2M053, Module 2: Spacelift Orientation and Maintenance Fundamentals

Module 2 of career development course (CDC) 2M053, Missile and Space Facilities Journeyman, will provide an introduction to the spacelift aspect of this career field. There will be further information on standard publications, including technical orders (TO) and civil engineering manuals (CEM). Common electrical test equipment will be introduced as well as some troubleshooting techniques. This volume will also familiarize you with the hardened intersite cable system (HICS).

Lesson 1 provides an introduction into spacelift, including the organizations, launch vehicles (LV), and the infrastructure for those LVs. This unit will explain some common spacecraft characteristics. While not necessarily part of spacelift, or the facilities maintenance specialty, this unit will also provide a basic understanding of the Air Force Research Laboratory (AFRL) and the Air Force Operational Test and Evaluation Center (AFOTEC).

Lesson 2 describes publications used in the career field. We will look at standard publications and how to identify and find them. TOs will be introduced along with procedures on how to correct mistakes in them. We will look at civil engineering manuals, how to use them together, and how to correct mistakes in them as well.

Lesson 3 presents some maintenance fundamentals. Everything from multimeter usage to troubleshooting will be explained. Additionally, you will learn about our maintenance information systems and how we correct supply deficiencies.

Lesson 4 will provide information on the hardened intersite cable system, which is a shop you may be soon assigned to or move to later in your career once you have fulfilled assignments in other work centers. A glossary is included for your use. Code numbers on figures are for preparing agency identification only. The use of a name of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

To get a response to your questions concerning subject matter in this course, or to point out technical errors in this module, knowledge checks, practice exercises, or course examination, please have your supervisor/Unit Training Manager (UTM) e-mail Air Force Career Development Academy (AFCDA) Support Services at 2AF.AFCDA.SupportServices@us.af.mil or call commercial: 228-377-7044/DSN: 597-7044, if you have any issues with AFCDA courseware. Support Services hours are: 0730-1630 Central Standard Time (CST).

Lesson 1. Spacelift, Research and Development

Main Points

1. Spacelift Organization and Units
    a. Space domain overview
    b. Mission of spacelift organizations
    c. Functions of spacelift units
2. Launch Vehicles and Spacecraft
    a. Atlas V vehicle configuration and infrastructure
    b. Delta IV vehicle configuration and infrastructure
    c. Spacecraft systems
3. Research and Development
    a. Mission of research and development organizations

“It is time for us as a service, regardless of specialty badge, to embrace space superiority with the same passion and sense of ownership as we apply to air superiority today.”

- General David Goldfein

Click here to begin Lesson 1.

An unarmed Minuteman III intercontinental ballistic missile launches during an operational test at 2:10 a.m. PT on Aug. 2, 2017, at Vandenberg Space Force Base (VSFB) in California.

The intercontinental ballistic missile (ICBM) force is only one aspect of this job you may have the opportunity to work in. The Air Force (AF) has devoted a lot of resources into space programs and the continued research and development of our weapon systems. This continued investment is just another indication that you are part of a dynamic career field that not only plays a critical role in missions beyond the ICBM in underground silos, but also supports critical security and communication missions into space.

This lesson will introduce you to the units that serve as our mainstay in the space program, ensuring that every mission is accomplished safely and effectively. We will then look at the different launch platforms and infrastructure used to launch satellites into orbit. The satellite is the ultimate payload and the sole vehicle for these platforms, so we will discuss the missions and characteristics of different satellites. Finally, we will see what missions the Air Force Research Laboratory (AFRL) and the Air Force Operational Test and Evaluation Center (AFOTEC) perform.

Click here to continue forward in the lesson.

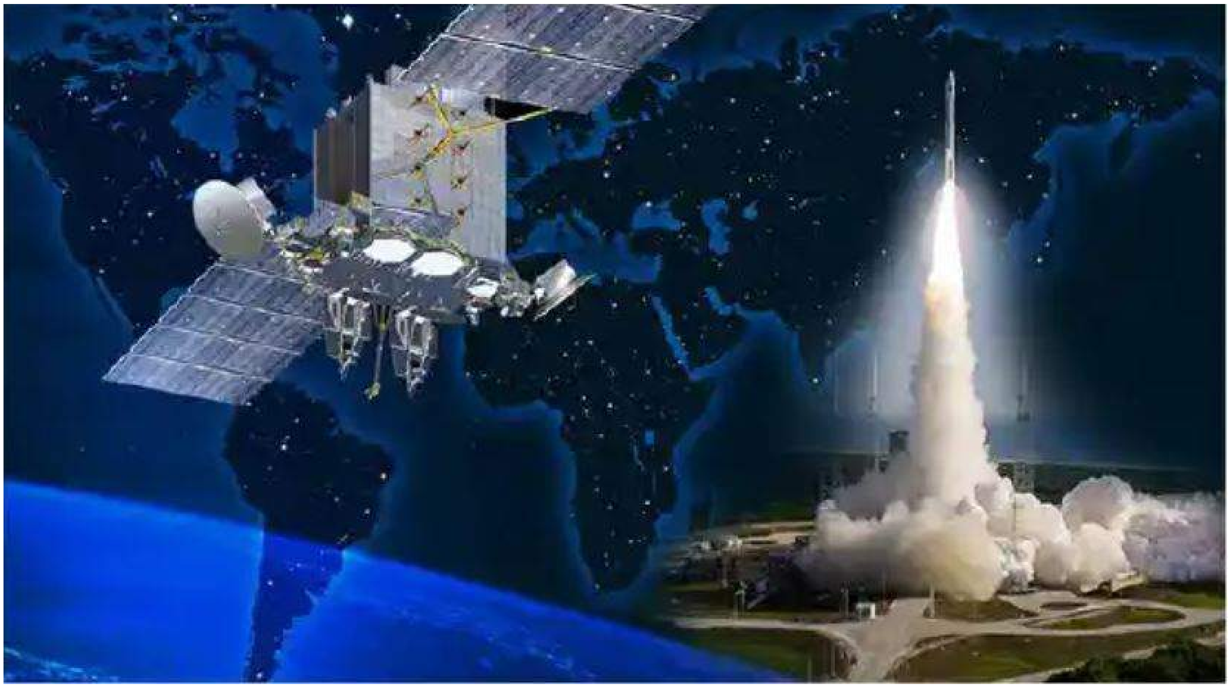
Air Force Global Strike Command (AFGSC) and Air Force Space Command (AFSPC) emblems.

Spacelift Organization and Units

By starting your career in ICBMs, along with the information in the previous career development course (CDC) volume, you are likely familiar with Air Force Global Strike Command (AFGSC), as well as its structure and responsibilities.

If you have the opportunity to work in the spacelift business, you will transition to Air Force Space Command (AFSPC). We will get started with some basic terms and ideas to get you up to speed, and then move into spacelift organizations and units.

Click here to learn about the space domain.



Space as a War-fighting Domain

Space Domain Overview

Nearly every military mission the United States (US) undertakes is enhanced by space. It provides Global Positioning System (GPS) information, satellite communications, advanced warning of missile attacks, spacelift capabilities, and space control operations for combat forces. There is little doubt that the use of space capabilities acts as a significant force multiplier. Any degradation to these systems could have a significant impact on the success of a military operation. In this lesson, we will concentrate on spacelift and the essential US military programs that spacelift directly supports.

Spacelift Description

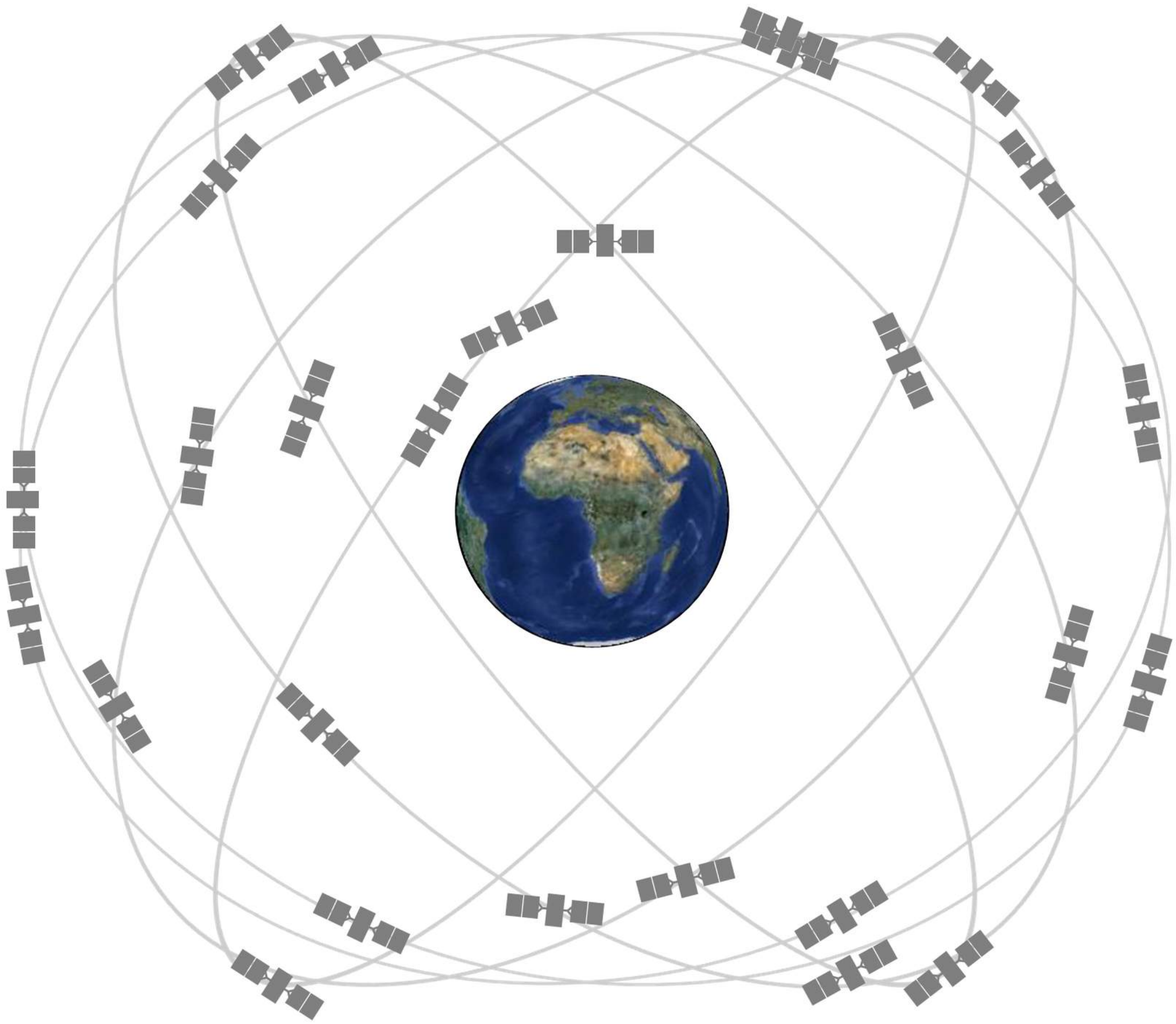
Spacelift is defined as the ability to deliver satellites, payloads, and material into space. Spacelift operations are conducted to deploy, sustain, augment, or reconstitute satellite constellations that support United States Military Operations (USMO). The AF is responsible for operating launch facilities within the United States, and dictates spacelift as one of the 17 key operational functions––assured access to space. Spacelift has four basic purposes:

