (it was 15 May 04).
- jj) Provision H.16.4.2 is revised to list the new date of 16 Jul 04 for the beginning of the Option 4 performance period (it was 16 May 04) and to list the new date of 15 Jul 05 (it was 15 May 05) for completion of the Option 4 effort.
- kk) Provision H.16.5.2 is revised to list the new end date of 15 Jul 05 (it was 15 May 05) for the exercise of Option 5, and list a new performance period for Option 5, if its exercised from 16 Jul 05 to 15 Jul 06 (it was 16 May 05 to 15 May 06).
- ll) Provision H.16.6.2 is revised to list the new performance period for Option 6 as from the time Option 6 was exercised to 15 Jul 04.
- mm) Provision H.16.7.2 is revised to list the new performance period for Option 7 from 16 Jul 04 to 15 Jul 05 (it was 16 May 04 to 15 May 05).
- nn) Provision H.16.8.2 is revised to list the new option exercise period for Option 8 as extending to 15 Jul 05 (it was 15 May 05) and the new performance period for Option 8, if it is exercised, from 16 Jul 05 to 15 Jul 06 (it was 16 May 05 to 15 May 06).
5. The total contract amount remains unchanged.
6. The effective date for this modification is 15 May 04.
7. All other terms and conditions of the contract, as previously modified, remain unchanged.

\*\*\* END OF NARRATIVE A 006 \*\*\*



CONTINUATION SHEET

Reference No. of Document Being Continued  
 PIIN/SIIN DAAE07-01-C-L075 MOD/AMD P00006

Name of Offeror or Contractor: BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

ITEM NO	SUPPLIES/SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	001                      0                      15-JUL-2004  \$                      50,000.00				
0010AA	<u>SERVICES LINE ITEM</u>  NOUN: OPTION 4 PRON: E142C121EH    PRON AMD: 01    ACRN: AD AMS CD: 622601C0511  <u>Inspection and Acceptance</u> INSPECTION: Destination    ACCEPTANCE: Destination  <u>Deliveries or Performance</u> DLVR SCH                      PERF COMPL <u>REL CD</u> <u>QUANTITY</u> <u>DATE</u> 001                      0                      15-JUL-2005  \$                      158,000.00				\$ 158,000.00
0012AA	<u>SERVICES LINE ITEM</u>  NOUN: OPTION 6 PRON: E142C122EH    PRON AMD: 01    ACRN: AD AMS CD: 622601C0511  <u>Inspection and Acceptance</u> INSPECTION: Destination    ACCEPTANCE: Destination  <u>Deliveries or Performance</u> DLVR SCH                      PERF COMPL <u>REL CD</u> <u>QUANTITY</u> <u>DATE</u> 001                      0                      15-JUL-2004  \$                      50,000.00				\$ 50,000.00
0013AA	<u>SERVICES LINE ITEM</u>  NOUN: OPT ION 7 PRON: E142C123EH    PRON AMD: 01    ACRN: AD AMS CD: 622601C0511  <u>Inspection and Acceptance</u> INSPECTION: Destination    ACCEPTANCE: Destination				\$ 144,000.00



**CONTINUATION SHEET****Reference No. of Document Being Continued**

Page 7 of 17

PIIN/SIIN DAAE07-01-C-L075

MOD/AMD P00006

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

## SECTION C - DESCRIPTION/SPECIFICATIONS/WORK STATEMENT

## C.1 SCOPE OF WORK

The Contractor as an independent Contractor and not as an agent of the Government shall conduct basic research on Polymeric Matrix composites (PMC) Metal Matrix composite (MMC) materials. The contractor shall be responsible for completing all tasks described below.

## C.1.1 The following tasks shall be performed by the contractor:

Task A: Mechanics of Composite to Metal Joints.

Task B: Crack Length Measurement in MMC Using Digital Speckle Pattern Interferometry

Task C: High Velocity Impact Studies of Thick Section Composites

## C.2 TASK DETAILS

## C.2.1 TASK A - Composite Joints

The objective of Task A is for the contractor to analyze, using theory, computational mechanics, and experimental techniques, the three-dimensional strain state and strength of a single-fastener bolted joint between a thick section composite and metal.

C.2.1.1 TASK A.1. The contractor shall perform surface strain analysis for a single-lap joint between polymer and metal using digital speckle pattern interferometry (DSPI) or Moire interferometry.

C.2.1.2 TASK A.2 The contractor shall perform stress analysis in the plane of symmetry using embedded polariscope photoelasticity for single-lap joint for composite and metal.

C.2.1.3 TASK A.3 The contractor shall perform surface strain analysis for the single-lap joint between composite and metal using digital speckle pattern interferometry (DSPI) or Moire interferometry.

C.2.1.4 TASK A.4 The contractor shall perform stress analysis in the plane of symmetry using embedded polariscope photoelasticity for a single-lap joint for composite and metal.

C.2.1.5 TASK A.5 The contractor shall construct a finite-element model to predict the three-dimensional stress distribution on the plane of symmetry of the single-lap joint between the isotropic polymer and metal.

C.2.1.6 TASK A.6 The contractor shall determine through a review of literature if there are any closed-form analytical solutions that apply to these problems, and, if so, perform the appropriate calculations.

C.2.1.7 TASK A.7 The contractor shall compare the results obtained by theory, computation, and experiment.

