**DEPARTMENT OF THE ARMY**
**HEADQUARTERS, US ARMY DEVELOPMENTAL TEST COMMAND**
**314 LONGS CORNER ROAD**
**ABERDEEN PROVING GROUND, MD 21005-5055**

REPLY TO
ATTENTION OF

TEDT-TMT 20 June 2011

MEMORANDUM FOR Program Manager (PM), Heavy Brigade Combat Team (HBCT) SFAE-GCS-HBCT-Q, Warren, MI 48397-5000

SUBJECT: Amendment 1, Safety Confirmation for the M1A2 System Enhancement Package (SEP) Version 2 (v2) Tank with System Software Version 4.4 (General Dynamics (GD) Version 3.4) in Support of Fielding

1. **References**.

a. Memorandum, US Army Aberdeen Test Center (ATC), CSTE-DTC-AT-AD-F, undated, subject: Recommendation for a Safety Confirmation for the M1A2 Abrams System Enhancement Package (SEP) Version 2 (v2) Tank with System Software Version 4.4 (General Dynamics Version 3.4), ATEC Project No. 2006-DT-ATC-M1A2B-D0104.

b. Memorandum, US Army Developmental Test Command (DTC), TEDT-TMT, 15 Feb 11, subject: Safety Confirmation for Use of the Common Remotely Operated Weapon Station II (CROWS II) Version 2 (v2) with Software Version 3.4.1 on an M1A2 Abrams System Enhancement Package (SEP) v2 Tank with System Software Version 4.3.2 in Support of Fielding.

c. Memorandum, Program Executive Officer (PEO) Ground Combat Systems (GCS), SFAE-GCS-HBCT-ST, 21 Mar 11, subject: M1A2 SEPv2 4.4 Software Information Paper.

d. Safety Assessment Report (SAR), General Dynamics Land Systems (GDLS), 13 Jan 11, subject: Draft SAR Revision 3 (M1A2 SEP v2 4.4 SW Drop 3.4) to Reflect Content Change to M1A2 SEP v2 4.4 Software SAR Revision 1.

e. Vision Digital Library (VDL), M1A2 SEP Software Test Project Folder, US Army Test and Evaluation Command (ATEC) Decision Support System (ADSS) Project Number 2008-DT-ATC-M1A2S-D9486, URL https://vdls.atc.army.mil/livelink/livelink.exe?func=ll&objId=7084870.

f. Technical Manuals (TM) 9-2350-388-XX series, Tank, Combat, Full-Tracked, 120mm Gun, M1A2 (2350-01-328-5964) (EIC: AAF), General Abrams, various dates.

g. MIL-STD-882D, Standard Practice for System Safety, 10 Feb 00.

h. Bi-Weekly Phone Conferences, Mr. Baetz, DTC (TEDT-TMT), Mr. Moran, Program Manager, Heavy Brigade Combat Team (PM HBCT) (SFAE-GCS-HBCT-Q), and Mr. Borowski, ATC (TEDT-AT-ADF), subject: Emerging ATC Test Results.

i. Memorandum, Program Manager (PM), Force XXI Battle Command, Brigade and Below, SFAE-C3S-FB, 17 Sep 01, subject: Loading of data/files from the FBCB2 Mission Data Loader to the M1A2 Abrams SEP.

j. Configuration Matrix, GDLS, Feb 10, subject: SEPv1/SEPv2 Baseline Configuration LRU and SRU Interchangeability Matrices (with National Stock Numbers).

k. Memorandum, Office of the Assistant Secretary of the Army (Acquisition Logistics and Technology) (ASA (ALT)), SAAL-PE, 10 Dec 10, subject: Environment, Safety and Occupational Health (ESOH) Risk Assessment and Risk Acceptance Guidance.

l. DTC Policy Bulletin No. 11-10, Software Safety Verification Policy and Guidelines, 27 Sep 10.

m. Memorandum, DTC, 10 Nov 10, subject: Safety Confirmation for the XM153 Common Remotely Operated Weapon Station (CROWS) with Software Version (SV) 3.3.1 Mounted on a Hardstand and the M1151A1 High Mobility Multipurpose Wheeled Vehicle (HMMWV) in Support of Material Release (MR).