1. Deploying space systems to fulfill new requirements for satellite service.

2. Sustaining existing space systems whose individual satellites are nearing the end of their useful life, predicted to fail, or have already failed.

3. Augmenting existing space systems with redundant or additional capabilities to enhance space system performance or increase system survivability.

4 Servicing and maintaining existing or newly deployed space systems.



GPS Constellation (expandable 24-slot as defined in Standard Positioning Service (SPS) Performance Standard.

Space Domain Dependence

Humanitarian aid all the way through the full spectrum of military operations is dependent upon the space domain. For example, more than half of all precision munitions utilize GPS. Remotely piloted aircraft that provide our critical intelligence, surveillance and reconnaissance missions are controlled using satellite communications.

Space capabilities integrate our forces, make them more aware, and provide a distinct advantage over our adversaries. Because of those advantages, we can protect the country's interests more effectively, and with fewer casualties than in past conflicts.

This brief lesson provided an overview of the space domain, a description of Spacelift, and closed out with an explanation of why the United States Air Force (USAF) depends on the space domain. Apply this information as we move through the following lessons.

Mission of Spacelift Organizations

Air Force Space Command (AFSPC) is comprised of roughly 30,000 dedicated military members and civilians that are responsible for placing satellites and spacecraft into orbit. This lesson will begin with an overview of AFSPC and the work down to the smaller units.

Click the play button below to watch the video on Air Force Space Command: Space Superiority.

Complete the content above before moving on.

Air Force Space Command Mission and Organization

AFSPC is an Air Force major command (MAJCOM) that is headquartered at Peterson Space Force Base (PSFB), Colorado and is responsible for units located around the world. It was established on 1 September 1982 in order to consolidate spacelift and ICBM, although ICBM forces were transferred to Air Force Global Strike Command (AFGSC) in 2009.

Air Force Space Command (AFSPC) Emblem.

The mission of AFSPC is to provide resilient defendable, and affordable space capabilities for the Air Force, joint force, and the nation. AFSPC has four primary mission areas:

- Build combat readiness.
- Innovate and accelerate to win.
- Develop joint warfighters.
- Organize for sustained success.

AFSPC launches and operates US military satellites to accomplish its mission, and you may have the opportunity to work as a part of the Spacelift mission once you have become a 5-level (Journeyman). These satellites are launched aboard Atlas V and Delta IV launch vehicles (LV) from facilities at Cape Canaveral Space Force Station (CCSFS), Florida as well as Vandenberg SFB, California. 14th Air Force (14 AF) operates the Air Force's worldwide space resources, and is the sole numbered Air Force (NAF) assigned to AFSPC.

Note that there are many organizations that fall under AFSPC, but you'll only be concerned with the 14 AF, and subsequently the 30th Space Wing (30 SW) and the 45 SW, since this lesson is focused on spacelift. Figure 1–1 displayed below shows how 30 SW and 45 SW are organized under AFSPC.

As a major command (MAJCOM), AFSPC also organizes, trains, and equips space units, and establishes the acceptable standards and manages configurations for launch and range systems, facilities, and support infrastructure. AFSPC uses the continuous improvement process to provide support to combat forces and makes space operations reliable and routine for the war fighter.

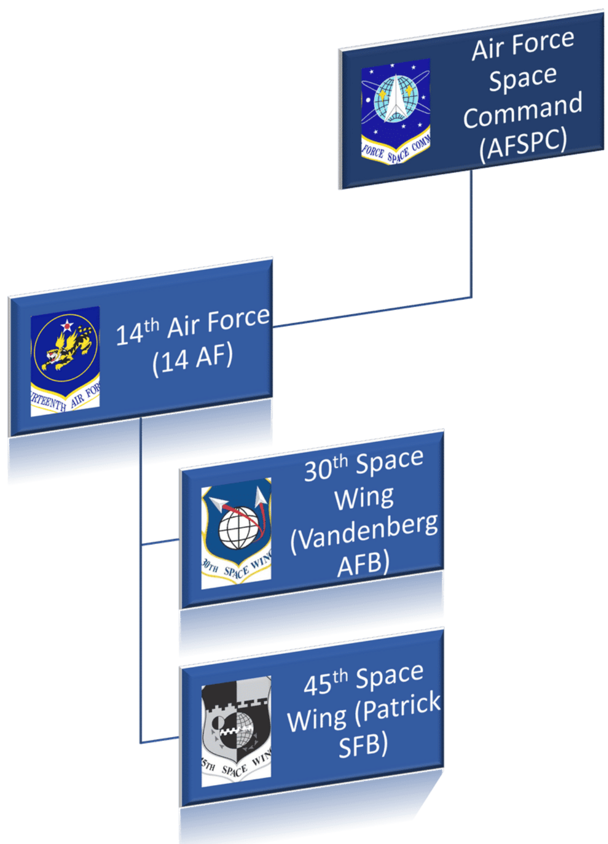


Figure 1–1. 30th Space Wing and 45th Space Wing portion of Air Force Space Command organizational chart.

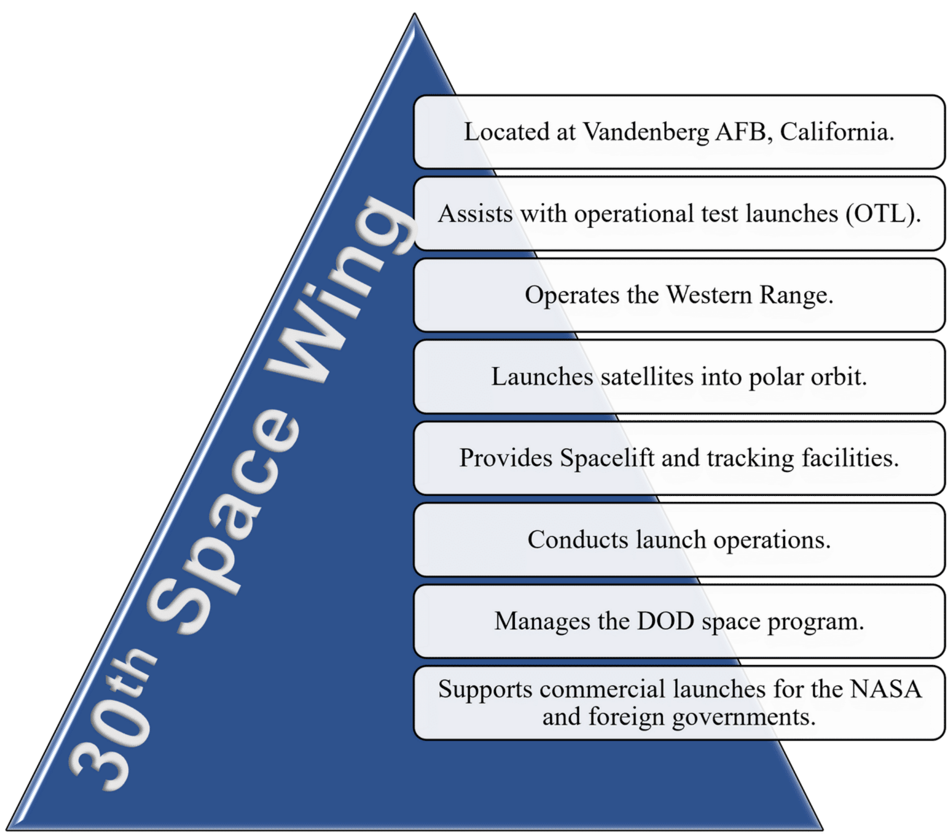
Click here to learn about the 14th Air Force mission and organization.

14th Air Force Emblem.