## C.2.2 TASK B - Digital Speckle Interferometry

The contractor shall use the software and hardware developed in Contract DAAE07-00-P-L063 for automated measurement of crack length using DSPI. The contractor shall also conduct experiments to assess the feasibility and limitations on using the DSPI device and software in the testing laboratory environment for measurement of crack length.

## C.2.3 TASK C - High-Velocity Impact Studies on Thick-Section Composites

The objective of Task C is for the contractor to develop a force measuring system for free projectiles for use in high velocity impact testing of thick section composites using MSU's nitrogen gas gun and to study the composite material response and impact loading history when subjected to high velocity impact.

C.2.3.1 TASK C.1 The contractor shall build a force measuring system using transducers and accelerometers attached to the projectile for use in the nitrogen gas gun to measure the material response and the loading history in composites when subjected to high velocity impact. The contractor shall develop the hardware and software to acquire and process the experimental data during high velocity impact tests.

C.2.3.2 TASK C.2 The contractor shall study the thickness effects in glass/epoxy composite laminates of 0.125 inches, 0.25 inches, 0.5 inches, and 1.00 inches thickness when subjected to high velocity impact, using the force measuring and data acquisition system developed in Task C.1.

## C.3 DELIVERABLES

## C.3.1 Status Reports

The contractor shall prepare and submit three (3) status reports in accordance with Data Item A001, Exhibit A. The first Status Report

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

shall be due by September 28, 2001, the second Status report shall be due by December 14, 2001 and the third Status report shall be due by March 1, 2002. The status reports shall briefly summarize work completed to date on the contract with specific reference to the contract tasks completed, the contract tasks still not completed, and any significant accomplishments, problems or delays. The status reports shall also report all total costs incurred to date, with specific reference to the costs incurred since the last status report was submitted.

**C.3.2 Status Review**

The contractor shall provide a Status Review summarizing the preliminary results of all work conducted under this contract to date to TARDEC by September 15, 2001, in accordance with Data Item A002, Exhibit A.

**C.3.3 Final Technical Report**

The contractor shall prepare a draft Final Report in accordance with Data Item A003, Exhibit A, by April 15, 2002. The government will provide comments regarding this draft back to the contractor by April 30, 2002 and the contractor shall submit a Final Technical Report by May 15, 2002, also in accordance with Data Item A003, Exhibit A. The Final Technical Report shall describe in detail the final outcome of all contract tasks (For example was a specific task completed? Was a task completed without any specific problems? What findings were made in accomplishing this task?). The Final Report shall also describe in detail all the significant problems, accomplishments and findings from performance of the contract as a whole.

**C.4 OPTION 1**

The Government has the unilateral right to exercise Option 1 in accordance with the terms and conditions of the Section H clause entitled "Exercise of Option".

**C.4.1 The contractor shall perform the following tasks in the event that Option 1 is exercised by the Government.****C.4.1.1 Option 1 - Task A: Composite Joints**

a) The contractor shall expand the test matrix to include at least two (2) arrays of fasteners to study the interactions of stress fields between bolt holes for the single lap joint strength and stiffness.

b) The contractor shall study the effects of a number of installation parameters such as bolting torque and washer type and size on the joint strength and stiffness.

c) The contractor shall measure the 3-dimensional stresses on other planes, particularly the transverse planes tangent to the hole, to correlate these stresses to shear (tear-out) failure modes in the joint.

**C.4.1.2 Option 1 - Task B: Theories of Penetration and Perforation of Composite Laminates:**

The contractor shall develop a quantitative interaction between impactor and composite laminates. The contractor shall utilize the results of the research conducted thus far on this contract to review and possibly propose a new theory for composite laminates as well as to propose new methods to improve the high-velocity impact resistance of composite laminates.

C.4.2 The contractor shall deliver quarterly status reports during the performance of Option 1, in accordance with the terms and conditions of the Section F clause entitled "Option Deliverables" and (CDRL) Data Item A001 in Exhibit A.

C.4.3 The contractor shall deliver a Final Technical Report upon the conclusion of Option 1, in accordance with the terms and conditions of the Section F clause entitled "Option Deliverables" and (CDRL) Data Item A003, in Exhibit A.

**C.5 OPTION 2 (DELETED)****C.6 Task 1: Thick Section Composite Joint Research****C.6.1 Introduction**

The contractor shall perform Task 1, incorporated in CLIN 0007 and SubCLIN 0007AA of Section B of the contract, involving full-field optical methods, deployable nondestructive inspection device and computer aided design for thick section composite joints. The contractor will conduct this research in these three related areas:

a) Develop three-dimensional experimental and computational techniques that are appropriate for research on fastening of thick composites in Army ground vehicles.

b) Investigate experimentally and computationally the three-dimensional stress/strain fields for thick-section composite-to-

Name of Offeror or Contractor: BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

metal joints. It may also include composite armor-to-metal. The composite armor would consist of lightweight advanced material layers such as S-Glass epoxy, Graphite/epoxy and ceramic materials. The lightweight metals would include titanium and aluminum. This research will lead to establishment of computer-aided design (CAD) procedures for mechanical joints subjected to static loads in armored vehicles. The joints include structural components made from composites, metals and ceramic material.

c) Develop and test a device that can be used for field inspection and assessment of structural integrity of composite and ceramic plates and bolted joints that involve combinations of composite, ceramic, and metal that are relevant to the Future Combat Systems (FCS) mission. The device will be based on speckle interferometry technology and utilize inventions that have been patented by the Principal Investigator (PI) with Michigan State University.

