UNITED STATES AIR FORCE
MISSILE ACCIDENT INVESTIGATION
BOARD REPORT

Minuteman III Launch Facility A06

319th Missile Squadron
90th Operations Group
90th Missile Wing
F.E. Warren AFB WY

LOCATION: F.E. Warren AFB WY

DATE OF ACCIDENT: 23 MAY 2008

BOARD PRESIDENT: COLONEL ROBERT M. WALKER

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Volume One of Two

EXECUTIVE SUMMARY

MISSILE ACCIDENT INVESTIGATION

Minuteman III Launch Facility A06
F.E. Warren AFB WY
23 May 2008

On 23 May 2008 at 1634 Mountain Standard Time (MST), Minuteman (MM) III Launch Facility (LF) A06, located near F.E. Warren AFB, WY, experienced a commercial (primary) power interruption. The LF automatically switched to backup power provided by a set of batteries located in the lower launcher equipment room (LER). The LF's battery charger, also located in the LER, had a loose electrical connection on a capacitor terminal. The battery charger had been modified by the 582d Missile Maintenance Squadron (582 MMXS) at Hill Air Force Base, Utah, to remove and replace capacitors that contained polychlorinated biphenyls (PCBs) with non-PCB components. The battery charger was installed at LF A06 on 4 March 2008. Between that date and 23 May 2008, the loose connection caused the charger to overcharge the batteries, which created excessive hydrogen gas (H_2) inside the LER. The H_2 accumulated to the point that it was flammable, and it was not sufficiently controlled or reduced by air circulation due to the LF's recently installed new environmental control system (ECS) that eliminated the flow of fresh or make-up air into the LER. A spark or fire from the loose connection inside the battery charger ignited the gas.

The fire ignited a shotgun storage case, destroyed the shotgun, and incinerated the shotgun shells. The burning of the shotgun case and its contents produced a large amount of soot, some of which was dispersed into launch support equipment racks and throughout the LER. The fire also ignited duct tape at the opening of the launch tube (LT), at the entrance for missile support cables including the lower and upper umbilical cables. The burning duct tape dripped onto a section of the lower umbilical cable where it ignited more duct tape. The fire charred the umbilical cable in several places, and burned through and short-circuited wires in the suspension system (pressure) monitor cables. On 28 May 2008, a maintenance team sent to resolve faults reported by sensors inside the LF discovered the evidence of the fire.

The AIB president found clear and convincing evidence the loose capacitor connection caused the mishap. The AIB president further found substantial evidence to conclude five factors substantially contributed to the mishap: First, the technical order (TO) provision concerning the installation of the capacitors in the LF battery charger is vague regarding the fastening of capacitor connection wires, which led to or permitted the loose connection. Second, 582 MMXS procedures for quality assurance (QA) evaluation of battery charger modifications and maintenance did not require visual or other direct inspection of the capacitor installation, which might have detected and corrected the loose connection. Third, modification of A06's ECS eliminated the flow of make-up fresh air into the LF and the LER. Some amount of fresh air might have prevented the H_2 build-up caused by the overcharged batteries from reaching the flammable concentration that fueled and spread the fire. Finally, the use of duct tape on the umbilical cables, and the holes cut in the shotgun case which exposed the internal foam insulation, introduced both of these flammable materials, absent which the fire might have extinguished itself after consuming the H_2 gas without causing further damage.

SUMMARY OF FACTS AND STATEMENT OF OPINION
Minuteman III Launch Facility A06
23 May 2008

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COMMONLY USED ACRONYMS AND ABBREVIATIONS

°	Degree
§	Section
1st Lt	1st Lieutenant
2d Lt	2d Lieutenant
AC	Alternating Current
ACC	Air Combat Command
AF	Air Force
AFB	Air Force Base
AFI	Air Force Instruction
AFRL	Air Force Research Laboratory
AFSC	Air Force Specialty Code
AFSPC	Air Force Space Command
AGE	Aerospace Ground Equipment
AIB	Accident Investigation Board
ASC	Aeronautical Systems Center
AVE	Aerospace Vehicle Equipment
BGG	Ballistic Gas Generator
BP	Board President
C	Celsius
Capt	Captain
CB	Circuit Breaker
cfm	Cubic feet per minute
C/O	Check out
CO	Carbon monoxide
CO_2	Carbon dioxide
Col	Colonel
CSD(G)	Command Signal Detector (Ground)
D-box	Distribution Box
DC	Direct Current
DMCCC	Deputy Missile Combat Crew Commander
DO	Director of Operations
ECS	Environmental Control System
EMT	Electro-mechanical Maintenance Team
EOD	Explosive Ordnance Disposal
ESA	Electrical Surge Arrestor
EWO	Emergency War Order
F	Fahrenheit
FMT	Facilities Maintenance Team
FOD	Foreign Object Debris
FSC	Flight Security Controller
GMR	Ground Maintenance Response
H_2	Hydrogen Gas
IAW	In Accordance With
ICBM	Intercontinental Ballistic Missile
ICBMSG	Intercontinental Ballistic Missile Systems Group
ICBMSS	Intercontinental Ballistic Missile Systems Squadron
IMMP	Improved Maintenance Management Program
IMPSS	Improved Minuteman Physical Security System
ISB	Interim Safety Board
IZ	Inner zone security alarm
LCC	Launch Control Center
LEL	Lower Explosive Limit
LER	Launcher Equipment Room
LF	Launch Facility
LFL	Lower Flammability Limit
LGM30G	Minuteman III Missile
LSB	Launcher Support Building
LT	Launch Tube
Lt Col	Lieutenant Colonel
µF	Micro farads
MADO	Missile Alert Duty Order
MAF	Missile Alert Facility
Maj	Major
MAJCOM	Major Command
MCC	Missile Combat Crew
MCCC	Missile Combat Crew Commander
MG	Motor Generator
MGS	Missile Guidance Set
MM	Minuteman
MMOC	Missile Maintenance Operations Center
MMT	Missile Maintenance Team
MMXG	Missile Maintenance Group
MMXS	Missile Maintenance Squadron
MOSR	Missile Operational Status Reply
MS	Missile Squadron
MSFS	Missile Security Forces Squadron
MST	Mountain Standard Time
MW	Missile Wing
NAF	Numbered Air Force
NCO	Noncommissioned Officer
NCOIC	Noncommissioned Officer in Charge
NSN	National Stock Number
O_2	Oxygen
OG	Operations Group
OGE	Operational Ground Equipment
OO-ALC	Ogden Air Logistics Center
Ops	Operations
OZ	Outer zone security alarm
PACS	Production Acceptance Certification Standards
PADS	Performance Assessment Data System
PAH	Personnel Access Hatch
PCB	Polychlorinated Biphenyls
PRP	Personnel Reliability Program
PSRE	Propulsion System Rocket Engine