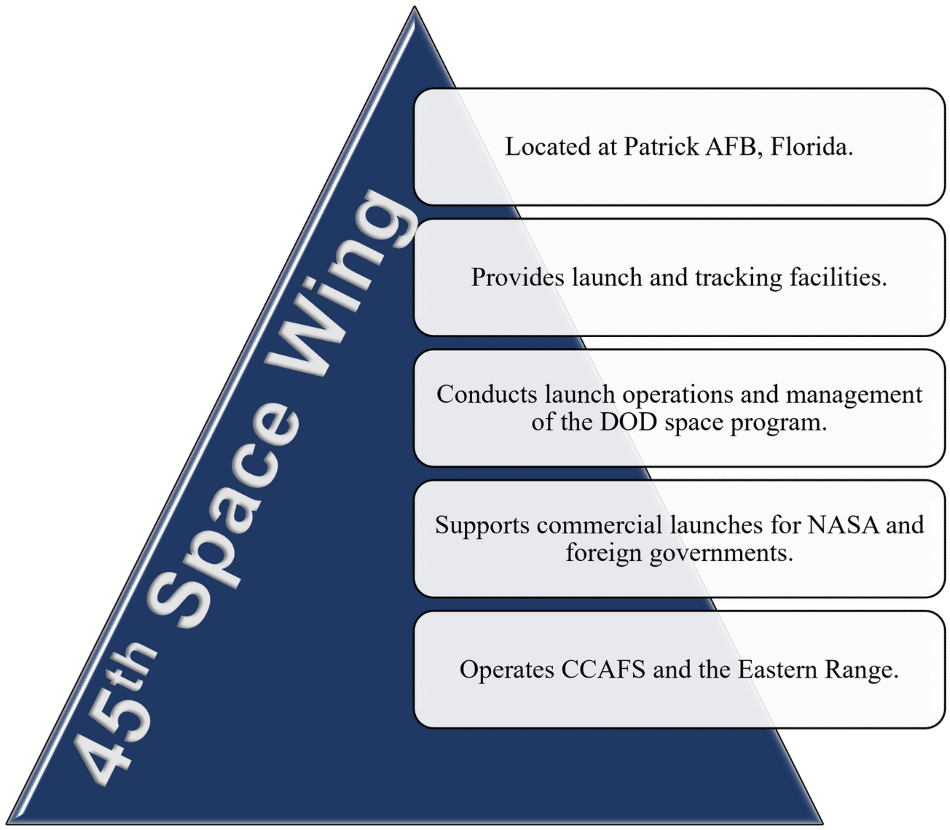
14th Air Force Mission and Organization

14 AF is assigned to United States Strategic Command (USSTRATCOM) for the purpose of space operations. 14 AF organizes, trains, equips, provides command and control, and employs Air Force space forces to support operational plans and missions for US combatant commanders and their subordinate commands. The 14 AF has many subordinate units, but for the purposes of discussing Spacelift, you're only concerned with the 30 SW and the 45 SW. Information on each of these is listed below.

This lesson focused on the basic structure and missions of space organizations, which provided you with a basic overview of the spacelift units that you may have the opportunity to be assigned to later in your career.



Major Units of 14 AF: 30th Space Wing Mission Chart.



Major Units of 14 AF: 45th Space Wing Mission Chart.

Click here to learn about the 14th Air Force mission and organization.

Functions of Spacelift Units

The United States' east and west coast launch facilities (fig. 1–2) provide unique launch-to-orbit capabilities, and nearly all DoD satellites in orbit today were launched from one of these locations. Their geographic positions enable various payloads to be placed into specific orbit profiles.

The integration of each of the agencies involved in launch operations requires a full-time, on-site Air Force launch team that is responsive to the requirements of the AFSPC Commander. The wings are directly subordinate to 14 AF, and manage, direct, control, and support space systems checkout and launch operations for AFSPC and other programs.

Now that you know the roles and responsibilities of the various space organizations, let's focus on the space units you might be assigned to: the 30th Space Wing (30 SW) and the 45th Space Wing (45 SW).

Figure 1–2. East and west coast launch facilities.

30th Space Wing

The 30th Space Wing is the DoD West Coast Launch Facility and the host unit for VSFB. Here, military, federal civilian employees, and contractor employees provide support services to DoD and non-DoD government tenants and aerospace contractors, as well as government and commercial launch support.

The 30th Space Wing manages the launch base and range infrastructure, range systems, as well as launch vehicles (LV) and satellite system processing. It also provides facility and infrastructure support to satellite owners that use LV at VSFB. 30 SW enforces compliance with Headquarters (HQ) AFSPC standards and configuration management for launch and range systems, facilities, and support infrastructure in the western US. The 30th Space Wing aids the Space Surveillance Center (SSC) by supporting the Space Surveillance Network, and operates the Western Range, which supports various aeronautical and sea-based operations conducted within the Pacific and Indian oceans.

30th Space Wing Emblem.

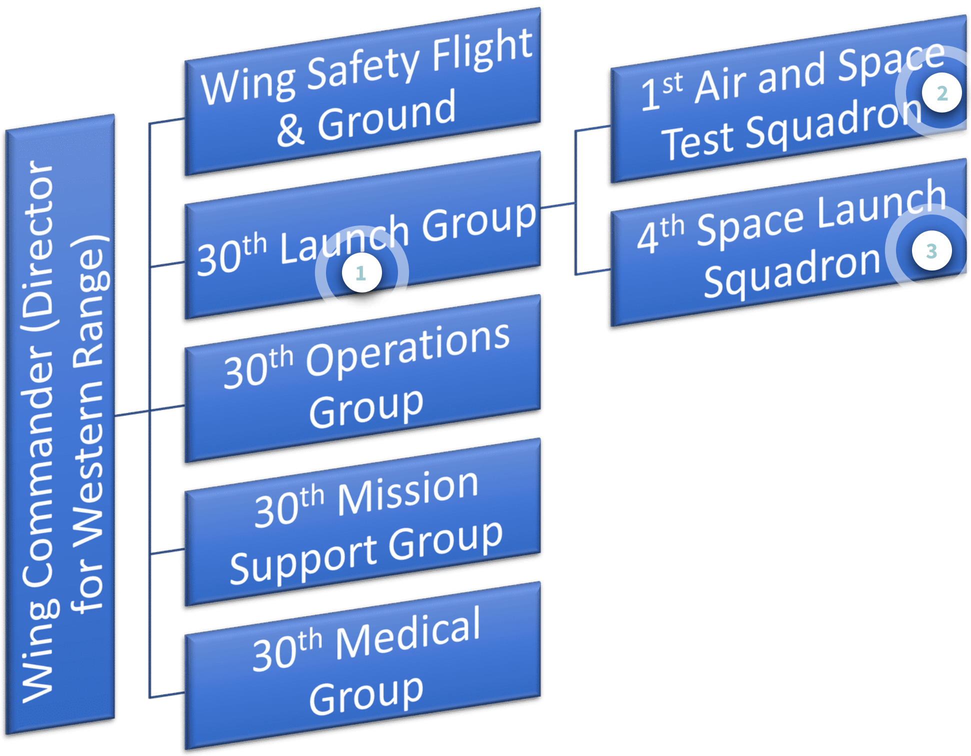
Vandenberg Air Force Base is a Department of Defense space and missile testing base placing satellites into polar orbit (passes over both poles) from the West Coast. The base also leases launch pad facilities to SpaceX for their reusable booster rockets.

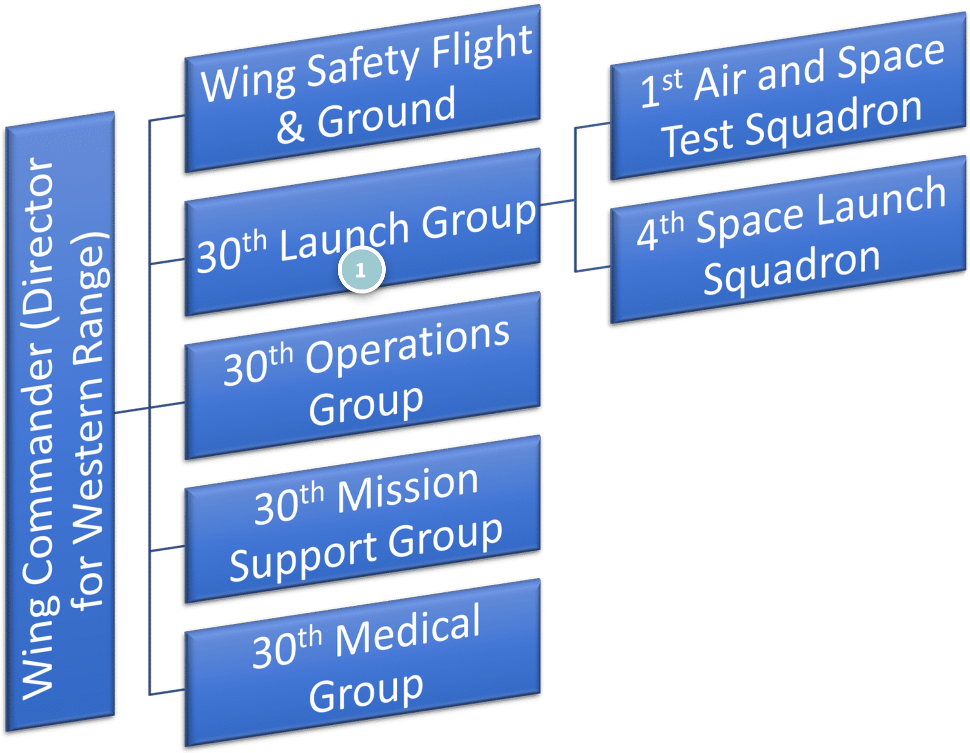
Vandenberg Space Force Base (formerly Vandenberg Air Force Base)

VSFB is situated along 26 miles of coastal desert covering more than 98,000 acres and is the only US military facility that can launch satellites into polar orbit. A satellite in a polar orbit moves between the north and south poles, and to an observer on the ground the satellite would appear to be moving. A satellite in polar orbit will eventually cover the earth's entire surface, which is very useful for the data collection of weather satellites. Vandenberg Space Force Base is also the only site used for tests of operational ICBMs, as well as other ballistic missile systems still under development. These tests are conducted along the 4,200-mile corridor of the Western Range towards the Kwajalein Atoll.