#### C.6.2 Task 1: Basic Effort

The contractor shall perform the following under the basic effort on Task 1:

(1) Develop a fiber reinforced polymer (FRP) composite material that is sufficiently transparent and birefringent to facilitate photoelasticity analysis of FRP.

(2) Find and obtain transparent birefringent ceramic for photoelasticity study of joints in ceramic armor.

(3) Develop technique for digital speckle Interferometry to determine strains on interior planes of specimens.

(4) Update the library of references on fastening of composites and enter these references into a comprehensive computerized database.

(5) Explore experimentally the strain fields on surface and 2 internal planes of single lap bolted joint for a thick composite bonded to metal or composite frame. The internal planes to be examined include the through-thickness medial bearing plane and the through-thickness tear-out plane.

(6) Conduct 3-dimensional finite element analysis of the composite-metal and/or composite-composite joints to assess agreement between analysis and the results of the experiments described in C.6.2(5).

(7) Test the feasibility of performing digital speckle Interferometry on objects that undergo large rigid body displacements.

C.6.3 The period of performance for the basic effort on Task 1 will be 12 months, from the award of Modification P00003 in June 2003 to July 15, 2004.

C.6.4 The contractor shall submit status reports every 90 days regarding his performance of Task 1, beginning 90 days after the start of the basic effort performance period, in accordance with Data Item A001, Exhibit A. These status reports will be combined with the status reports submitted on any other work simultaneously being performed under the contract including Task 2, incorporated in Clause C.10, and including any exercised options.

C.6.5 The contractor shall submit to the government a draft Final Technical Report by July 15, 2004, 30 days before completion date for the basic effort on Task 1 of July 15, 2004, in accordance with Data Item A001, Exhibit A. The government will have 15 days to provide comments on the contractor's draft report. The contractor's Final Technical Report shall be due by July 15, 2004. The contractor's draft Final Technical Report and Final Technical Report will be combined with the draft Final Technical Report and Technical Report being submitted on the basic effort on Task 2 (see Clause C.10) and on Option 3 and Option 6 if one or both of those options have been exercised.

C.6.6 The total cost for performing the basic effort on Task 1, listed in C.6.2, shall not exceed \$75,000.00.

C.6.7 If Option 4 in C.8 is not exercised by the government the contractor shall deliver to the government COTR by July 15, 2004, at the COTR's mailing address listed in the Section G "Communications" clause, a CD-ROM which incorporates the computer-aided (CAD) design procedure for mechanical joints subjected to static loads to join composites, metals and ceramics for use in Army ground vehicles, in accordance with Data Item A004, Exhibit A. However, if Option 4 is exercised by the government this CD-ROM will not be delivered by July 15, 2004 but upon completion of the last Task 1 option which has been exercised by the government.

#### C.7. Option 3: Continuing Research on Task 1 (2003-2004)

The government has the unilateral right to exercise Option 3, incorporated in CLIN 0009 in Section B of the contract, for continuing research on Task 1, in accordance with the Section H clause entitled "Exercise of Option".

C.7.1 The contractor shall perform the following tasks if Option 3 is exercised:

(1) Test the composite-to-metal bolted joint at successively higher loads to determine if failure mode correlates with calculated and measured stresses. The loads and test procedure will be guided by the FRP material developed under C.6.2(1) and the results of the experiment and analysis described in C.6.2(5) and (6) above.

(2) Design a rugged portable device that can be used for field inspection of structural integrity of composite panels and joining.

C.7.2 The government may exercise Option 3 any time up to January 15, 2004, in accordance with the Section H clause entitled "Exercise

**CONTINUATION SHEET****Reference No. of Document Being Continued****Page 10 of 17**

PIIN/SIIN DAAE07-01-C-L075

MOD/AMD P00006

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

of Option".

C.7.3 The performance period for Option 3 will begin when it is exercised, but not later than January 15, 2004, and end on July 15, 2004, in accordance with the Section H clause entitled "Exercise of Option".

C.7.4 The contractor will submit a status report every 90 days to summarize progress of the work being performed under Option 3, in accordance with the Section F clause entitled "Option Deliverables", the Section H clause entitled "Exercise of Option" and Data Item A001, Exhibit A. The status reports for Option 3 will be combined with the status reports being submitted on all other work being performed on the contract so that only one overall status report will be submitted on all work being performed under the contract every 90 days.

C.7.5 The contractor shall submit a draft Technical Final Report by June 15, 2004, in accordance with the Section H clause entitled "Exercise of Option", the Section F clause entitled "Option Deliverables" and Data Item A003, Exhibit A. The government will have 15 days to review this draft report and provide comments on it back to the contractor. The contractor will submit the Final Technical Report by July 15, 2004. The draft Final Technical Report and the Final Technical Report for Option 3 will be combined with the draft Final Technical Report and Final Technical Report required under C.6 for the basic effort for Task 1.

C.7.6 The total amount for Option 3 will not exceed \$50,000.00.

C.8 Option 4: Continuing Research on Task 1 (2004-2005)

The government has the unilateral right to exercise Option 4, incorporated in CLIN 0010 in Section B of the contract, to perform continuing research on Task 1, in accordance with the Section H clause entitled "Exercise of Option".

C.8.1 The contractor shall perform the following tasks if Option 4 is exercised:

(1) Refine 3-dimensional digital speckle interferometry technique and apparatus developed under C.6.2(3) to determine strains and displacements on interior planes of 3-dimensional specimens.