n. System Safety Hazard Analysis (SSHA), KDA, 18 Apr 08subject: Protector CROWS II SSHA Report, Document Number: SSHA60202468.

o. Fault Tree Analysis (FTA), KDA, 1 May 08, subject: Protector CROWS II FTA, Document Number: A109991, Revision.

p. Memorandum, ATC, CSTE-DTC-AT-AD-F, 16 Jun 11, subject: Recommendation for a Safety Confirmation for the Integrated Player Unit (IPU) on the M1A2 Abrams System Enhancement Package (SEP) Version 2 (v2) Tank with System Software Version 4.4, ATEC Project No. 2006-DT-ATC-M1A2B-D0104.

q. E-mail, PM HBCT, SFAE-GCS-HBCT-Q, 20 Jun 11, subject: RE: Status of CROWS cable.

2. **Purpose.** This US Army Developmental Test Command (DTC) Safety Confirmation for the M1A2 System Enhancement Package (SEP) Version 2 (v2) tank with system software version 4.4 (General Dynamics (GD) Version 3.4) is provided in support of Fielding. The Safety Confirmation has been amended to include use of the Integrated Player Unit (IPU) training device on M1A2 SEPv2 tanks with system software version 4.4. A safety evaluation in accordance with (IAW) MIL-STD-882D (reference 1g) was conducted. The overall risk of the use of the M1A2 SEPv2 with system software version 4.4 is considered MEDIUM. The mitigations identified in this document and in the reference 1f should be implemented in order to minimize risk.

3. **System Description.**

a. The M1A2 SEPv2 Tank (formerly the M1A2 SEP Continuous Electronics Evolution Program) is an upgrade to replace electronic components in the M1A2 SEP Version 1 tank that have become obsolete, no longer meet user requirements, or are no longer available from the manufacturer. The following Line Replaceable Units (LRUs)

have been upgraded by the addition of faster processors, more memory, and higher speed internal communication: Improved Hull and Turret Mission Processor Units (IHMPU & ITMPU), Improved Commander's Electronic Unit, Improved Driver's Integrated Display (IDID), Improved Gunner's Control and Display Panel (IGCDP), Improved Fire Control Electronics Unit, and the Improved Commander's Display Unit (ICDU). Other M1A2 SEP v2 improvements include: Block I improved second Generation (2 Gen) Forward Looking Infrared (FLIR) sights for the Commander's Independent Thermal Viewer (CITV) and the Gunner's Primary Sight (GuPS) Thermal Imaging System (TIS). A representative photograph of the M1A2 SEPv2 Abrams tank is shown in Figure 1.

Figure 1. M1A2 SEP v2 Abrams tank.

b. The M1A2 SEPv2 tank has been upgraded to include the Common Remotely Operated Weapon Station (CROWS) IIv2 along with system software version 4.4. The CROWS IIv2 is based on the Type Classified, M151 CROWS II Protector. The CROWS IIv2 replaces the externally-mounted and fired Improved Commander's Weapon Station machine gun mount. The CROWS IIv2 provides the Commander with provisions for engagement of targets with both day and thermal sights utilizing the M2 Heavy Barrel 0.50 caliber machine gun and the M240 7.62 millimeter machine gun. The CROWS IIv2 provides two-axis stabilization for firing on the move, 360 degrees of traversable rotation, and -20 to +60 degrees of elevation. The CROWS IIv2 software provides for the integration of no-fire and no-traverse zones to account for vehicle deck clearances and open hatches. The operator is provided the ability to override some of the no-fire and all of the no-traverse zones, as well as the ability to create no-fire and no-traverse zones.

c. M1A2 SEPv2 system software version 4.4 (GD Version 3.4) includes the CROWS IIv2 video display integrated into the Commanders Display Unit, CROWS IIv2 software upgrades, Rear View Sensor System (RVSS) video integrated into the Driver's Integrated Display, revised breech ring prognostics, diagnostic/Vehicle Health Management Subsystem enhancements, Digital Engine Control Unit (DECU) J6 diagnostic enhancements, a DECU J7 software update, fire control enhancements, a tank system interface change to compensate for the unexpected interface change in

FLIR 5.01 and newer software, embedded training mode, second generation FLIR Block I software version 6.00, and Force XXI Battle Command, Brigade-and-Below (FBCB2) software.

d. System software version 4.4 (GD Version 3.4) was tested on two M1A2 Abrams SEPv2 vehicles. The vehicles were configured with the following subsystems:

(1) FBCB2 software version 6.5.2.2 with patch F7 and various databases.