The four groups under 30 SW are the 30th Launch Group, 30th Mission Support Group, 30th Medical Group, and 30th Operations Group. The organization chart shown in figure 1–3 is abbreviated and may not show all components of each organization. You will be concerned mostly with the 30th Launch Group.

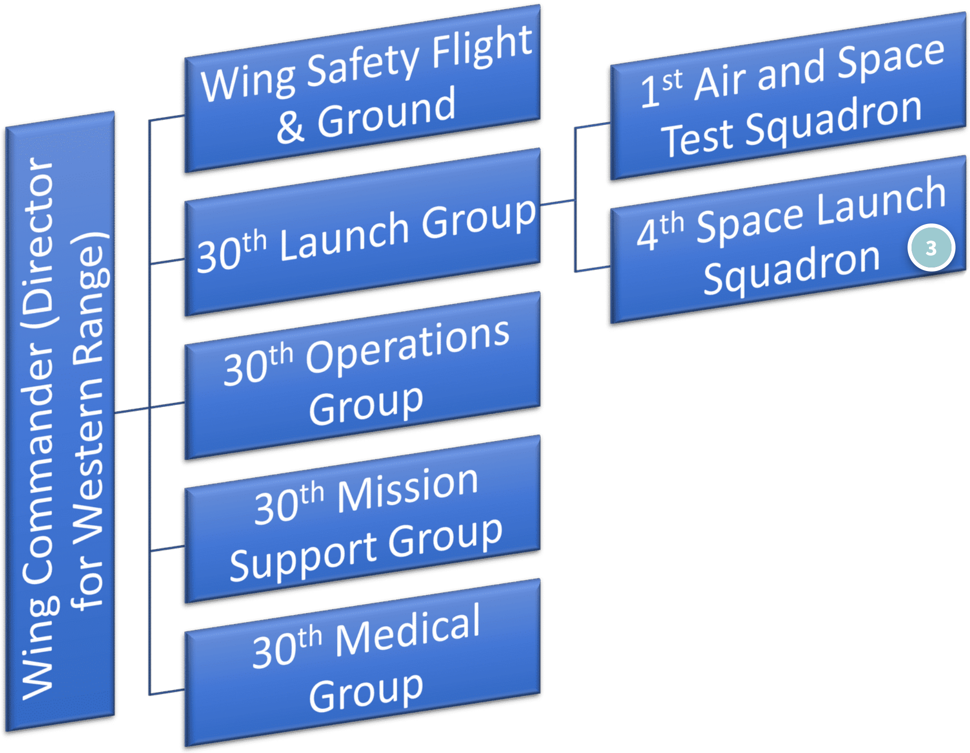
Listed below is the organizational structure of the 30th Space Wing. Click on each number to learn about the 30th Launch Group.


Wing Commander (Director for Western Range)
Wing Safety Flight & Ground
30th Launch Group
30th Operations Group
30th Mission Support Group
30th Medical Group
1st Air and Space Test Squadron
4th Space Launch Squadron
1
2
3



30th Launch Group

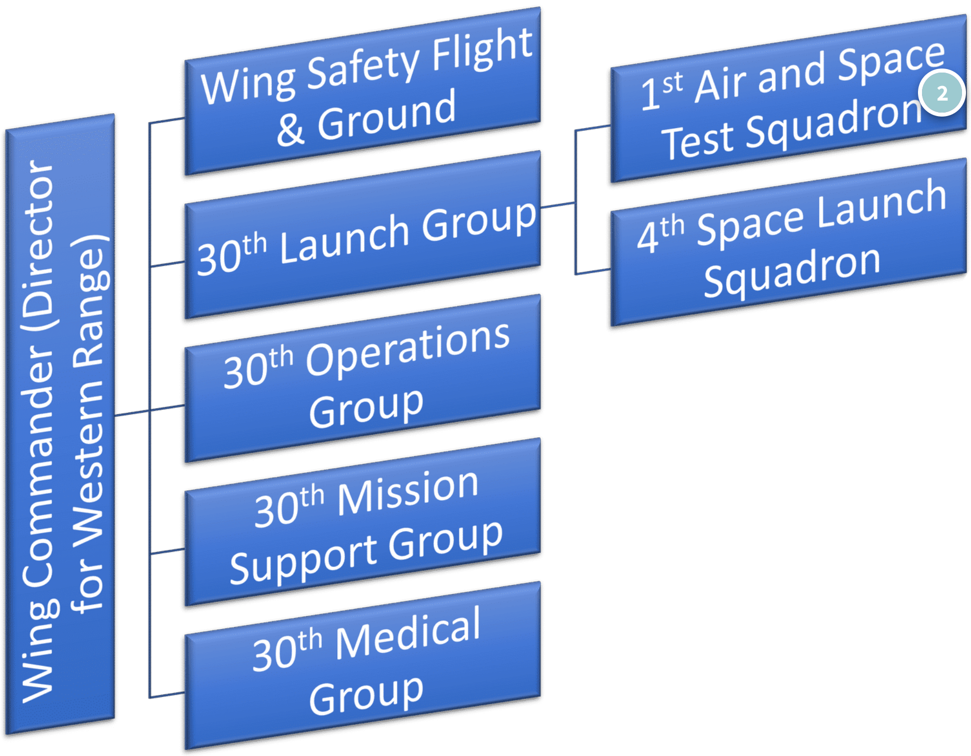
The 30th Launch Group (30 LCG) processes, tests, and launches boosters and satellites, and provides mission assurance, performs launch operations, and oversees mission integration. The 1st Air and Space Test Squadron (1 ASTS) and 4th Space launch Squadron (4 SLS) are the main components of 30 LCG.



4th Space Launch Squadron

The 4th Space Launch Squadron (SLS) leads the Air Force's Evolved Expendable Launch Vehicle (EELV) program on the West Coast. The squadron is responsible for the Delta IV and Atlas V LV, which provide the nation's sole medium and heavy lift capability into polar orbit. EELV operations are used to provide continuous risk assessment and mission assurance (MA) on the Delta IV and Atlas V LV families to 30 SW and the Space Systems Center (SSC) (formerly Space and Missile Systems Center). The 4th SLS also manages satellite processing to ensure reliability, safety, security, resource protection, and environmental compliance. They enable mission assurance by providing technical surveillance for on-site acquisition management and engineering. The 4th SLS oversees the contract for satellite program offices and other payload customers, processes satellites and boosters, and are lead coordinators for construction, modification, and repair activities. These activities support facility operations by reviewing, analyzing, and providing recommendations on proposed building modifications.

If assigned to 4 SLS as a mission assurance technician (MAT), you will use your ICBM experience from previous assignments to provide technical oversight of contractor launch processing activities. You will observe contractors for adherence to technical requirements and maintenance practices. The 4th SLS is a blended organization comprised of military, government civilians, and contractors.



1st Air and Space Test Squadron

The 1st Air and Space Test Squadron is the only full-service Air Force developmental test and evaluation organization for missiles, LVs, and satellite-to-LV Integration. It reuses deactivated ICBMs for a variety of new missions, including space and target launch. The 1st ASTS also performs test and integration functions for experimental space systems, spacelift vehicles, targets, and national and theater missile defense interceptors.

Complete the content above before moving on to learn about the 45th Space Wing.

The United States Space Force has re-designated the 45th Space Wing, which oversees launches on Florida's Space Coast, as Space Launch Delta 45. Via a virtual ceremony held at Patrick Space Force Base in Florida, the change occurred May 11, 2021. Space Launch Delta 45's commander is Brig. Gen. Stephen Purdy.

Click below to learn about the 45th Space Wing.

Click on each tab below to learn about the 45th Space Wing

45TH SPACE WING	PATRICK SPACE FORCE BASE	CAPE CANAVERAL SPACE FORCE ST...

The 45th Space Wing (45 SW) supports services at Patrick SFB, CCSFS, Antigua Air Station, and Ascension Auxiliary Air Field, and provides launch services to a variety of other commercial users. It also supports Spacelift and missile tests for the AF, DoD, NASA, and other CCSFS agencies. 45 SW operates the Eastern Range, which supports various aeronautical and sea-based operations conducted within this vast area. It is also responsible for facilities, LVs, and satellites, which have reached operational maturity, as well as launching new DoD and certain NASA satellites into low, medium, and high altitude geosynchronous, and geostationary orbits. Unlike other orbit types, a satellite in a geosynchronous or geostationary orbit matches the rotation speed of the earth. To the observer on the ground, the satellite would appear to be stationary.

45TH SPACE WING | PATRICK SPACE FORCE BASE | CAPE CANAVERAL SPACE FORCE ST...