(2) Develop and test the feasibility of a technique involving high-speed image acquisition and advanced computer processing for performing digital speckle Interferometry on moving specimens.

(3) Fabricate and test a pilot model of the deployable nondestructive inspection device developed under C.7.1(2)

(4) Explore experimentally the strain fields on surface and 2 interior planes for single lap joint to ceramic bonded to metal or other composite material.

(5) Explore experimentally the strain fields on surface and 2 interior planes for single lap bolted joint of composite material and metal where a spring washer is used.

(6) Perform finite element analysis of:

(i) the ceramic to metal or composite material bolted joint in C.8.1(5)

(ii) the bolted joint of composite material to metal that uses a spring washer.

(7) Investigate experimentally the effects of interference fits of fasteners on surface and interior strain fields for bolted joint of composite and metal.

(8) Determine the extent to which existing design codes for fastenings, including those design codes in Military Handbook-17-3E, Section 5.3, Page 5-31, support the findings of the experiments conducted so far under this contract that involve determination of strains in bolted joinings of composite material to metal, ceramic to composite material or metal using a spring washer.

C.8.2 The government may exercise Option 4 any time up to May 15, 2004, in accordance with the Section H clause entitled "Exercise of Option", as long as Option 3 has been exercised.

C.8.3 The performance period for Option 4 will begin on July 16, 2004 and end on July 15, 2005, in accordance with the Section H clause entitled "Exercise of Option".

C.8.4 The contractor shall submit a status report every 90 days which reports on the progress of the work being performed on Option 4, in accordance with the Section F clause entitled "Option Deliverables", the Section H clause entitled "Exercise of Option", and Data Item A001, Exhibit A. The status reports for Option 4 will be combined with the status reports on all other work being performed on the contract so that only one overall status report will be submitted on all work being performed, every 90 days.

C.8.5 The contractor shall submit a draft Final Technical Report by June 15, 2005, in accordance with the Section H clause entitled "Exercise of Option", the Section F clause entitled "Option Deliverables" and Data Item A003, Exhibit A. The government will have 15 days to review this draft report and provide comments on it back to the contractor. The contractor will submit the Final Technical Report by May 15, 2005.

C.8.6 The total amount for Option 4 will not exceed \$158,000.00.

C.8.7 The contractor will deliver the pilot model of the deployable nondestructive inspection device listed in C.8.1(3), along with

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

the instructions for that device, by July 15, 2005 to the COTR at the COTR's mailing address listed in the Section G "Communications" clause, unless Option 5 in C.9 is exercised. If Option 5 in C.9 is exercised the contractor will not deliver the deployable nondestructive device, with the operating and instruction instructions, to the COTR until the completion date of July 15, 2006 for Option 5 in accordance with C.9.7.

C.8.8 If Option 5 in C.9 is not exercised by the government the contractor shall deliver to the government COTR by July 15, 2005, a CD-ROM which incorporates the computer-aided (CAD) design procedure for mechanical joints subjected to static loads to join composites, metals, and ceramics for use in Army ground vehicles, in accordance with Data Item A004, Exhibit A. However, if Option 5 in C.9 is exercised by the government this CD-ROM will not be delivered by July 15, 2005 but upon completion of Option 5 on July 15, 2006.

C.9 Option 5: Continuing Research on Task 1 (2005-2006)

The government has the unilateral right to exercise Option 5, incorporated in CLIN 0011 in Section B of the contract, to perform continuing research on Task 1, in accordance with the Section H clause entitled "Exercise of Option".

C.9.1 The contractor shall perform the following tasks if Option 5 is exercised:

(1) Test and further develop the deployable nondestructive inspection device for use as a possible prototype, the pilot model of which was developed and first tested in C.8.1(3). The objective is to converge to a field model that can detect damage in small areas of composite structures in the field

(2) Refine the methodology defined in C.8.1(2). The objective is to measure strains with a sensitivity of at least 100 microstrain on the surface of objects moving at speeds up to at least 100 mm/sec.

(3) Measure the strain fields on surface and 2 interior planes for single lap bolted joint of composite or ceramic joined to metal where 2 types of hole inserts are used. The goal is to determine whether hole inserts can be used to improve the performance of bolted joints of thick composite or ceramic materials and metal.

(4) Perform finite element analysis of the cases studied under C.9.1(3).

(5) Fabricate and test one configuration of a hybrid repairable adhesive-bolted joint to demonstrate feasibility.

(6) Use the results obtained under C.9.1(2) above to determine the feasibility of experimentally determining stress field resulting from the interaction of shock wave and mechanical fastener.

(7) Test joinings studied so far to failure to determine whether failure modes are adequately predicted by experimental and finite analyses conducted.

(8) Formulate improvements in commonly accepted American Society of Mechanical Engineers (ASME) and other codes, including codes listed in the Military Handbook-17-3E, Section 5.3, Page 5-31, for design of mechanical fastening of thick composite materials.

C.9.2 The government may exercise Option 5 any time up to July 15, 2005, in accordance with the Section H provision entitled "Exercise of Option", as long as Option 4 has been exercised.

C.9.3 The performance period for Option 5, if Option 5 is exercised by the government, will begin on July 16, 2005 and end on July 15, 2006, in accordance with the Section H provision entitled "Exercise of Option".