(2) Enhanced Position Location Reporting System with software version 11.4.0.8.5.1.1 or Blue Force Tracker (BFT) Transceiver MT-2011F.

(3) Single Channel Ground/Airborne Radio System software versions 6.6.3 or 7.0.

(4) Block 1 Improved 2 Gen FLIR software version 6.0.

(5) Version 3.0 or version 3.1 sidecar modules.

(6) DECU hardware version J6 or J7 with software versions J6_06_01 or J7_03_04.

(7) Removable Memory Cartridges (RMC) of 10 Gigabyte (GB) or 80 GB storage capacity.

(8) Position and time information from an ITMPU with Abrams Embedded Global Position System (GPS) Receiver Selective Availability Anti Spoofing Module or Defense Advanced GPS Receiver with software version 984-3006-002.

(9) Additional vehicle configuration information is included in reference 1a.

e. M1A2 SEPv2 LRUs and Shop Replaceable Units (SRUs) were inspected by the system prime contractor and test center to fully document the hardware configuration. Results of the inspection were verified against the current, approved M1A2 SEPv2 configuration matrix (reference 1j).

f. The IPU is the next generation of the currently fielded Digital Range Training System. The IPU is a computer hardware and software system comprised of several components designed to capture, record, and present training data. The data are captured during live fire training events and simulated fire laser engagements at training facilities. The system monitors the vehicle data bus, the GPS position/location, audio, and visual information on the tank. The video, audio, and vehicle data can then be transmitted by the IPU to a Range Operations Center hundreds of meters away.

4. **Evaluation Limiting Factors.** An unlimited combination of M1A2 SEPv2 LRUs and SRUs exist. Field history, Program Manager, Heavy Brigade Combat Team (PM HBCT) regression testing and extensive safety test efforts indicate that the combinations of LRUs and SRUs contained in the latest configuration matrix (reference 1j) will operate together properly and safely. Future maintenance actions should limit the installation of

LRUs and SRUs to the configurations listed in the established configuration reference document.

5. **Evaluation Results.**

a. Information in this DTC Safety Confirmation is based on testing conducted at the US Army Aberdeen Test Center (ATC) during the period 21 Mar through 08 Jun 11 and the review of referenced documentation. Risk Assessment Codes (RACs) were assigned IAW the guidelines given in ASA(ALT) Risk Acceptance Memorandum (reference 1k). The M1A2 SEPv2 contains safety critical software as defined by DTC Policy Bulletin No. 11-10 (reference 1l). Identified safety hazards are summarized below.

b. Two M1A2 SEP v2 tanks were used for testing (Serial Numbers AN28008U and LA28260M). Both tanks were equipped with system software version 4.4 (GD Version 3.4). Detailed results of the safety testing at ATC are presented in references 1a and 1e.

c. PM HBCT provided an Information Paper (reference 1c) and Safety Assessment Report (SAR) (reference 1d) detailing the changes and potential hazards of the new software.

d. The configuration of the test vehicle was well understood and documented down to the SRU level (reference 1a).

e. The following testing was conducted:

(1) Automotive and fire control system checks were performed by ATC personnel. These checks included approximately 290 system specification checks, which involved all levels of system functionality, including basic operations, built-in ballistic computer solutions, boresighting, Muzzle Reference System updates, diagnostics, thermal sight operations, triggers, automotive systems, circuit breaker operations, and sighting system plumb and synchronization verification.

(2) Each test vehicle completed a single 80 kilometer (km) mission. The mobility operations stressed the suspension, intercom, fire control stabilization, boresight retention, powertrain, braking, steering, power distribution system, weapon triggers, DECU, hydraulic system, FBCB2, GuPS, ammunition door, GuPS TIS, Eye-Safe Laser Rangefinder (ELRF), and the CITV. A mounted over-watch of three hour duration was performed with each 80 km mission.