QA	Quality Assurance
RMS	Remote Monitoring System
R&R	Remove and Replace
RS	Reentry System
RV	Reentry Vehicle
SALRT	Strategic Alert
SCS	Safety Control Switch
SELECT	System Engineering Level Evaluation and Correction Team
SELM	Simulated Electronic Launch Minuteman
SFS	Security Forces Squadron
SIB	Safety Investigation Board
SMIC	Strategic Missile Integration Complex
S/N	Serial Number
SSgt	Staff Sergeant
Stan/Eval	Standardization and Evaluation
SW	Space Wing
TCTO	Time Compliance Technical Order
TDY	Temporary Duty
Tech data	technical data
Tech School	Technical School
T.O.	Technical Order
TSgt	Technical Sergeant
UHF	Ultra High Frequency
U.S.	United States
USAF	United States Air Force
U.S.C.	United States Code
V	Volt

The above list was compiled from the Summary of Facts, the Statement of Opinion, the Index of Tabs, and Witness Testimony (Tab V).

SUMMARY OF FACTS

1. AUTHORITY, PURPOSE, AND CIRCUMSTANCES

a. Authority

On 18 July 2008, General C. Robert Kehler, Commander, Air Force Space Command (AFSPC), appointed Colonel Robert M. Walker to conduct an accident investigation of a mishap that occurred on or about 23 May 2008 involving Minuteman (MM) III launch facility (LF) A06 (referred to as "A06" for the remainder of the report) near F.E. Warren Air Force Base (AFB), WY. (Tabs Y-3 thru Y-4) The investigation was conducted at F.E. Warren AFB from 23 July 2008 through 22 August 2008. Other Accident Investigation Board (AIB) members were Captain Michael W. Richards (Maintenance), Captain Jason R. Smith (Legal Advisor), and Master Sergeant Frank A. Seagren (Recorder). (Tab Y-3)

b. Purpose

The purpose of this investigation is to provide a publicly releasable report of the facts and circumstances surrounding the accident, to include a statement of opinion on the cause or causes of the accident; to gather and preserve evidence for claims, litigation, disciplinary, and adverse administrative actions; and for other purposes. This report is available for public dissemination under the Freedom of Information Act (5 United States Code (U.S.C.) § 552).

c. Circumstances

The accident board was convened to investigate the Class A mishap involving A06, assigned to the 319th Missile Squadron (MS), 90th Operations Group (OG), 90th Missile Wing (MW), F.E. Warren AFB.

2. ACCIDENT SUMMARY

On 23 May 2008 at 1634 MST, the on-duty missile combat crew (MCC) at the A-01 Launch Control Center (LCC), 319 MS, received an electronically transmitted alarm, known as a ground maintenance response (GMR), indicating a commercial power interruption at A06. The GMRs are transmitted to the LCC when abnormal status is detected by LF support equipment sensors. (Tab BB-8) At 1638 MST a GMR 30 reported to the LCC, which indicated a missile suspension system alarm. (Tab D-24; Tab BB-9) After approximately six hours, all GMRs cleared except for a launch tube (LT) temperature alarm (GMR 28) and a missile suspension system alarm (GMR 30). (Tab D-24) The MCC reported the remaining GMRs to maintenance personnel for resolution. (Tabs U-39 thru U-41) On 28 May an electro-mechanical maintenance team (EMT) from the 90 MMXS went to A06 to attempt to clear the GMR 30. Their task required them to enter the launcher equipment room (LER). When they entered the LER, they discovered evidence a fire had occurred. (Tab V-9.4)

There were no injuries or fatalities related to this mishap. The most probable total damage estimate is $1,029,855.77. (Tab P-3) There was no damage to private property.

There was no local or national media interest in this incident.

3. BACKGROUND

a. F.E. Warren AFB is home to the 90 MW, one of the Air Force's three operational ICBM units. The 90 MW is responsible for defending the United States by maintaining a fleet of 150 MMIII missiles located in underground LFs in a 9,600 square mile area across three states.

b. The 90th Operations Group includes three missile squadrons (319th, 320th, and 321st), each of which is responsible for five MAFs and 50 MM III ICBMs. (Tab CC-7) The 319 MS is composed of five smaller units known as flights that handle the day-to-day operations of the MM III LFs assigned to F.E. Warren AFB. The flights are named alphabetically. (Tab T-11) Each LF is designated first with a letter according to the flight responsible for that LF and then a sequential number. Alpha flight within 319 MS is responsible for 10 LFs, including A06. (Tab O-3)). A06 is located approximately 42 miles east of F.E. Warren AFB. (Tab B-3)

c. The 90th Maintenance Group is responsible for providing maintenance and logistics support for the wing's ICBM fleet. The 90th Missile Maintenance Squadron (90 MMXS) and the 90th Maintenance Operations Squadron (90 MOS) are assigned to the group. The 90 MMXS maintains the readiness of MMIII ICBMs and corresponding Missile Alert Facilities (MAFs) and LFs through the replacement of limited life components, munitions, missiles, reentry systems, and guidance sets; troubleshooting/repairing security, electrical, and communication systems, coding, and corrosion control; and through periodic inspections.

d. The 582d Missile Maintenance Squadron (582 MMXS) is a part of the 309th Missile Maintenance Group, and in turn the 309th Maintenance Wing at Hill AFB, Utah. 582 MMXS is responsible for maintenance, repair, overhaul, and modification of MM III ICBM systems.