C.9.4 The contractor shall submit a status report every 90 days which reports on the progress of the work being performed under Option 5, in accordance with the Section F clause entitled "Option Deliverables", the Section H clause entitled "Exercise of Option", and Data Item A001, Exhibit A, if Option 5 is exercised by the government. The status reports for Option 5 will be combined with the status reports on all other work being performed on the contract so that only one overall status report will be submitted on all work being performed on the contract, every 90 days.

C.9.5 The contractor shall submit a draft Final Technical Report by June 15, 2006, in accordance with the Section H clause entitled "Exercise of Option", the Section F clause entitled "Option Deliverables" and Data Item A003, Exhibit A, if Option 5 is exercised by the government. The government will have 15 days to review this draft report and provide comments on it back to the contractor. The contractor will submit the Final Technical Report by July 15, 2006. The final report submitted under Option 5 shall include the work done under this option and this contract pertaining to a full-field optical stress capability for layered laminates made from composites, ceramics, and metals.

C.9.6 The total amount for Option 5 will not exceed \$120,000.00.

C.9.7 The contractor shall deliver the deployable nondestructive inspection device, which was refined and tested under C.9.1(1), to the COTR at the COTR's mailing address listed in the Section G clause entitled "Communications" by July 15, 2006, if Option 5 is exercised by the government.

C.9.8 The contractor shall deliver to the government COTR by July 15, 2006, if Option 5 is exercised by the government, a CD-ROM which incorporates the computer-aided (CAD) design procedure for mechanical joints subjected to static loads to join composites, metals and ceramics for use in Army ground vehicles, in accordance with Data Item A004, Exhibit A.

C.10 Task 2: High Velocity Impact Studies

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## C.10.1 Introduction

The contractor shall perform Task 2, incorporated in CLIN 0008, SubCLIN 0008AA of Section B of the contract, involving investigating the response of composite materials and joints subjected to high velocity impact loading. This research will also identify the damage mechanisms of composite laminates and joints during high-velocity impact. The major studies to be performed under Task 2 are:

- (1) Optimization of three-dimensional woven composites.
- (2) Development of innovative composite joining.
- (3) Development of a novel high-speed impact testing device (700 meters/second)
- (4) Development of Impact damage models.
- (5) Analysis of high-velocity impact in composite joints using new composite theoretical models.

## C.10.2 The contractor shall perform the following under the basic effort of Task 2:

(1) Identify a composite material consisting of S-glass, Kevlar, HS-graphite fabrics, or combination of them and a polymer matrix and fabricate a minimum of at least 30 composite panels. The in-plane dimensions of the composite panels will be around 150 mm x 150 mm and the thicknesses will range from 12.5mm and 37.5mm.

(2) Design and fabricate innovative joints for thick composite panels based on:

- (i) conventional mechanical fastening with modifications accounting for thickness effects
- (ii) combinations of finger-joint and scarf-joint designs
- (iii) combinations of mechanical fastening and adhesive bonding

(3) Design a high-velocity impact testing system consisting of a shock tube (a high-pressure gas generator), a piston impactor (a force generator), and a vacuum target chamber (for safety protection). The impact velocity of the impactor should reach up to 700m/s.

(4) Build two numerical models and perform a numerical simulation for each of the composite panels and composite joints, identified in C.10.2(1) and (2), subjected to impact loading.

C.10.3 The period of performance for the basic effort on Task 2 will be from the award of Modification P00003 in June 2003 to July 15, 2004.

C.10.4 The contractor shall submit status reports every 90 days regarding his performance on Task 2, in accordance with Data Item A001, Exhibit A. These status reports will be combined with the status reports submitted on any other work simultaneously being performed under the contract including Task 1, incorporated in Clause C.6, and including any exercised options.

C.10.5 The contractor shall submit to the government a draft Final Technical Report by June 15, 2004, 30 days before the completion date of July 15, 2004 for the basic effort on Task 2, in accordance with Data Item A001, Exhibit A. The government will have 15 days to provide comments on the contractor's draft report. The contractor's Final Technical Report shall be due by July 15, 2004. The contractor's draft Final Technical Report and Final Technical Report will be combined with the draft Final Technical Report and Final Technical Report being submitted on the basic effort on Task 1 (see Clause C.6) and on Option 3 and/or 6 if either of those options has been exercised.

C.10.6 The total cost for performing the basic effort on Task 2, listed in Clause C.10.2, shall not exceed \$75,000.00.

## C.11 Option 6: Continuing Research on Task 2 (2003-2004)

The government has the unilateral right to exercise Option 6, incorporated in CLIN 0012 in Section B of the contract, to perform continuing research on Task 2, in accordance with the Section H clause entitled "Exercise of Option".

## C.11.1 The contractor shall perform the following task if Option 6 is exercised:

Construct the high-velocity impact testing system consisting of the shock tube, the piston impactor, and the vacuum target chamber identified in C.10.2(3).

C.11.2 The government may exercise Option 6 any time up to January 15, 2004, in accordance with the Section clause entitled "Exercise of Option".

C.11.3 The performance period for Option 6 will begin when it is exercised but not later than January 15, 2004, and will end on July 15, 2004, in accordance with the Section H clause entitled "Exercise of Option".

C.11.4 The contractor shall submit a status report every 90 days which reports on the progress of the work being performed under Option 6, in accordance with the Section F clause entitled "Option Deliverables", the Section H clause entitled "Exercise of Option", and Data Item A001, Exhibit A. The status reports for Option 6 will be combined with the status reports being submitted on\* all other work being

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performed under the contract so that only one overall status report will be submitted on all work being performed every 90 days.