(3) The operation of the main Nuclear, Biological and Chemical (NBC) protection system was verified during the specification checks and the 80 km missions.

(4) Built-in diagnostic checks were performed on both vehicles at each crew station before and after the new system software was loaded into the vehicles.

(5) Software controls and limits on manual data entry into the fire control system were stressed by attempting to input invalid entries into the ballistic fire control computer. The vehicle was evaluated for acceptance of proper data and rejection of

invalid data. The fire control system properly accepted valid inputs and rejected all invalid inputs.

(6) A total of 123 main weapon rounds were fired from the two vehicles to confirm proper operation of the fire control system. These main weapon rounds were directed to the targets using the GuPS, GuPS FLIR, and the CITV. Magnifications of 10x, 13x, 25x and 50x were selected in the sights during firing. All combinations of stationary tank, moving tank, stationary target, and moving target firing were performed.

(7) Several FBCB2 messages, including free text, contact reports, call for fire, check fire, obstacle relay, route overlay, situation report, mayday, target overlay, and others were transmitted between the two vehicles. Precedence of flash, immediate, priority, and routine were given to the messages. Situational awareness was established between the vehicles. Current and previous FBCB2 testing has found FBCB2 data products (maps & data bases) can be updated in the field with no detrimental effects for the system. These updates must be performed IAW reference 1i.

(8) Internal vehicle communications were established and exercised during system specification checks, mobility operations, and the main weapon firing.

(9) The ELRF was operated during the 80 km mission and main weapon firing. The ELRF properly obtained and implemented range data.

(10) Proper functionality of the solenoid that operates the coaxial machine gun was confirmed.

(11) Plumb and synchronization of the sights were adjusted and confirmed.

(12) The performance of the Driver’s Hatch Interlock (DHI) was confirmed.

(13) Proper functionality of the fire suppression system for the crew compartment and the engine compartment was verified using a fire suppression test set.

(14) The azimuth and elevation frequency response of the fire control system was checked throughout the entire design spectrum on both test vehicles. The fire control system remained stable throughout the operational spectrum.

(15) The Through-Sight Video Recorder, Multiple Integrated Laser Engagement System (MILES) 2000, and MILES XXI training devices were checked for fit and functionality in both test vehicles. Legacy MILES, Direct/Indirect Fire Cue, and the Main Gun Simulator System were not tested with either vehicle.

(16) Accuracy of the ballistic fire control computers was confirmed by performing the built-in ballistic computer solutions check, followed by ballistic solution gridboard checks on both test vehicles.

(17) Boresight retention testing occurred during specification checks and the 80 km missions.

(18) A Personal Computer Card based-backup map of Iraq was properly loaded into FBCB2.

(19) Two different FBCB2 databases were tested. Version 1CD-MOD1.0-5B and BFT-TRADOC1.0-14 were downloaded and tested.

(20) Proper implementation of the CITV slew to cue functionality was confirmed during the mobility missions and on the firing range.

(21) CROWS II software version 3.4.2 and Protector Platform Configuration file version 2607 were successfully downloaded with the RMC and Dolch computer. The no-fire zones were verified to be correct. A total of 200 rounds of 0.50 caliber ammunition was fired from an M2 Heavy Barrel machine gun mounted in the CROWS IIv2. All firing rates were tested.

(22) The RVSS was operated during a mobility mission using the ATC intensified operational mode summary. Proper video display performance was confirmed on the Driver's Video Display (DVD) and IDID Plus. The RVSS operated properly at a temperature of -25 degrees Fahrenheit. The RVSS met requirements for Radiated Susceptibility and Electromagnetic Compatibility. However, bonding and grounding resistances exceeded the 2.5 megaohm (mΩ) limit at the camera control unit J3 connector and DVD.

(23) DECU testing included a full engine health check, acceleration, towing, gradeability, and side slope operations.