4. SEQUENCE OF EVENTS

a. Mission

The operations and maintenance teams at 90 MW work together to ensure its MM IIIs remain on strategic alert, which means they are prepared to launch when directed. The LFs are monitored 24 hours/day, 7 days/week for potential faults that might change the missiles' strategic alert status. When the MM IIIs are on strategic alert, they provide a critical component of America's strategic defense. (Tabs C-11 thru C-12) The MM III inside A06 remained on strategic alert at the time of the mishap. (Tab D-24; Tab V-2.7)

b. Planning

Each MCC receives a pre-departure briefing prior to travelling to the LCC. (See Tab T-11; Tab AA-3) The squadron commander and operations officer attend this briefing to ensure crews

are properly briefed. The briefings cover, at a minimum, safety; weather forecast; road conditions; status of the MAF, LCC and LF; and maintenance scheduled or in progress. (See Tab AA-3) Once the on-coming crew arrives at the LCC, they receive a detailed crew changeover briefing from the off-going crew on any on-going or recently transpired events at the LFs. (e.g., Tabs V-3.3 thru V-3.4; Tab V-2.3; Tab V-5.4)

On 23 May 2008 at 1100 MST, the Alpha flight MCC completed crew changeover. (Tab O-9; Tabs T-11 thru T-13) It is the responsibility of the oncoming crew to verify the write-ups for their MAF and LCC. (e.g., Tab V-2.3; Tab V-5.4) In addition, the MCC must check the operational status for each of the LFs within their flight and note any maintenance in progress or scheduled during their alert. (Tab V-2.3; Tab V-5.4)

At the time of crew changeover, the LFs for Alpha flight were experiencing little activity. (Tab O-9; Tab V-3.3; Tab U-29) Following crew changeover, the MCC received weather forecasts and weather condition updates. (Tab V-3.4) The MCC for Alpha flight was able to prepare for any changes in weather conditions. (Tabs W-3 thru W-7) The forecast for the afternoon of 23 May called for thunderstorms and elevated wind speeds. (Tabs W-3 thru W-7; Tab V-5.3) In advance of severe weather conditions, the MCC ensures all personnel are aware of changes or updates to weather conditions and reviews fault procedures for anticipated commercial power outages. (Tab V-2.8)

When GMRs report from LFs to the LCC and do not clear, the MCC refers to its technical orders (T.O.) for GMR response procedures. T.O. 21M-LGM30G-1-22 directs the MCC to report indications and actions taken to the missile maintenance operations center (MMOC). (Tab BB-16) The MMOC will, according to guidance in their T.O.s, direct the MCC to attempt to clear the fault remotely; have the MCC monitor the fault for a specified period of time; or send a maintenance team to the LF. Some faults have higher priority than others depending on whether the fault will render the missile incapable of launching. (See Tab BB-16)

In the event of an emergency at the LF or missile alert facility (MAF), the MCC responds according to their T.O.s and/or a contingency checklist. (Tab V-2.8; Tabs BB-17 thru BB-18) The contingency checklist provides steps to ensure personnel safety; record event details; and notify emergency response personnel (e.g., fire department, medical and safety, security forces), and their chain of command. (Tabs BB-17 thru BB-18)

The Alpha flight MCC had sufficient planning to appropriately respond to the mishap at A06 on 23 May 2008.

c. Preflight

On 21 April 2008, a general site hardware and equipment configuration inspection of A06, including the LER, found no abnormalities. (Tab R-86) There were no other entries or inspections of A06 until the discovery of the fire damage on 28 May 2008. (Tab V-9.4) There is also no evidence or any unauthorized entries to A06 between 21 April 2008 and 23 May 2008. (Tabs O-5 thru O-13)

On 12 December 2007, A06 was modified with a new environmental control system (ECS). (Tab U-13) On 4 March 2008, a non- PCB battery charger was installed at A06. (Tab U-3) On 21 April 2008, a general site hardware and equipment configuration inspection of A06 found no abnormalities. (Tab R-86) A06 was unmanned and in an operational configuration at the time of the mishap. (Tab D-24)

d. Summary of Accident

Between 21 April and 28 May 2008, the Alpha flight MCCs received no direct indications of a fire at A06. On 23 May 2008, thunderstorms caused commercial power interruptions at several Alpha flight LFs, including A06. (Tab U-29) When equipment sensors inside each LF detect power interruptions, the MCC receives a GMR 2 from the affected LF. (Tab BB-8) At 1634 MST, A06 reported GMRs 2, 26, 27, 28 and 29. (Tab D-24) It is normal for GMRs 26-29 to report when there is an interruption in commercial power, and they will usually clear when commercial power comes back on line. (Tab V-2.7; Tab V-6.6; Tab BB-8) At 1638 MST, A06 reported a missile suspension system fault (GMR 30). (Tab D-24) The MCC notified the MMOC of the GMRs reporting at A06. (Tabs U-39 thru U-41) All GMRs cleared by 2241 MST except for GMRs 28 and 30. (Tab D-25)

When the maintenance team entered the LER on 28 May, they found the walls of the LER and the outer LT covered with soot. The shotgun storage case in the lower LER was resting on the floor and had melted and burned, along with the plastic parts of the shotgun and shotgun shells in the case. The motor generator was running, providing power to the facility. (Tab R-13) The LT heater fan was off. (Tab R-9) The team checked the power distribution panel and found circuit breaker (CB) 13/15 for the LT heater fan tripped. (Tab R-13) The tripped CB explained the GMR 28. (See Tab V-8.2)

After further inspections of A06's LER, it was discovered the suspension system monitor cables were burned approximately 20 feet down inside the LT at the suspension system arms. (Tabs V-11.5 thru V-11.6; Tabs Z-11 thru Z-13) This explained the GMR 30 missile suspension fault.

e. Impact

The exact time of the mishap is unknown. The GMRs from A06 at 1634 MST and 1638 MST on 23 May 2008 are consistent with the fire damage subsequently discovered.

f. Life Support Equipment, Egress and Survival

Not applicable. There were no personnel inside A06 at the time of the mishap.

g. Search and Rescue (SAR)

Not applicable. There were no personnel inside A06 at the time of the mishap.

h. Recovery of Remains

Not applicable. There were no deaths as a result of the mishap.