C.11.5 The contractor shall submit a draft Final Technical Report by June 15, 2004, in accordance with the Section F clause entitled "Option Deliverables", the H clause entitled "Exercise of Option" and Data Item A003, Exhibit A. The government will have 15 days to review this draft report and provide comments back on it to the contractor. The contractor will submit the Final Technical Report by July 15, 2004. The draft Final Technical Report and the Final Technical Report for Option 6 will be combined with the draft Final Technical Report and the Final Technical Report required under C.10 for the basic effort for Task 2.

C.11.6 The total amount for Option 6 will not exceed \$50,000.00.

C.12 Option 7: Continuing Research on Task 2 (2004-2005)

The government has the unilateral right to exercise Option 7, incorporated in CLIN 0013 in Section B of the contract, to perform continuing research on Task 2, in accordance with the Section H clause entitled "Exercise of Option".

C.12.1 The contractor shall perform the following tasks under Option 7:

(1) Assemble the high-velocity impact testing system, install the measuring components such as pressure transducers and build a data acquisition system based on a piezo-ceramic accelerometer, a digital oscilloscope and a computer. Calibrate the impact testing system.

(2) Perform high-velocity impact tests for the composite panels to study thickness effects on impact resistance and to optimize the design of thick composites.

(3) Compare the experimental results with numerical simulations based on the numerical models identified in C.10.2(4). This comparison can help to improve the accuracy of numerical simulations for further refinement of the numerical models.

(4) Perform damage mechanics analysis for the composite panels and present a preliminary phenomenological model for damage processes of composite panels.

(5) Perform high-velocity impact test for the innovative composite joints to optimize the design of thick composite joints.

(6) Compare the experimental results with the numerical simulations for refinement of the numerical models.

(7) Perform damage mechanics analysis for the innovative composite joints and present a preliminary phenomenological model for damage processes of innovative composite joints.

C.12.2 The government may exercise Option 7 any time up to May 15, 2004, in accordance with the Section H clause entitled "Exercise of Option", as long as Option 6 has been exercised.

C.12.3 The performance period for Option 7 will begin on July 16, 2004 and end on July 15, 2005, in accordance with the Section H clause entitled "Exercise of Option".

C.12.4 The contractor shall submit a status report every 90 days which reports on the progress of the work being performed on Option 7, in accordance with the Section F clause entitled "Option Deliverables", the Section H clause entitled "Exercise of Option" and Data Item A001, Exhibit A. The status reports for Option 7 will be combined with the status reports on all other work being performed on the contract so that only one overall status report will be submitted on all work being performed under the contract, every 90 days.

C.12.5 The contractor shall submit a draft Final Technical Report by June 15, 2005, in accordance with the Section H clause entitled "Exercise of Option", the Section F clause entitled "Option Deliverables", and Data Item A003, Exhibit A. The government will have 15 days to review this draft report and provide comments on it back to the contractor. The contractor will submit the Final Technical Report by July 15, 2005.

C.12.6 The total amount for Option 7 will not exceed \$144,000.00.

C.12.7 If Option 8 in C.13 is not exercised by the government the contractor shall deliver to the government COTR by July 15, 2005 a CD-ROM which incorporates a computer-aided (CAD) design for thick section composite and composite joints subjected to high velocity impacts, in accordance with Data Item A005, Exhibit A. However, if Option 8 is exercised by the government this CD-ROM will not be delivered by July 15, 2005 but by July 15, 2006 upon completion of Option 8.

C.13 Option 8: Continuing Research on Task 2 (2005-2006)

The government has the unilateral right to exercise Option 8, incorporated in CLIN 0014 in Section B of the contract, to perform continuing research on Task 2, in accordance with the Section H clause entitled "Exercise of Option".

C.13.1 The contractor shall perform the following tasks if Option 8 is exercised:

(1) Refine the design of thick composite panels and fabricate some specimen panels. The ultimate goal is to achieve a composite panel with the specific perforation resistance (the ratio of perforation resistance to weight) higher than the Rolled Homogenized Armor (RHA) steel used in combat vehicles.

(2) Refine the design of thick composite joints and fabricate at least three specimens for each design.

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(3) Perform high-velocity impact tests for the refined thick composite panels and joints.

(4) Perform a numerical simulation for each of the refined thick composite panels and composite joints subjected to impact loading. It is estimated that three thick composite panels and three composite joints will be involved in the numerical simulations.

(5) Perform damage mechanics analysis for the refined thick composite panels and joints.

(6) Compare the experimental results with the analytical studies to finalize the phenomenological models for damage processes of refined thick composite panels and joints.

C.13.2 The government may exercise Option 8 anytime up to July 15, 2005, in accordance with the Section H clause entitled "Exercise of Option", as long as Option 7 has been exercised.

C.13.3 The performance period for Option 8, if Option 8 is exercised, will end on July 15, 2006, in accordance with the Section H clause entitled "Exercise of Option".

C.13.4 The contractor shall submit a status report every 90 days which reports on the progress of the work being performed under Option 8, in accordance with the Section F clause entitled "Option Deliverables", the Section H clause entitled "Exercise of Option" and Data Item A003, Exhibit A. The status reports for Option 8 will be combined with the status reports on all other work being performed under the contract so that only one overall progress report will be submitted on all work being performed on the contract, every 90 days.