Patrick Space Force Base (formerly Patrick Air Force Base) is the administrative hub of 45 SW and the home for most of the wing's many tenants. It is located between the Banana River and the Atlantic Ocean on Florida's East Coast, about 69 miles east of Orlando. The base was initially established by the Navy during World War II and was activated on 1 October 1940 as the Banana River Naval Air Station, which served as a base for anti–submarine sea patrol planes during the war. On 1 September 1946, it was transferred to the AF, and then was immediately deactivated in 1947. It remained in standby status awaiting activation of the Joint Long-Range Proving Ground. The station was activated as Patrick AFB in 1950, named for Major General Mason M. Patrick, Chief of the American Expeditionary Forces Air Service during World War I.

45TH SPACE WING	PATRICK SPACE FORCE BASE	CAPE CANAVERAL SPACE FORCE ST...

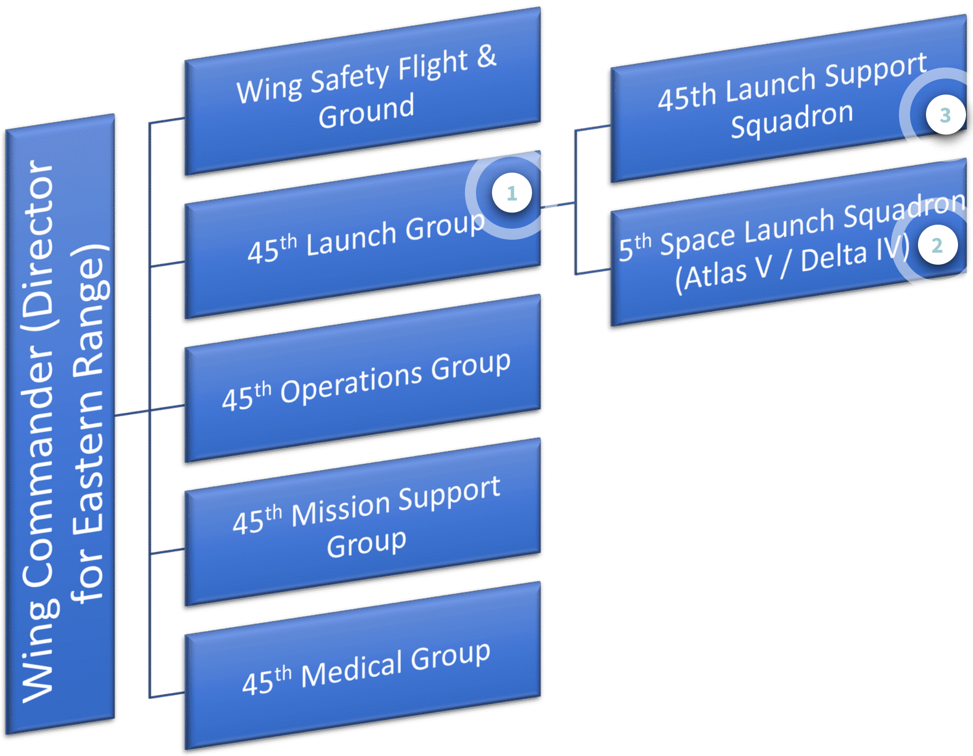
CCSFS covers over 15,000 acres located 20 miles north of Patrick AFB and has been the scene of more than 3,000 launches since 1950. The first US mission in space took place here in 1958 with the launch of the satellite Explorer. In 1961, Al Shepard became the first American astronaut to complete a suborbital space flight after being launched from Cape Canaveral during the Mercury Space Program. The CCSFS Range Control Center oversees all safety functions and monitors all launches and range resources.

Active launch sites include Space launch Complex 41 (SLC–41), where preparation and launch of the Atlas V occurs. Delta IV LVs are launched from Complex 37, and weather rockets are launched from the Meteorological Rocket Launch Facility. DoD satellites are prepared for launch in three facilities: The Satellite Processing and Integration Facility, the Navstar Processing Facility, and the Defense Satellite Communications System Processing Facility.

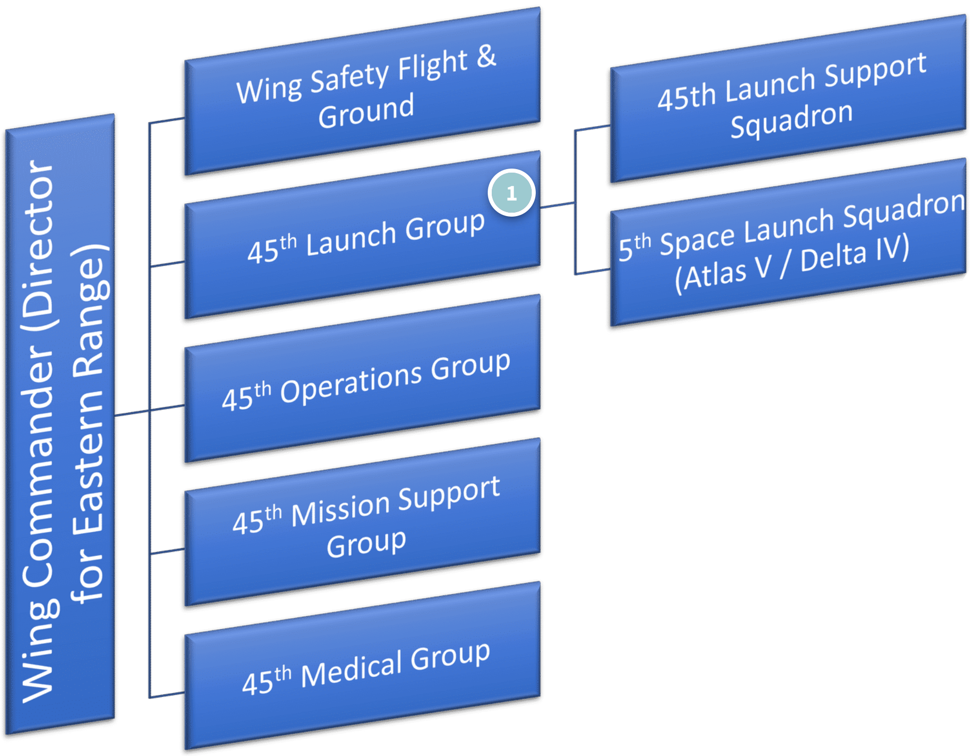
CCSFS takes advantages of the extra 1,000 feet per second of velocity provided by Earth's rotation to launch heavy payloads into circular, elliptical, equatorial, or deep space trajectories. The 45th Space Wing is comprised of 45th Operations, 45th Launch Group, 45th Mission Support, and 45th Medical Groups. The organizational chart in figure 1–4 is abbreviated and may not show all components of each organization. We will focus on the 45th Launch Group (45 LCG).

Click on each tab above before moving on to learn about the 45th Space Wing.

Listed below is the organizational structure of the 45th Space Wing. Click on each number to learn about the 45th Launch Group.

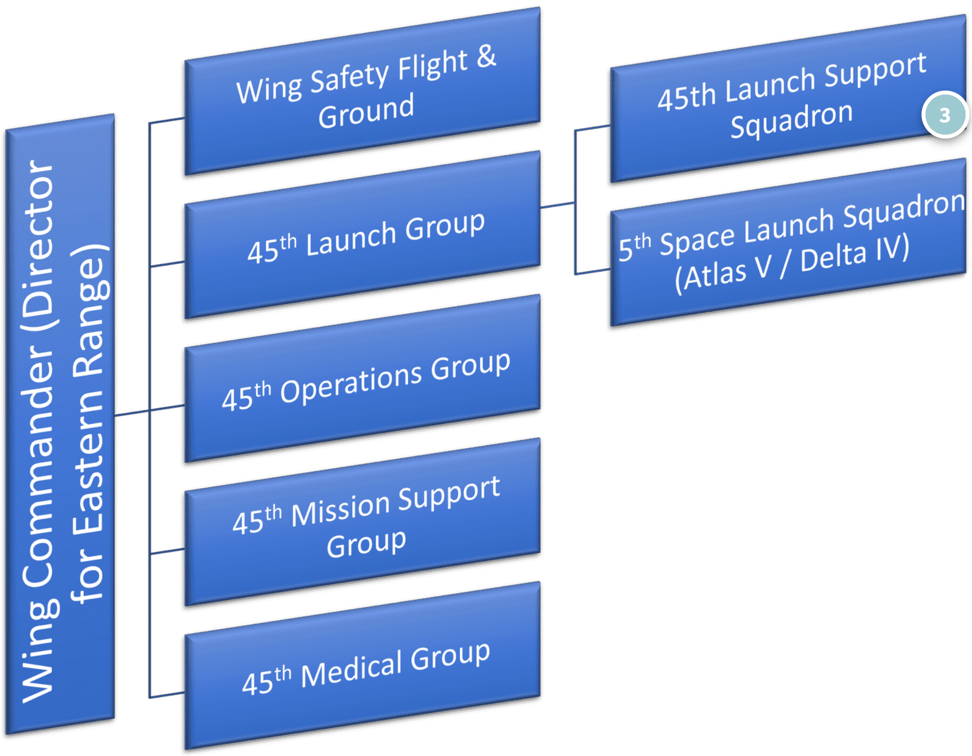


Wing Commander (Director for Eastern Range)
Wing Safety Flight & Ground
45th Launch Group
45th Operations Group
45th Mission Support Group
45th Medical Group
45th Launch Support Squadron
5th Space Launch Squadron (Atlas V / Delta IV)
1
2
3