5. MAINTENANCE

a. Forms Documentation

A review of the records for A06 did not reveal any recurring maintenance problems prior to the mishap. However, two significant maintenance procedures were conducted at A06 shortly before the mishap. (Tabs D-13 thru D-17)

(1) On 3 December 2007, 90 MMXS personnel initiated a work order to replace A06's battery charger. (Tab D-15) The battery charger charges LF batteries located inside the LER, which provide emergency backup power to the facility and are located inside the LER.

The replacement battery charger was installed on 4 March 2008 and properly documented in the Improved Maintenance Management Program (IMMP) history. (Tab U-3) The particular unit installed was provided by the 526th ICBM Systems Group (ICBMSG), Hill AFB, UT. The charger had a -10 part number, indicating it had been modified to remove capacitors containing PCBs. (Tab U-37) Once modified, the battery charger's function and capability were unchanged from the previous battery charger. The modification was completed by 582 MMXS in accordance with T.O. 21M-LGM30G-863, *Modification of 950300-1 Battery Chargers to Remove PCB Capacitors and Replace with Non-PCB Capacitors*. (Tab BB-3)

T.O. 21M-LGM30G-863, paragraph 8.1a, required completion of an Air Force Technical Order (AFTO) Form 349, *Air Force Maintenance Data Collection Record*, for each battery charger modified. (Tab BB-6) 582 MMXS was responsible for completing and maintaining the AFTO Form 349 for A06's battery charger, but this form was not located. (Tab BB-6; Tab U-16) 582 MMXS technicians were also required to update the Depot Maintenance Master Log Form when A06's battery charger was modified, but this form was also not located. (Tabs BB-6)

The AIB searched for other evidence to identify when the battery charger was modified. According to 582 MMXS common practice, technicians marked with permanent marker on the battery charger capacitors the date the capacitors were checked for micro farad (µF) output, following which they were installed into the battery charger and assembly was completed. (Tabs U-35 thru U-36) Two capacitors inside the A06 battery charger were marked with permanent marker with the dates of 1 March 2007 and 5 March 2007. (Tab Z-39) Thus, it was most likely modified on or about 5 March 2007. A supervisor from the 582 MMXS confirmed a battery charger was modified on 5 March 2007 and left their shop on 8 March 2007. (Tabs U-15 thru U-16)

In addition, a second technician normally conducts a production acceptance certification standards (PACS) inspection following completion of a battery charger modification. (Tab U-12) Following a PACS inspection, the battery charger documentation is

stamped to show the inspection was completed. (Tab U-12) In this instance, since the documentation could not be found, 582 MMXS could not verify whether a PACS inspection was completed on the battery charger that was later installed at A06. (Tab U-16)

T.O. 21M-LGM30G-863, paragraph 6 provides, "Variations in accordance with standard maintenance practices are permissible, provided the intent of the TCTO is accomplished." (Tab BB-4) With regards to installing nuts on capacitor terminals, paragraph 6.4.1(b) instructs technicians to "fasten the nuts using 3/8" wrench." (Tab BB-5) The T.O. does not require a specific torque value against which a QA inspector could measure. Personnel at 582 MMXS were unable to identify any other instances where loose hardware was found inside a battery charger. (Tab U-37)

(2) A work order was entered on 12 December 2007 to install a new Environmental Control System ECS at A06. (Tabs D-11 thru D-12) The new ECS was installed on 12 December 2007 and properly documented in IMMP. (Tab U-13)

b. Inspections

A facility maintenance team (FMT) conducted a routine annual inspection of the LF batteries on 21 April 2008. (Tab D-9) The FMT found the batteries' measured voltages each within the normal range. (Tab D-9) The FMT also added water to all battery cells to the fill line as required, consistent with the amount normally required for annual battery inspections at other LFs. (Tabs D-9; V-12.4; V-12.5)

There were no overdue inspections listed for A06 as of 23 May 2008. (Tabs D-13 thru D-16; Tabs U-3)

c. Maintenance Procedures

Prior to 28 May 2008 two significant maintenance procedures were performed at A06.

(1) On 4 March 2008, an electro-mechanical maintenance team (EMT) from the 90 MMXS installed the new battery charger at A06. (Tabs U-3; V-19.2)

(2) The new ECS installed on 12 December 2007 draws air from within the LER through its air handler. (Tab U-13) The ECS' chiller then cools that air and recycles it back into the LER. (Tabs DD-11 thru DD-15) The new ECS eliminated the addition of fresh air, called make-up air, into the LER. (Tabs DD-11; V-16.4; Z-47) The previous ECS provided make-up air at a rate of 5 cubic feet per minute (cfm) into the LER, through an air line from the launcher support building (LSB) adjacent to the LER. The technical order which directed the removal of make-up air required the make-up air line to be capped and sealed. (Tabs DD-15; V-16.14) The make-up air line at A06 was capped and sealed. (Tab Z-47)

Several studies were conducted to examine the significance of make-up air and explore whether its removal would endanger personnel or risk damage to the MM III, the LF or its components. (Tab DD-19) Specifically, the studies looked at whether removal of make-up air would

potentially allow hydrogen gas (H_2) to build up inside the LER to a concentration sufficient to be flammable (called the lower flammability limit (LFL)). (Tab DD-15). The H_2 is continuously generated in small amounts by discharge from the batteries as they are charged, called "off-gassing". Overcharging the batteries causes a proportionately higher rate of off-gassing. (Tab DD-18) Without make-up air, the air inside the LER is recycled. (Tab DD-15) If excessive H_2 is produced, the air content inside the LER can more easily reach the LFL for H_2. Ultimately, a 2002 study concluded the removal of make-up air would not significantly increase risk to personnel, facilities or equipment. (Tabs DD-41 thru DD-42). As part of the new ECS installation, a new K-5 motor starter was also installed. (Tab V-16.10) The K-5 acts as a relay to convert AC 110V input to an adequate voltage to operate the launch tube (LT) heater fan. (Tab V-15.5)