C.13.5 The contractor shall submit a draft Final Technical Report by June 15, 2006, if Option 8 is exercised, in accordance with the Section H clause entitled "Exercise of Option", the Section F clause entitled "Option Deliverables" and Data Item A003, Exhibit A of the contract. The government will have 15 days to review this draft report and provide comments on it back to the contractor. The contractor will submit the Final Technical Report by July 15, 2006.

C.13.6 The total amount for Option 8 will not exceed \$102,000.00.

C.13.7 The contractor shall deliver to the government COTR a CD-ROM which incorporates a computer-aided (CAD) design of thick section composites and composite joints subjected to high velocity impacts, in accordance with Data Item A005, Exhibit A.

\*\*\* END OF NARRATIVE C 001 \*\*\*

**CONTINUATION SHEET****Reference No. of Document Being Continued**

Page 15 of 17

PIIN/SIIN DAAE07-01-C-L075

MOD/AMD P00006

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

## SECTION F - DELIVERIES OR PERFORMANCE

F.1 DATA

The contractor shall submit all required reports, studies, plans and findings electronically in accordance with the Contract Data Requirements List (CDRL), DD Form 1423, Exhibit A. Any exceptions made to this requirement for electronic submission (such as submission of specific data for which it is considered impractical to submit electronically) shall be made on a case by case basis with the mutual consent of both parties.

F.2 DELIVERABLES

F.2.1 The contractor shall prepare and submit three (3) Status Reports, in accordance with the Clause C.3.1 and Data Item A001, in Exhibit A. The first such report shall be submitted by September 28, 2001, the second such report shall be submitted by December 14, 2001, and the third and final such report shall be submitted by March 1, 2002.

F.2.2 The contractor shall prepare and submit a Status Review Report summarizing the preliminary results of the work conducted under any contract awarded from this solicitation to TARDEC by September 15, 2001, in accordance with Clause C.3.2 and Data Item A002, Exhibit A.

F.2.3 The contractor shall prepare and submit a Final Technical Report in accordance with Clause C.3.3, and Data Item A003, Exhibit A.

F.3 OPTION DELIVERABLES

F.3.1 For any option(s) exercised by the government contracting officer under the Section H clause entitled "Exercise of Option" of the contract the contractor shall prepare and submit quarterly status reports every 90 days for that exercised option(s), in accordance with the Section C Scope of Work, the Section H clause entitled "Exercise of Option" and Data Item A001, Exhibit A. The contractor will submit one combined status report every 90 days for all the work being currently performed under the contract, including work being done on any options which are currently being performed.

F.3.2 For any option is exercised by the government contracting officer under the Section H clause entitled "Exercise of Option" of the contract, the contractor, in accordance with the Section C Scope of Work, the Section H clause entitled "Exercise of Option" and Data Item A003, Exhibit A, shall prepare and submit a draft Final Technical Report by 30 days before the end of the option performance period, the government will have 15 days to review this draft report and provide comments and the contractor's Final Technical Report shall be due at the end of the option performance period.

F.3.3 If Option 4 is exercised by the government contracting officer, but Option 5 is not exercised, the contractor shall provide the following deliverables under Option 4 by the option completion date of July 15, 2005, to the government COTR:

(i) The pilot model of the deployable nondestructive inspection device, in accordance with C.8.7.

(ii) The CD-ROM incorporating the computer-aided (CAD) design procedure for mechanical joints subjected to static loads, in accordance with C.8.8 and Data Item A004, Exhibit A.

F.3.4 If Option 5 is exercised by the government contracting officer the contractor shall provide the following deliverables under Option 5 by the option completion date of July 15, 2006, to the government COTR:

(i) The refined and tested deployable nondestructive inspection device, in accordance with C.9.7.

(ii) The CD-Rom incorporating the computer-aided (CAD) design procedure for mechanical joints subjected to static loads, in accordance with C.9.8 and Data Item A004, Exhibit A.

F.3.5 If Option 7 is exercised by the government contracting officer, but Option 8 is not exercised, the contractor shall provide to the government COTR by the Option 7 completion date of July 15, 2005, in accordance with C.12.7 and Data Item A005, Exhibit A, a CD-ROM which incorporates a computer-aided (CAD) design for thick section composite and composite joints subjected to high-velocity impacts.

F.3.6 If Option 8 is exercised by the government contracting officer the contractor shall provide to the government COTR by the Option 8 completion date of July 15, 2006, in accordance with C.13.7 and Data Item A005, Exhibit A, a CD-ROM which incorporates a computer-aided (CAD) design for thick section composite and composite joints subjected to high-velocity impacts.

F.4 PERIOD OF PERFORMANCE

All work under the contract, including the submission of the Final Technical Report shall be completed by July 15, 2005. If any additional option (s) are exercised by the government contracting officer the contract will be extended to the end of the performance period specified in the Section H clause entitled "Exercise of Option" for those option(s) which have been exercised.

\*\*\* END OF NARRATIVE F 001 \*\*\*

**CONTINUATION SHEET****Reference No. of Document Being Continued****Page 16 of 17**

PIIN/SIIN DAAE07-01-C-L075

MOD/AMD P00006

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

## SECTION H - SPECIAL CONTRACT REQUIREMENTS

H.16 EXERCISE OF OPTION

## H.16.1 OPTION 1

H.16.1.1 The government reserves the right to unilaterally exercise the option for CLIN 0005 (Option 1) at the amount shown in Section B, by contract modification. The Contracting Officer may exercise this option, per paragraph (b) below by executing a contract modification for this Option 1.

H.16.1.2 Option 1, CLIN 0005, may be exercised anytime from contract award to May 15, 2002.