(24) The round counter for the on-hand ammunition assistant on the IGCDP and the round counters for the gun tube and breech effective life were assessed during firing operations. Following main weapon firing, a checkout of the fire control system revealed an anomaly with the new main weapon ammunition round count capability. The Effective Full Charge (EFC) round count did not consistently update to reflect the actual number of rounds fired. The EFC round count updated after firing 4 of the 6 M829A1 rounds and after firing 2 of the 3 M829A3 rounds. Later, the EFC round count did not update after firing with the manual firing mechanism (blasting machine) or when the ITMPU was powered off.

(25) An exercise was performed to assess the Soldier Machine Interface of the new software. Numerous degraded states, including IHMPU takeover, ITMPU takeover, air mode, stare filters, firing over the rear deck, emergency mode, battle range, backup NBC protection system operation, Thermal Management System operation, firing during engine start, firing during FBCB2 shut down and start up, NBC overheat warnings, and firing while bypassing the Driver's Hatch Interlock were created and assessed.

(26) The IPU, including the prototype wiring harness that supports CROWS IIv2 video display on the ICDU, was installed. A functional checkout revealed all of the previously reported issues with the IPU, CROWS IIv2 control and video (reference 1q) were no longer present. The CROWS IIv2 video was properly displayed on the ICDU and the Commander had proper operational control of the CROWS IIv2 (reference 1p).

(27) System level software was downloaded into the M1A2 SEPv2 test vehicles via RMC using the embedded downloader function and via the Maintenance Support Device (MSD). There were no issues with either download method.

f. The following known hazards on the CROWS IIv2 were documented in the Safety Confirmation for the XM153 CROWS II with software version 3.3.1 (reference 1m). While the software and vehicle application differed, there is no evidence to support that the hazards were eliminated by the CROWS IIv2 software version 3.4.2 upgrade and the integration into the M1A2 SEPv2 tank.

(1) A lead angle anomaly was noted during previous CROWS IIv2 software testing. When lead angle was placed in the ON position, two conditions existed that had the potential to result in the Line-of-Fire (LOF) of the weapon differing from that of the aim point by as much as 17.6 degrees. The lead angle anomaly was created by taking the following actions:

(a) Slewing at higher speeds, with lead angle in the ON position, resulted in aim point misalignment. When the weapon station was slewed in a particular direction (i.e., clockwise, upwards, downwards, etc.) at higher speeds (greater than 50 percent of the maximum slewing rate) with the lead angle functionality in the ON position and the palm switch released to halt weapon station motion, the weapon LOF differed from the aim point of the MPU. Because weapon motion is not permitted without engagement of the palm switch, the weapon is incapable of realigning with the aim point. Once the palm switch was re-engaged, it took approximately one second before the weapon LOF realigned with the aim point. During that one second period, the operator was able to fire, which resulted in a deviation between the aim point and the potential projectile impact point. The maximum deviation observed was 10 degrees in azimuth with the M249 Squad Automatic Weapon. Errors this large could cause the weapons to fire on friendly troops when the operator believed he was targeting enemy combatants. This situation was assessed as a Catastrophic-Remote hazard (RAC 1-D, SERIOUS Risk). The gunner should receive proper training, to include waiting a few seconds, with the palm switch depressed after completing slewing, to ensure that the weapon and sight are in alignment before firing, this will mitigate this to a Catastrophic-Improbable hazard (RAC 1-E, MEDIUM Risk).

(b) Slewing at lower speeds, with lead angle in the ON position, resulted in erratic motion and aim point misalignment. Erratic motion of the CROWS IIv2 Sight Servo Assembly (SSA) was observed when the station was slewed at slower speeds (less than 10 percent of the maximum slewing rate) with a range greater than 2,625 feet (800 meters) and the lead angle in the ON position. When the weapon station was slewed in alternating directions at lower speeds, the SSA exhibited erratic motion in the direction opposite the commanded direction with a deviation of approximately one degree before it resumed motion in the commanded direction. The operator was able to fire after the erratic motion ceased but before the weapon LOF was realigned with the aim point. This anomaly was observed with each weapon type. The erratic motion or LOF misalignment could cause the weapons in the CROWS IIv2 to fire on friendly units when the operator believed he was targeting enemy units. This was assessed as a Catastrophic-Remote hazard (RAC 1-D, SERIOUS Risk). The characteristics of the anomaly are easily observed provided a Soldier has been trained to identify them.