d. Maintenance Personnel and Supervision

Training records from the 582 MMXS do not specifically list battery charger modification as a trained task. (Tabs T-3 thru T-5) 582 MMXS supervisors explained the PACS system used for tracking technician qualifications lists tasks under a heading (example A2.1: Security) followed by a task code and task name list. (Tabs T-3 thru T-5) "Task LM-HS/RS/015/00" is the heading under which battery charger overhaul procedures were listed. This format does not clearly document task qualification and training for specific tasks. The practice in March 2007 was to qualify technicians on all tasks under each heading. Once the technician was qualified on all tasks under a heading, the heading was signed off. As of March 2007, there were three technicians in 582 MMXS qualified to perform battery charger modifications. (Tabs T-3 thru T-5) These technicians completed their training between 2002 and 2004. (Tabs T-3 thru T-5) Each of these three technicians' training records showed certification under that particular heading. (Tabs T-3 thru T-5) When the AIB team visited Hill AFB, UT, the technicians were able to demonstrate their skills and appeared highly qualified, mission-focused, safety-conscious, and professional. Thus, although detailed training documentation was lacking, the technicians performing the battery charger modifications appear to have been adequately trained.

Work Control Documents (WCD) issued for each battery charger direct 582 MMXS technicians to have a second PACS-qualified technician (qualified to perform battery charger overhaul/modifications) visually inspect and verify all electrical checkout results in accordance with T.O. 21M-LGM30F-22-3-4, *Depot Level Operations and Maintenance Control Electrical and Electronic Repair*, prior to approving a battery charger for placement into service. Following this inspection, the WCD is stamped in the corresponding block with a number identifying the technician who certified the work. (Tabs U-7 thru U-12). As previously discussed above in Section 5a(1), 582 MMXS could not produce this documentation for the A06 battery charger.

Finally, personnel from a separate quality assurance (QA) office within 582 MMXS randomly inspect the quality of work performed at the shop. The QA inspections results should be recorded on a computer system, but 582 MMXS personnel were unable to find a log of the last time QA was performed in their shop.

(2) Boeing Company technicians install the new ECS and its ancillary components in LFs. (Tabs U-19; V-17.4) The technicians are supervised by Boeing representatives. (Tab U-19) Boeing also provides a quality assurance (QA) representative on each installation team. (Tab U-19) Upon completion of the installation, a representative from Northrop Grumman Corporation (NGC) inspects the quality of the work and accepts the work. (Tab V-16.2) The NGC representative who accepted the new ECS installation at A06 did not note anything related to problems with the quality of the workmanship by the installation technicians. (Tabs V-16.2 thru V-16.3)

e. Fuel, Hydraulics and Oil Inspection Analyses

Not applicable. There is no record of fuel, hydraulics or oil analysis for A06.

f. Unscheduled Maintenance

Not applicable. There is no record of unscheduled maintenance at A06 prior to the mishap.

6. AIRCRAFT AND AIRFRAME, MISSILE OR SPACE VEHICLE SYSTEMS

a. Condition of Systems

The mishap at A06 resulted in damage limited to the inside of the LER. Soot from the burning of the plastic of the shotgun case in the lower LER accumulated throughout the LER. (e.g., Tabs R-7; V-4.3; V-11.3) The ECS air handler absorbed some of the soot, (Tab Z-45) but the rest was dispersed by the ECS into the LER and support equipment drawers. (Tabs J-34 thru J-46)

The shotgun case was melted from its normal form except for the side touching the LER floor and the top end. (Tabs Z-17 thru Z-21) The synthetic stock of the shotgun was nearly destroyed. (Tab Z-17) The cushion foam inside the case was consumed by the fire, and all ammunition inside the case was expended and/or consumed due to the fire inside the case. (Tabs Z-17 thru Z-21)

Melted plastic and plastic splatters were found on the I-beam where the shotgun case was mounted, on the outside of the LT walls and in the area surrounding the shotgun case. (Tabs Z-17 thru Z-31) The paint was blistered on the inside wall of the LT adjacent to where the shotgun case came in contact with the outside of the LT wall. (Tab Z-7) The remains of the nylon retention straps that held the shotgun case to the I-beam and the metal hooks from the straps were found on the floor next to the I-beam. Several straps remained affixed to the I-beam. (Tab V-10.7) No evidence of electrical arcing was found on any of the retention strap hooks, ratcheting mechanisms, or shotgun. (Tab DD-102)

After the site was powered down on 29 May 2008, the battery charger was no longer charging the LF batteries, and the batteries were no longer losing electrolyte (water) due to normal cycle of charging and off-gassing. (See Tab J-103) Upon subsequent inspection, it was determined the batteries collectively lost a total of approximately 12 gallons of water. (Tabs O-39; J-118)

The lower umbilical cable, a set of cables that electrically connects the LF support equipment to the missile, was charred on its outer insulation from the point it entered the LT from the lower LER to the left articulating arm, which is about 20 feet down inside the LT. (Tabs V-11.5; Z-9 thru Z-15) Most burning occurred in sections where duct tape was wrapped around the cable. (Tabs Z-9 thru Z-15) No damage was found to the inner shielding or conductors on the lower umbilical cable. (Tab DD-101) The suspension system monitor cables, commonly referred to as pressure monitor cables, were bundled with the lower umbilical cable. They were also damaged as a result of the duct tape burning. (Tabs V-11.5; Z-11 thru Z-13)

The battery charger was removed from the LER and taken to 526 ICBMSG for testing. There was charring on the top panel and a large amount of silicone around the bottom mounting plate. (Tabs J-25; DD-311) 582 MMXS technicians disassembled the battery charger and discovered extensive internal fire damage. (Tabs J-25; DD-319) They also found a loose connection on one of the terminals to capacitor C101A. (Tabs J-25; Z-37) The solder-filled vents on top of the capacitors C101A and C101B near the terminal lugs had vented, indicating the capacitors overheated. (Tab J-25) There was evidence of electrical arcing in two place between one of the AC input wires to C101A (wire #4) and the chassis of the charger. (Tabs J-25; Z-37)