45th Launch Group

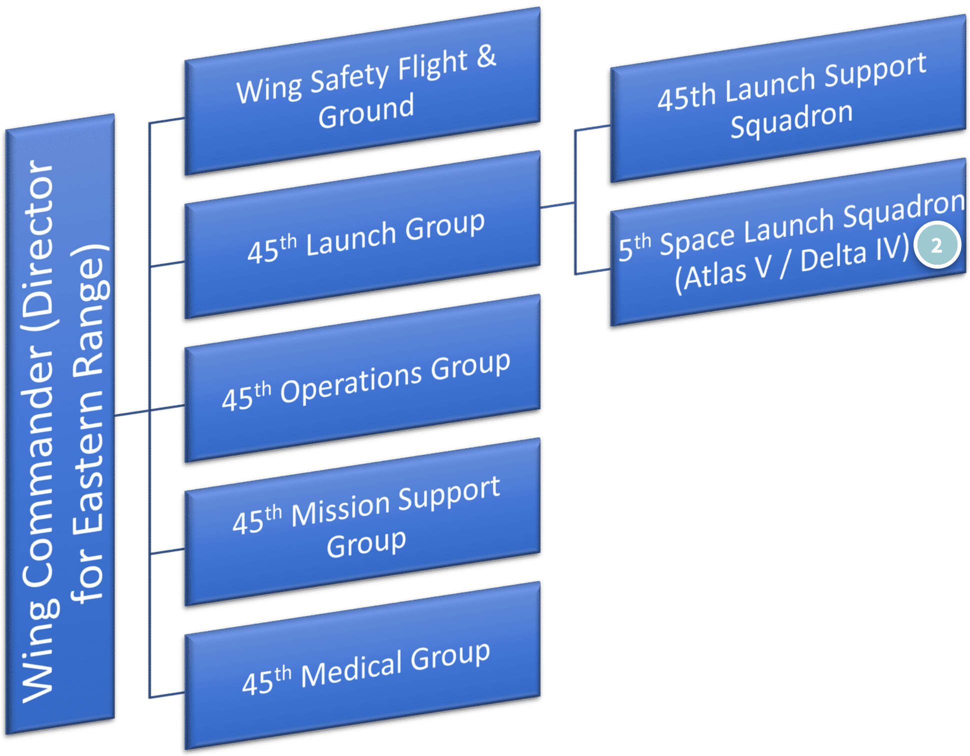
The 45th Launch Group oversees program management and overall operation of the 5th Space Launch Squadron (5 SLS) and the 45th Launch Support Squadron (45 LCSS).



45th Launch Support Squadron

The 45th Launch Support Squadron (45 LCSS) was activated on 30 June 2005 and is responsible for launch go/no–go readiness for all DoD satellites launched from CCSFS. 45 LCSS is in charge of operations and maintenance for launch and payload processing infrastructure, and also provides satellite launch operations training and certifies engineers, operators, and maintenance personnel. The 45 LCSS supervises contracting teams while they perform Air Force maintenance, checkout, and operations of critical flight hardware and infrastructure. The 45 LCSS operates the only DoD satellite processing facilities capable of placing satellites into geosynchronous orbit. The squadron leads all launch processing, LV generation, satellite integration, launch complex refurbishment, and bridges the expertise gap between current day operations and future space initiatives.

This lesson was focused on the organizational structure and responsibilities of 30 SW at VSFB and 45 SW at CCSFS. A general understanding of this information is important for future assignments you might have to either of these locations.



5th Space Launch Squadron

The 5th Space Launch Squadron was activated on 1 December 2003 and is responsible for mission assurance and risk assessment on the Atlas V and Delta IV LV families.

The Delta IV LV is launched from CCSFS Launch Complex 37. Critical additional facilities for the Delta IV program include the mobile service tower (MST), horizontal integration facility (HIF), and Delta Operation Center (DOC). The 5 SLS Atlas V program launches from Launch Complex 41. Critical facilities for this program include the Atlas V spaceflight operation center and the vertical integration facility (VIF).

Both LV families are designed to handle payloads from the DoD, the National Reconnaissance Organization (NRO), NASA, and commercial satellite sectors.

The 5th Space Launch Squadron manages launch base satellite processing to ensure reliability, safety, security, resource protection, and environmental compliance. They also provide technical oversight to assure mission success for supported programs and on–site acquisition management. The 5 SLS oversees engineering and contracts for satellite program offices and other payload customers.

As a 5 SLS MAT, you will use your experience following technical requirements and maintenance practices from previous ICBM assignments to provide oversight of contractor processing activities, procedure compliance, and safety. The 5 SLS is a blended organization comprised of military, government civilians, and contractors.

Complete the content above before moving on to the self-test questions.

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the space domain overview.

1. What role does spacelift play regarding existing space systems whose individual satellites are nearing the end of their useful life, predicted to fail, or have already failed?

Type your answer here

SUBMIT

1

2. Humanitarian aid all the way through the full spectrum of military operations is dependent upon what?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to the mission of spacelift organizations.

1. What major command (MAJCOM) has a mission to develop joint warfighters?

Type your answer here

SUBMIT

2

2. From what locations in the United States are the Atlas V and Delta IV launch vehicles (LV) launched from?

Type your answer here

SUBMIT

3

3. Where is the 30th Space Wing (30 SW) located?

Type your answer here

SUBMIT

4

4. What organization operates Cape Canaveral Space Force Station (CCSFS) and the Eastern Range?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to the functions of spacelift units.

1. Vandenberg Space Force Base is a critical launch site for what type of satellite?

Type your answer here

SUBMIT

5

2. What does the 1st Air and Space Test Squadron specialize in?

Type your answer here

SUBMIT

6

3. The 4th Space Launch Squadron is responsible for the Delta IV and Atlas V launch vehicles, which provide the nation's only capability to do what?

Type your answer here

SUBMIT

7

4. Who uses previous intercontinental ballistic mission knowledge to provide technical oversight of government contractors when they perform launch processing activities?

Type your answer here

SUBMIT

5. What wing is responsible for launching DoD satellites and certain National Aeronautics and Space Administration programs into low, medium, and high altitude geosynchronous and geostationary orbits?

- 4th Space Wing
- 30th Space Wing
- 45th Space Wing

35th Space Wing

SUBMIT

9

6. What base was transferred to the Air Force and then immediately deactivated in 1947?

Type your answer here

SUBMIT

10

7. What site is used for the launch of Delta IV LVs?

Type your answer here

SUBMIT

11

8. What does the 45th Launch Support Squadron oversee?

Type your answer here

SUBMIT

Complete the content above before moving on.

Launch Vehicles and Spacecraft

The spacelift program uses a variety of LVs to place satellites into various orbits, and payload weight, type of satellite, and required orbit will determine which spacelift vehicle is used.

The EELV program is a government procured commercial launch service that currently uses the Atlas V and Delta IV LVs to accomplish its mission.

In this section, we will focus on these two LVs as well as the mission and characteristics of the satellites they place into orbit.

Atlas V Vehicle Configuration and Infrastructure

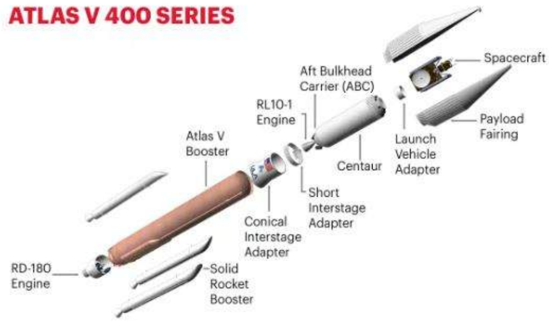
The original Atlas LV was designed in the late 1950s and served as a part of our ICBM force until it was removed from alert in 1965, and from 1962 to 1963 Atlas boosters were also used to put the first four American astronauts into Earth's orbit.

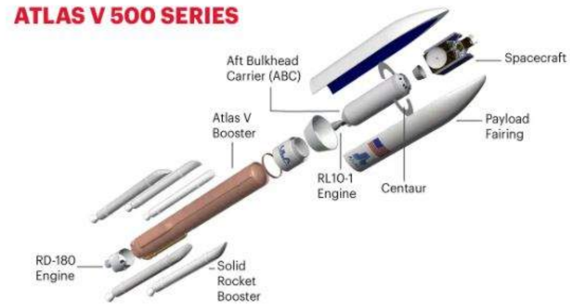
The Atlas LV evolved through several different configurations to become the current Atlas V LV that we use today. It was developed by the Lockheed Martin Company to reduce the cost and effort needed to launch satellites into orbit.

Click on each tab below to learn the mission and configuration of the Atlas V.

MISSION	CONFIGURATION

The Atlas V was designed for the USAF EELV program, which supports DoD and commercial satellite needs. It can place single or multiple payloads into polar, sun-synchronous, geosynchronous, geosynchronous transfer, and low-Earth orbits.





MISSION | CONFIGURATION

The Atlas V LV has two available configurations, the 400- and 500-series. Both consist of three major assemblies: the common core booster (CCB), the Centaur upper stage, and the payload fairing (PLF), as shown in the next image below in figure 1–5.

Complete the content above before moving on.