H.16.1.3 The performance period for Option 1, if Option 1 is exercised, shall be from May 15, 2002 to May 15, 2003.

H.16.1.4 The contractor shall perform the tasks set forth in C.4 for Option 1, if Option 1 is exercised by the government.

## H.16.2 OPTION 2

H.16.2.1 Option 2 is hereby deleted in its entirety by Modification P00003.

## H.16.3 OPTION 3

H.16.3.1 Option 3 is an option established under CLIN 0009 which may be exercised by the government contracting officer (PCO) by execution of a unilateral modification to the contract, in one or more increments, for performance of the Task 1 effort listed in Clause C.7.

H.16.3.2 The total amount of Option 3 shall not exceed \$50,000.00. Option 3 may be exercised at any time up to January 15, 2004. The performance period for Option 3 will be from time of the exercise of Option 3 until July 15, 2004. Option 3 may be performed at the same time as the basic effort for Task 1 is performed under CLIN 0007 and SubCLIN 0007AA.

H.16.3.3 The contractor shall perform the tasks set forth in C.7, if Option 3 is exercised

## H.16.4 OPTION 4

H.16.4.1 Option 4 is an option established under CLIN 0010 which may be exercised by the government contracting officer (PCO) by execution of a unilateral modification to the contract, in one or more increments, for performance of the Task 1 effort listed in Clause C.8. Option 4 may not be exercised unless Option 3 has been exercised.

H.16.4.2 The total amount for Option 4 shall not exceed \$158,000.00. Option 4 may be exercised at any time up to May 15, 2004, as long as Option 3 has been exercised. The performance period for Option 4 will begin on July 16, 2004, once the performance period for Option 3 has ended, and will last for 12 months until July 15, 2005.

## H.16.5 OPTION 5

H.16.5.1 Option 5 is an option established under CLIN 0011 which may be exercised by the government contracting officer (PCO) by execution of a unilateral modification to the contract, in one or more increments, for performance of the Task 1 effort listed in Clause C.9. Option 5 may not be exercised unless Option 4 has been exercised.

H.16.5.2 The total amount for Option 5 shall not exceed \$120,000.00. Option 5 may be exercised at any time up to July 15, 2005, as long as Option 4 has been exercised. The performance period for Option 5 will begin on July 16, 2005, once the performance period for Option 4 has ended, and will last 12 months until July 15, 2006.

## H.16.6 OPTION 6

H.16.6.1 Option 6 is an option established under CLIN 0012 which may be exercised by the government contracting officer (PCO) by execution of a unilateral modification to the contract, in one or more increments, for performance of the Task 2 effort listed in Clause C.11.

H.16.6.2 The total amount of Option 6 shall not exceed \$50,000.00. Option 6 may be exercised at any time up to January 15, 2004. The performance period for Option 6 will be from the time of exercise of Option 6 to July 15, 2004. Option 6 may be performed at the same time as the basic effort for Task 2 is performed under CLIN 0008 and SubCLIN 0008AA.

## H.16.7 OPTION 7

H.16.7.1 Option 7 is an option established under CLIN 0013 which may be exercised by the government contracting officer by execution

**CONTINUATION SHEET****Reference No. of Document Being Continued****Page 17 of 17**

PIIN/SIIN DAAE07-01-C-L075

MOD/AMD P00006

**Name of Offeror or Contractor:** BOARD OF TRUSTEES OF MICHIGAN STATE UNIVERSITY

of a unilateral modification to the contract, in one or more increments, for performance of the Task 2 effort listed in Clause C.12. Option 7 may not be exercised unless Option 6 has been exercised.

H.16.7.2 The total amount of Option 7 shall not exceed \$144,000.00. Option 7 may be exercised at any time up to May 15, 2004, as long as Option 6 has been exercised. The performance period for Option 7 will begin on July 16, 2004, once the performance period for Option 6 has ended, and will last 12 months until July 15, 2005.

## H.16.8 OPTION 8

H.16.8.1 Option 8 is an option established under CLIN 0014 which may be exercised by the government contracting officer by execution of a unilateral modification to the contract, in one or more increments, for performance of the Task 2 effort listed under Clause C.13. Option 8 may not be exercised unless Option 7 has been exercised.

H.16.8.2 The total amount for Option 8 shall not exceed \$102,000.00. Option 8 may be exercised at any time up to July 15, 2005, as long as Option 7 has been exercised. The performance period for Option 8 will begin on July 16, 2005, once the performance period for Option 7 has ended, and will end on July 15, 2006

## H.16.9 Status Reports for Options

H.16.9.1 The contractor is required to prepare and submit status reports every 90 days for any options that have been exercised under this options clause in accordance with the Section C Scope of Work, the Section F clause entitled "Option Deliverables", and the Data Item A001, in Exhibit A. The contractor will submit one combined status report for all work being performed under the contract, including any work currently being performed under one or more options which could be performed at the same time.

## H.16.10 Final Technical Report for Options

H.16.10.1 The contractor is required to prepare and submit a draft Final Technical Report and a Final Technical Report for the work performed on each option, in accordance with the Section C Scope of Work, the Section F clause entitled "Option Deliverables" and Data Item A003, in Exhibit A. The draft Final Technical Report shall be submitted 30 days before the end of the option performance period, the government will have fifteen (15) days to provide their comments, with the Final Technical Report for each option due by the performance completion date for that option.

\*\*\* END OF NARRATIVE H 001 \*\*\*