Since the initial inspection of A06 found that the circuit breaker (CB) for the LT heater fan, CB 13/15, was tripped, safety investigators also inspected the interior of the K-5 motor starter panel. (Tabs V-15.4; V-16.7 thru V-16.8) When they pulled the panel off, investigators observed heat damage on the wires running to the K-5 motor starter. (Tabs V-15.4; Z-43) They removed the K-5 motor starter from the panel, and two wires fell out as if they were loose. (Tabs V-15.4; V-16.8 thru V-16.9)

Safety investigators also looked in the electrical surge arrestor (ESA) room, which is designed to protect the launch facility (LF) from power surges. They found no evidence of an electrical energy event that could have caused or ignited the fire. (Tab V-13.5)

b. Repair Stations involved in testing components

Several components were removed from A06 and sent to various facilities for testing and analysis. The LER equipment drawers and battery charger were initially sent to Systems Engineering Level Evaluation and Correction Team (SELECT) at Hill AFB for testing. (Tab J-18) After initial inspection of the battery charger at Hill AFB, it was sent to the Air Force Research Laboratory (AFRL), at Wright-Patterson AFB, OH for analysis on the internal electrical components. (Tabs DD-299 thru DD-372)

The missile booster and propulsion system rocket engine (PSRE) were sent to the 526 ICBMSG for testing. (Tab EE-4)

The lower (skirt) umbilical cable, suspension system (pressure) monitor cables, K-5 motor starter and shotgun case and its contents were sent directly to the AFRL, Wright-Patterson AFB for testing and analysis. (Tabs DD-99 thru DD-372; EE-4)

The motor generator and reentry system (RS) were taken to F.E. Warren AFB for testing.

The missile guidance system (MGS) was sent to Boeing Guidance Repair Center (BGRC) in Heath, OH. (Tabs J-14; EE-4)

There were also analyses completed at the 526 ICBMSG to determine the air flow inside the LER (Tabs J-131 thru J-149); to assess the amount of H_2 that may have been discharged from the batteries (Tabs J-99 thru J-125); and to estimate concentrations of H_2 at the time of the mishap (Tabs J-139 thru J-149)

Because lightning strikes were recorded in the vicinity of A06 at the time of the mishap (Tabs F-3 thru F-6), electromagnetic environmental effects technical experts from Aeronautical Systems Center (ASC), Wright-Patterson AFB, analyzed lightning strike as the potential cause of the mishap. (Tabs F-4 thru F-13)

c. Equipment Functionality

With the exception of the battery charger and the K-5 motor starter, visual inspections and tests concluded that the remaining components removed from A06 were functioning adequately at the time of the mishap. There was a loose connection on capacitor C101A inside the battery charger, which caused the battery charger to overheat and malfunction. (Tabs J-25; DD-300). When the K-5 motor starter was inspected, wires were found bubbled and discolored. (Tabs V-9.8; V-15.4; Z-43) Since the GMR 28 on 23 May 2008 failed to clear as of 1634 MST (Tab D-24), it is likely the K-5 motor starter was not operating properly at the time of the mishap.

d. Review of Equipment Test Results

(1) Battery Charger

SELECT personnel removed the panels/covers of A06's battery charger and disassembled the internal connections. They found a loose connection on one of the terminals to capacitor C101A. (Tab J-25) They insulated the damaged wires to determine if a connection could be established, but found that the wires were short-circuited and arcing. (Tab J-29)

The battery charger was then sent to AFRL, Wright-Patterson AFB, for further analysis on the internal electrical components. (Tab J-17) AFRL found the loose connection on the C101A terminal increased current across the connection elevating heat and resistance, which in turn melted the AC input wire (wire #4) from inside. Wires #4 and #15 were connected to the same terminal. Wire #15 was the connecting wire between capacitors C101A and C101B, and was almost completely burned through by the heat from wire #4. There was also thermal damage from the heat from wire #4 to several of the other nearby wires running to and between the capacitors. Red copper oxide was found at the loose terminal connection on C101A, which is a result of copper melting at a temperature of at least 1025° C. AFRL found that other than the loose terminal connection on C101A, all other terminal connections and wire crimping in the battery charger were acceptable. (Tab DD-306)

The AFRL report theorized that the loss of commercial power ("power cycling") could have exacerbated the contact resistance on the loose terminal connection in the battery charger, which ultimately may have caused an electrical spark or fire inside the battery charger. (Tab DD 307)

(2) Lower Umbilical

Electrical testing on the lower umbilical cable by AFRL, Wright-Patterson AFB, revealed shorting of the pressure monitor cables. (Tab DD-101) All other cables in the bundle were electrically sound and showed no evidence of exposure to high current conditions. (Tab DD-101)

AFRL concluded the damage to the umbilical cable and duct tape on the cable was from external thermal exposure (i.e. the fire). (Tab DD-101) They found no evidence of internal heating from high arcing or high current and voltage in the cable shield or primary conductors. (Tab DD-101) AFRL also determined the duct tape and, to a lesser extent, the outer cable jacket are flammable. (Tab DD-101) They concluded that incendiary drippings from burning duct tape could have caused the thermal damage observed on the mishap cable harness. (Tab D-101) (Tab DD-100)

(3) Shotgun Case, Shotgun, Shells and Retention Straps

AFRL, Tyndall AFB, FL, tested different pieces of the shotgun case, its contents and the retention straps for flammability. They found the cushion foam inside the case ignited after one to two seconds when exposed to a propane torch or equivalent flame. (Tabs DD-6; DD-7) The downside of this approach to testing the foam's flammability was they could not quantify the energy (temperature) at which it would ignite. (Tab DD-7) Prior to the use of a direct flame, they also tested flammability by wrapping wire around a piece of the foam and a piece of the plastic from the shotgun case and applying current. (Tab J-160) This gave them an estimated temperature at which these items would ignite. They estimated the shotgun's inside foam would ignite at 890°F. (Tab J-160) This study was not directly applicable to the investigation in that damage discovered in the LER such as the charring on the lower umbilical cables indicates a flame was present.