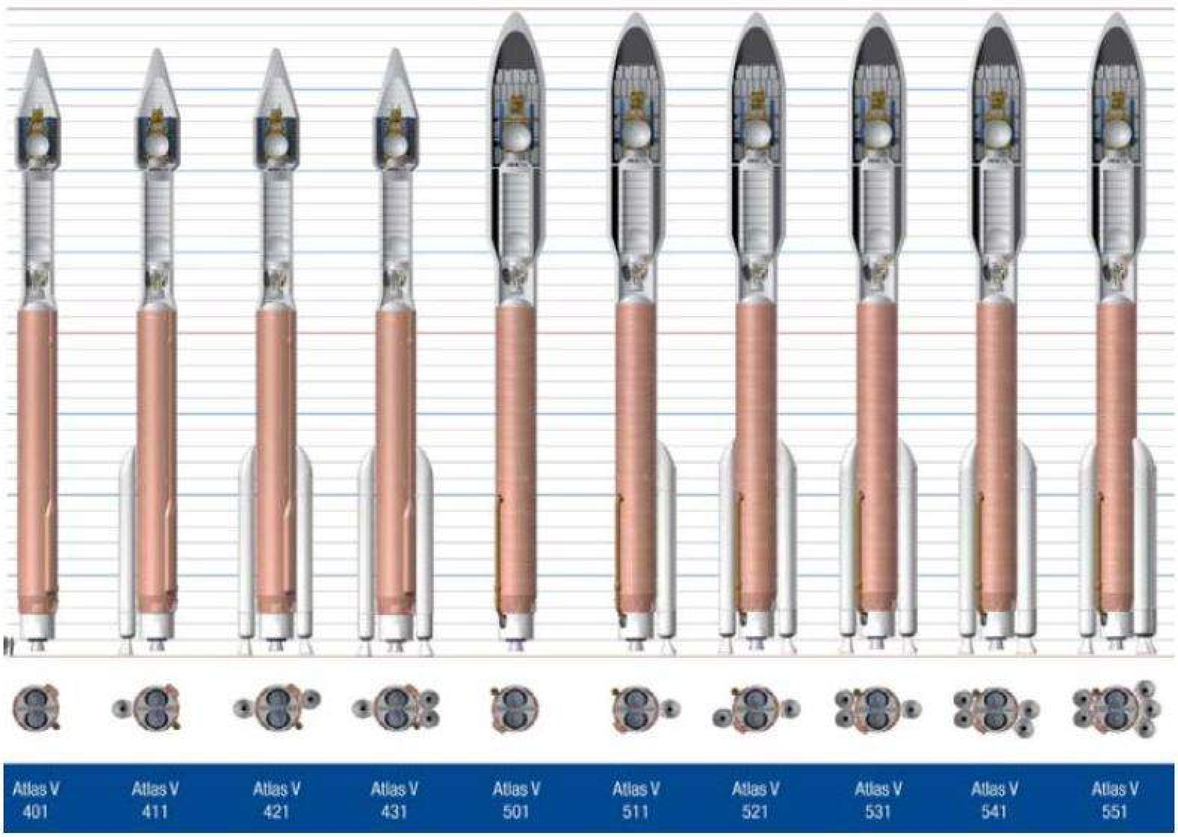
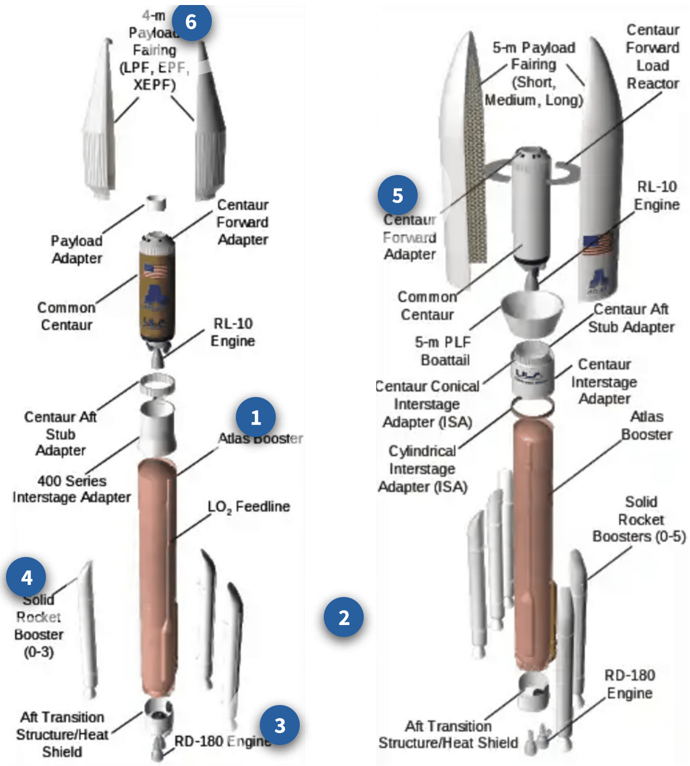
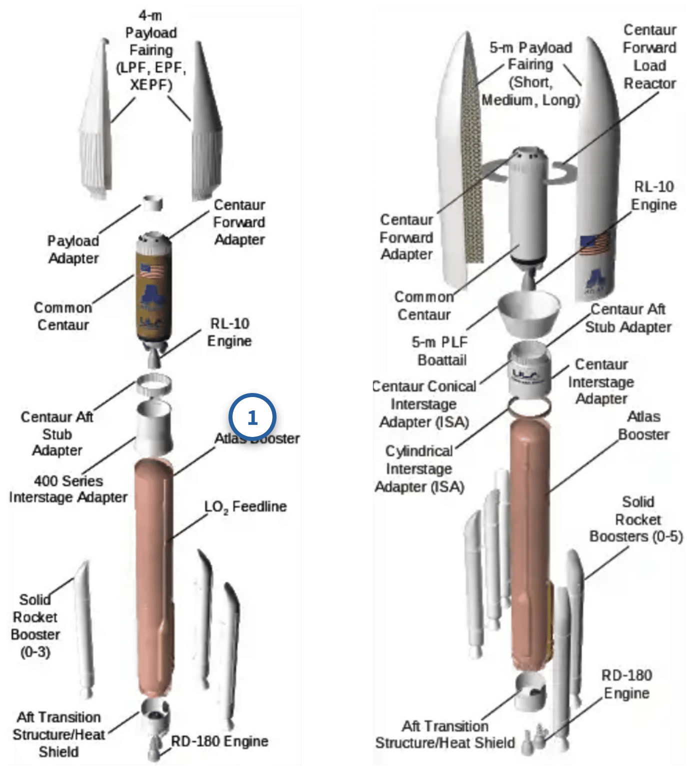


Figure 1–5. Atlas V Launch Vehicle.

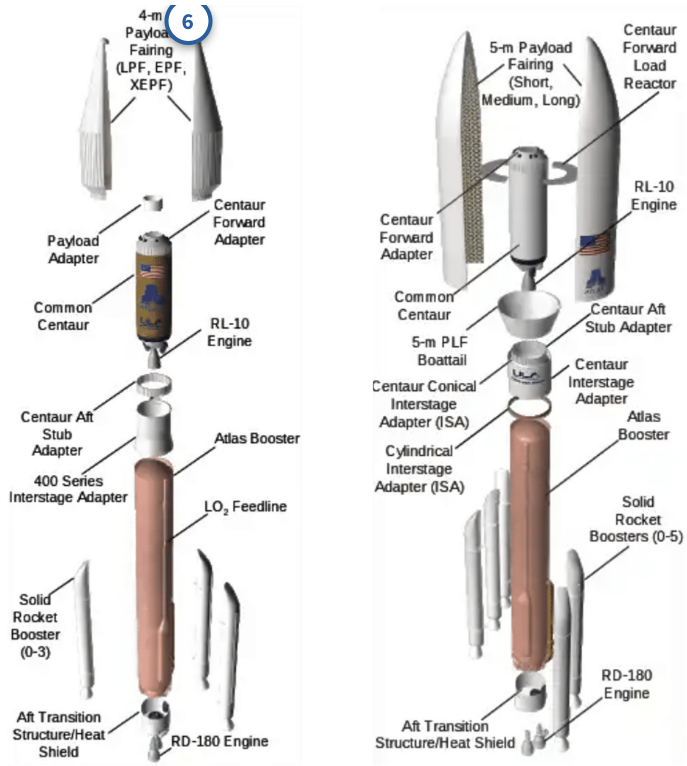
Listed below are the Atlas V 400 and 500 series internal components. Click on each number to learn about the functions of the components.


6
4-m Payload Fairing (LPF, EPF, XEPF)
Payload Adapter
Centaur Forward Adapter
Common Centaur
RL-10 Engine
Centaur Aft Stub Adapter
1
Atlas Booster
400 Series Interstage Adapter
LO_2 Feedline
4
Solid Rocket Booster (0-3)
Aft Transition Structure/Heat Shield
3
RD-180 Engine
2
5-m Payload Fairing (Short, Medium, Long)
Centaur Forward Load Reactor
5
Centaur Forward Adapter
RL-10 Engine
Common Centaur
5-m PLF Boattail
Centaur Aft Stub Adapter
Centaur Conical Interstage Adapter (ISA)
Centaur Interstage Adapter
Cylindrical Interstage Adapter (ISA)
Atlas Booster
Solid Rocket Boosters (0-5)
RD-180 Engine
Aft Transition Structure/Heat Shield



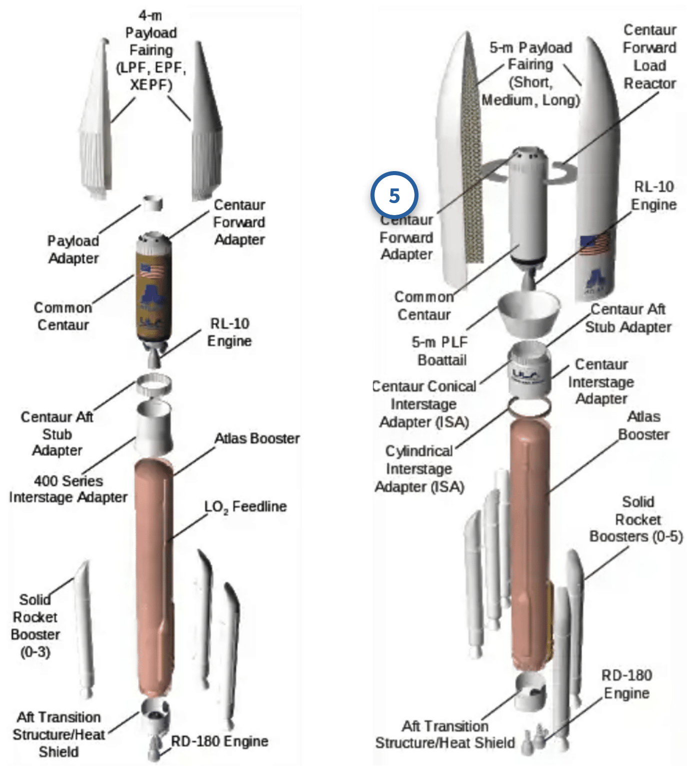
Common Core Booster

The Atlas V CCB is a single body booster which uses one two-nozzle RD–180 engine, and provides attachment points for up to five strap-on solid rocket boosters (SRB), depending on the configuration. The CCB is the core of the Atlas V LV, and all configuration types will have one.