When the characteristics are observed, firing should not be commanded. Consequently, training will mitigate this to a Catastrophic-Improbable hazard (RAC 1-E, MEDIUM Risk).

(2) Residual Hazards. The following residual hazards are derived from the Kongsberg Defense and Aerospace (KDA) System Safety Hazard Analysis (reference 1n) and Fault Tree Analysis (FTA) (reference 1o):

(a) Section 7-1 of the KDA FTA calls out the potential for alignment of the weapon and camera to become offset because of an incorrect software ballistic calculation. This anomaly would cause the weapon LOF to differ from the aim point, which could result in death or severe personnel injury. This is assessed as a Catastrophic-Improbable hazard (RAC 1-E, MEDIUM Risk). No risk mitigation exists.

(b) Section 7-2 of the KDA FTA indicates the potential exists for incorrect function of sector protection limits allowing weapon firing or motion in defined safe zones to result in death or severe personnel injury. This is assessed as a Catastrophic-Improbable hazard (RAC 1-E, MEDIUM Risk). No risk mitigation exists.

(c) Section 7-3 of the KDA FTA reviews the potential for unintended main servo axis movement during firing, which could result in death or severe personnel injury. This is assessed as a Catastrophic-Improbable hazard (RAC 1-E, MEDIUM Risk). No risk mitigation exists.

g. An issue was identified with the automatic tracking and counting of the weapon EFC. Firing beyond the EFC limit could result in catastrophic damage to the main weapon or breech assembly. This condition is assessed as a Catastrophic-Remote hazard (RAC 1-D, SERIOUS Risk). It is highly recommended that Soldiers and mechanics disregard the new software based EFC system and continue to rely on traditional main weapon and breech life tracking methods. These traditional life tracking methods have sufficient safety margin built into them to preclude a catastrophic failure of the weapon or breech. Awareness of the software EFC error and continuing dependence on existing main weapon life tracking methods will eliminate this hazard.

h. The following technical issues were also identified during testing. Action to eliminate these issues is recommended:

(1) A timing issue associated with silent watch mode was identified. Approximately 5 seconds after coming out of silent watch mode, three cautions became active and displayed on the ICDU. The cautions were DID fault, GCDP fault, and system data bus fault. An audible tone was also present while the cautions were active. After approximately 5 more seconds the cautions became inactive. And, after approximately 15 more seconds, the cautions self-cleared. This issue was consistently experienced on both test vehicles.

(2) The RVSS exceeded the 2.5-mΩ grounding limit at the camera control unit J3 connector and DVD.

6. **Conclusions and Recommendations.**

a. This DTC Safety Confirmation is issued for the M1A2 SEPv2 with system software version 4.4 (GD version 3.4) for use in support of Fielding. A safety evaluation IAW MIL-STD-882D (reference 1g) was conducted. The overall risk for the use of the M1A2 SEPv2 with system software version 4.4 is considered MEDIUM. The mitigations identified in this document and in the references 1f should be implemented in order to minimize risk.

b. Future hardware and software upgrades to the M1A2 SEPv2 tanks must be assessed for their impact to system safety.

c. Future maintenance actions should limit the installation of LRUs and SRUs to the configurations listed in the established M1A2 SEPv2 configuration reference document.

d. Hazards identified in paragraphs 5f and 5g must be eliminated or controlled to an acceptable level. If the hazards are not eliminated, the residual hazards must be accepted by the appropriate decision authority IAW ASA(ALT) Risk Acceptance Memorandum, dated 10 Dec 10 (reference 1k). The technical or operational limitations or precautions identified herein, needed to prevent injury and property damage during operation, are the responsibility of the PM. To permit revision of this Safety Confirmation, all design changes effected by the PM to reduce or eliminate hazards identified above will be verified and validated as acceptable through analysis or testing.

7. The DTC point of contact is Mr. Bill Baetz, TEDT-TMT, bill.baetz@us.army.mil, DSN 298-4716, commercial (410) 278-4716.

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