Mr. John Staub, AFSPC Command Fire Chief, during a preliminary investigation, speculated the mishap could have been caused by lightning striking A06. (Tab O-45) However, if lightning had struck A06, it would have flowed through the ESA room into the LER. AFRL found no signs of electrical arcing on the hooks and metal ratcheting mechanisms on the shotgun case retention straps. (Tab DD-102)

(4) LER Support Equipment Drawers

SELECT first tested the LER support equipment drawers for electrical functionality, and all passed. Next, they installed and tested the drawers for operational functionality at the Strategic Missile Integration Complex (SMIC), which is a fully equipped test LF. All passed these tests as well.

(5) Missile Assembly and Motor Generator

The missile assembly, which is comprised of the PSRE, missile booster, reentry system (RS) and the missile guidance set (MGS), was removed from A06. The PSRE and missile booster were sent to 526 ICBMSG for testing. Tests found no abnormalities. (Tab J-10)

Visual inspection and electrical testing of the missile booster found no anomalies. (Tab J-10)

Inspection and electrical testing of the RS and its components found no anomalies. (Tabs J-4; J-5)

The MGS passed electrical and mechanical testing. (Tab J-14)

Analysis of the MG found no anomalies or operational flaws. (Tab O-37) Additionally, the MG showed no signs of arcing or sparking and the commutator and brushes showed no signs of damage or irregular wear. (Tab O-45)

(6) Airflow in the LER and H_2

526 ICBMSG analyzed the airflow inside a MM III LF, including the LER and the LT. The analysis found the greatest flow of air is in the lower LER near the ECS air handler and the LT heater fan. (Tab J-134) The burned shotgun case was adjacent to the ECS air handler. (See Tab Z-21; Tab Z-29) The analysis also depicts how the air flows in and out of the LT. (Tab J-135) First, the LT heater fan blows air down a duct that extends almost to the bottom of the inside of the LT, then the air flows back up to be pulled into the LER through access points. This includes the LT opening where the lower umbilical enters the LT from the LER. (Tab J-135)

The AIB received a report discussing the types of batteries installed at LFs and their normal charging and off-gassing cycle. (Tabs J-99 thru J-125) The study estimated the amount of water lost by the A06 batteries and the amount of H_2 produced between 21 April 2008 and 23 May 2008. (Tabs J-118 thru J-123)

An additional report built upon this analysis to estimate the concentration of H_2 in A06's LER at the time of the mishap and to determine if the concentrations had reached the lower flammability limit (LFL) of 4.1%. (Tabs J-139 thru J-144) The calculations in this report assumed a volume of 12,750 ft^3 for the LER and an air leakage rate of 2.1 cfm from the LER. (Tab J-142) The report's calculations estimated the concentration of H_2 would have reached the LFL if air leaked from the LER at less than 2.1 cfm. (Tab J-143)

The AIB received a third report from a chemist at the 809th Maintenance Support Squadron (MXSS), Hill AFB. (Tab DD-3) This study assumed a volume at 7,500 ft^3 for the LER and no air leakage from the LER and estimated H_2 concentrations would have been 17%, which is above the LFL. (Tab DD-3) None of these three studies considered whether H_2 might have collected in higher concentrations in different areas of the LER. (See Tabs D-3; J-139 thru J-144)

(7) Lightning study

A study by ASC electromagnetic environmental effects technical experts found no evidence indicating A06 might have experienced a lightning strike that could have caused or contributed to the mishap. (Tabs F-4 thru F-13)

(8) K-5 Motor Starter

At the time of this report testing of this component is ongoing at the AFRL, Wright-Patterson AFB.

7. WEATHER

a. Forecast Weather

The forecast called for potentially severe thunderstorms, winds between 15 and 30 knots and occasional wind gusts of 30 knots. (Tab W-4) The temperature was forecasted to range between 44° and 64° F. (Tab W-4) There was also a potential for hail and/or tornadoes. (Tab W-3)

b. Observed Weather

On 23 May 2008, from 1530 to 1730 MST, the following weather conditions were observed in the vicinity of A06:

(1) Sky: mostly cloudy conditions.
(2) Temperature: 57 – 60° F.
(3) Wind: SE 20 – 29 MPH with gusts to 39 MPH.
(4) Pressure: from 29.60 to 29.67 in/hg.
(5) Weather: thunderstorms

(Tab F-3) Between 1600 and 1700 MST there were approximately eight lightning strikes within one mile of A06. (Tab F-7)

c. Space Environment

Not applicable. The mishap did not occur in space.

d. Conclusion

A06 is configured to operate in all weather conditions including thunderstorms and extreme winds. Thus, it was within prescribed weather limitations on 23 May 2008.

8. CREW QUALIFICATIONS

a. Training

The Alpha flight MCC serving on alert duty on 23 May 2008 was current on all training and fully qualified. The MCCC initially served on the Peacekeeper (PK) ICBM weapon system from 2003 to 2005. After completing MM III transition training in November 2005, the MCCC certified as a MM III MCCC on 9 February 2006. (Tabs T-7 thru T-8) The DMCCC completed initial qualification training on 8 August 2006, and certified as a DMCCC on 17 January 2007. (Tab T-9)

b. Experience

As of 23 May 2008, the MCCC had completed over 275 alerts; the DMCCC had completed approximately 120 alerts. Crew qualifications were not a factor in this mishap.

9. MEDICAL

There is no evidence to suggest health or lifestyle was a factor in this mishap.

10. OPERATIONS AND SUPERVISION

a. Operations

The squadron did not have an elevated operations tempo between 21 April and 28 May 2008. Witnesses described the operations tempo as routine.

b. Supervision

The alert for 23 May 2008 was executed as scheduled and planned. Supervision was not a factor in this mishap.

11. HUMAN FACTORS

There were no human factors substantially contributing to the mishap.

12. GOVERNING DIRECTIVES AND PUBLICATIONS

a. Primary Operations Directives and Publications

1. Air Force Space Command Instruction (AFSPCI) 10-204, *Missile Alert Facility (MAF) Management and Maintenance*, 1 July 1999
2. Technical Order (T.O.) 21M-LGM30G-1-22, *Minuteman Weapon System Wings III and V*, 17 June 1994 with Change 43, 20 November 2007

b. Maintenance Directives and Publications

1. Air Force Instruction (AFI) 21-101, *Aircraft and Equipment Maintenance Management*, 29 June 2006
2. AFI 21-118, *Improving Air and Space Equipment Reliability and Maintainability*, 2 October 2003
3. AFI 21-200, *Munitions and Missile Maintenance Management*, 10 March 2007
4. AFI 21-202, *Missile and Space Systems Maintenance Management*, 15 November 2007
5. AFSPCI 21-202V1, *Intercontinental Ballistic Missile (ICBM) Maintenance Management*, 15 October 2007
6. AFI 21-204, *Nuclear Weapons Maintenance Procedures*, 17 January 2008, with Change 1, 12 May 2008
7. AFI 21-204_AFSPCSup_1, *Nuclear Weapons Maintenance Procedures*, 1 December 2005
8. AFSPCI 21-114_90SWSup1, *Intercontinental Ballistic Missile (ICBM) Maintenance Management*, 15 September 2005
9. AFI 91-107, *Design, Evaluation, Troubleshooting and Maintenance Criteria for Nuclear Weapons Systems*, 6 April 1994
10. AFI 91-116, *Safety Rules for Long-Term Storage and Maintenance Operations for Nuclear Weapons*, 3 April 2006
11. T.O. 21M-LGM30G-2-10, *Launch Facility and Support Building Procedures*, 1 November 2005, with Change 12, 26 March 2008
12. T.O. 21M-LGM30G-2-11, *Power Subsystems Wings I, III, V*, 1 February 2002, with Change 25, 18 Jan 2008
13. T.O. 21M-LGM30G-2-1-7, *Organizational Maintenance Control, Minuteman Weapon System*, 1 June 2005, with Change 9, 30 November 2007
14. T.O. 21M-LGM30G-2-7-4, *Launch Facility Environmental Control System*, 21 July 2002, with Change 28, 21 May 2008
15. T.O. 21M-LGM30G-22-3-4, *Depot Level Operations and Maintenance Control Electrical and Electronic Repair*, 1 February 2002, with Change 11, 22 May 2008
16. T.O. 21M-LGM30G-863, *Modification of 950300-1 Battery Chargers to Remove PCB Capacitors and Replace with Non-PCB Capacitors*, 1 August 1996

NOTICE: The AFIs listed above are available digitally on the AF Departmental Publishing Office internet site at: **http://www.e-publishing.af.mil.**

c. Known or Suspected Deviations from Directives or Publications

The 582 MMXS technician who modified the battery charger for A06 likely deviated from T.O. 21M-LGM30G-863, which required nuts to be fastened to the terminals on the capacitors. (Tab BB-5) The term "fasten" lacks quantitative measurement, and thus may be subject to varying interpretation and application. The 582 MMXS technicians qualified to perform battery charger modifications consistently explained that they used a ratchet and socket to firmly tighten the nuts onto the terminals with a lock washer. (Tab U-38) (Tab BB-5) Therefore, if a nut was initially tight, it should not ordinarily come loose on its own. Testing at SELECT and AFRL did not produce any other rationale for the nut on the capacitor terminal in the battery charger to

have come loose after proper installation. (Tabs J-18 thru J-32; Tab DD-299 thru DD-309) Therefore, it is most likely that the nut was never fastened correctly, and remained loose from the time the capacitor was installed.

13. NEWS MEDIA INVOLVEMENT

The 90th Missile Wing Public Affairs Office confirmed there was no local or national media involvement in this mishap. The Air Force has not presented an official media release of this mishap.

14. ADDITIONAL AREAS OF CONCERN

No additional areas of concern were identified as contributing to this mishap.

18 September 2008

ROBERT M. WALKER, Colonel, USAF
President, Accident Investigation Board

STATEMENT OF OPINION

MINUTEMAN III LF A06 MISHAP
23 MAY 2008

Under 10 U.S.C. 2254(d), any opinion of the accident investigators as to the cause of, or the factors contributing to, the accident set forth in the accident investigation report may not be considered as evidence in any civil or criminal proceeding arising from the accident, nor may such information be considered an admission of liability of the United States or by any person referred to in those conclusions or statements.

I find by clear and convincing evidence the cause of the mishap at A06 was a loose connection on capacitor C101A of the battery charger inside A06's launcher equipment room (LER). The loose connection was most likely caused by the failure of the technician who installed the capacitor to securely fasten the nut. This failure was not detected or corrected by subsequent quality assurance inspection of the unit prior to its installation at A06, or otherwise upon routine equipment inspections of the facility.

I further find substantial evidence to conclude the following factors substantially contributed to the mishap or to damage within the LER. First, the T.O. provided inadequate direction to technicians. The direction to "fasten the nuts with 3/8 inch wrench" in T.O. 21M-LGM30G-863, para 6.4.1(b), is vague in that it fails to require a specific torque value for the capacitor connection. This permitted variation in the fastening of the capacitor connection wires, which led to or permitted the loose connection.

Second, 582 MMXS procedures for quality assurance (QA) evaluation of battery charger modifications and maintenance did not require visual or other direct inspection of the capacitor installation, which might have detected and corrected the loose connection. The QA procedure merely verified electrical continuity and did not require a visual hardware check or other steps to validate proper installation of the capacitors.

Third, the modification of A06's ECS eliminated inflow of make-up fresh air into the LF and the LER. Although the defective battery charger overcharging the LF batteries caused increased off-gassing which created the H_2 buildup, make up air might have prevented or delayed the H_2 from reaching the flammable concentration that, once ignited, fueled and spread the fire.

I further find substantial evidence to conclude that two additional factors substantially contributed to the damage caused by this mishap. First, the use of duct tape on the lower umbilical cables introduced a flammable substance into the LER which, once ignited by the fire, charred the lower umbilical, rendering it unfit for further use and requiring its replacement.. Second, the holes cut in the shotgun case exposed the internal foam insulation to the fire, resulting in the melting and burning of the shotgun case and its contents, which produced soot residue deposited throughout the LER and equipment racks. Absent the presence of either or both of these additional flammable materials, the fire might have extinguished itself after consuming the H_2 gas, without causing any further damage inside the LER.

18 September 2008

ROBERT M. WALKER, Colonel, USAF
President, Accident Investigation Board

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