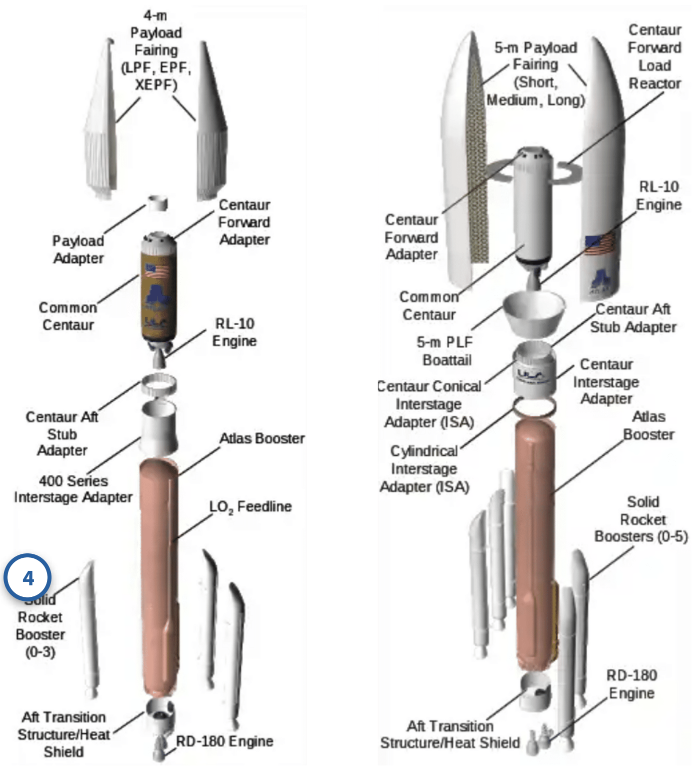
Payload Fairing

The PLF is the aerodynamic shroud that protects the payload and/or upper stage from external environments and contamination. The Atlas V uses two types of PLFs, depending on the needs of the mission. The 400-series PLF is approximately 13.5 feet long, and the 500-series is approximately 18 feet long. The payload adapter connects the payload to the standard interface plane, which is located at the top of the Centaur forward adapter.



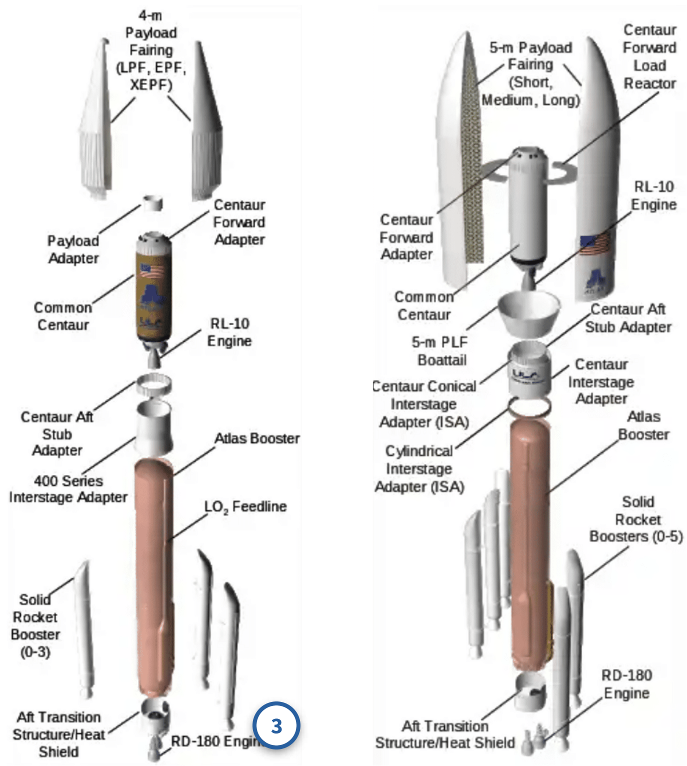
Centaur Upper Stage

The development of the Centaur upper stage began in 1958 and was intended for use with the Atlas program. The first development flight took place in 1962, which was then followed by research and development flights boosted by the Atlas rocket. The first Atlas/Centaur operational flight was the launch of the Surveyor Lunar Lander in 1966. Since then the Atlas/Centaur has been used for many missions that include the Mariner and Pioneer planetary missions. The Centaur upper stage provides the propulsion, guidance, and control capability to place satellites into selected orbits. The Centaur system consists of four major structural elements: the propellant tank, stub adapter, Centaur forward adapter, and tank insulation. The cryogenic liquid oxygen and liquid hydrogen propellant tanks are constructed of thin-wall stainless steel that are separated by a double-wall barrier called a bulkhead. The avionics package is located on the Centaur forward adapter, which also serves as the satellite adapter. The inter-stage adapter is the interface between the CCB and the Centaur, and it provides shelter for the Centaur engines, as well as structural integrity for the vehicle. The Centaur uses either one or two Pratt & Whitney engines.



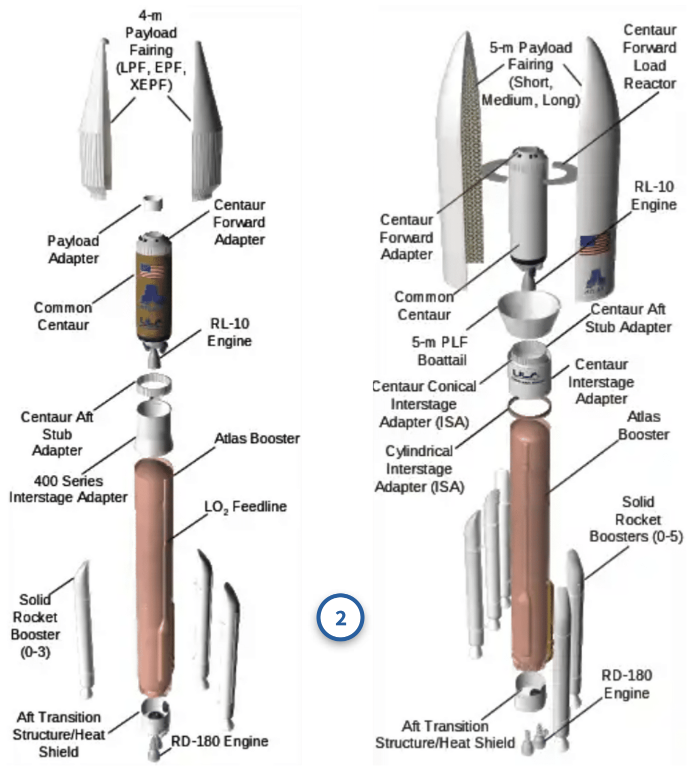
Solid Rocket Boosters

Extra thrust is provided by attaching up to five solid propellant rocket boosters to the CCB. They are approximately 5 feet in diameter and 66 feet long, from nose tip to nozzle exit, and have a gross weight of roughly 51 tons. The solid propellant is cast in a 7–point star configuration.



Engine (RD–180)

The RD–180 is a total propulsion unit with two-thrust chambers. It employs a hot gas generator, main turbopump assembly, and a single turbine.



Propellant Tanks

There are two propellant tanks, one for RP–1 fuel and the other for liquid oxygen. The primary tank structure (both pressurized and unpressurized) is composed of stiffened aluminum alloy isogrid panels that are formed to the 12.5-foot vehicle inside diameter. The two tanks are separated by inter-tank skirts.

Complete the content above before moving on to learn about the Atlas V infrastructure.

Atlas V rocket and CST-100 crew capsule on the launch pad.

Atlas V Infrastructure

The Atlas V SLCs are located at VSFB and CCSFS, and both sites have the capability to launch the 400- and 500-series configurations. Some of the major structures are the launch operations building (LOB), MST and crane, umbilical tower (UT), payload environmental control system (ECS) building, fixed launch platform (FLP), launch support building (LSB), and technical support buildings. Let's learn more about some of these structures.

Click on each tab to learn about the major structures of the Atlas V.

LAUNCH OPERATIONS BUILDING | MOBILE SERVICE TOWER | UMBILICAL TOWER | LAUNCH SUPPORT BUILDING | FIX P

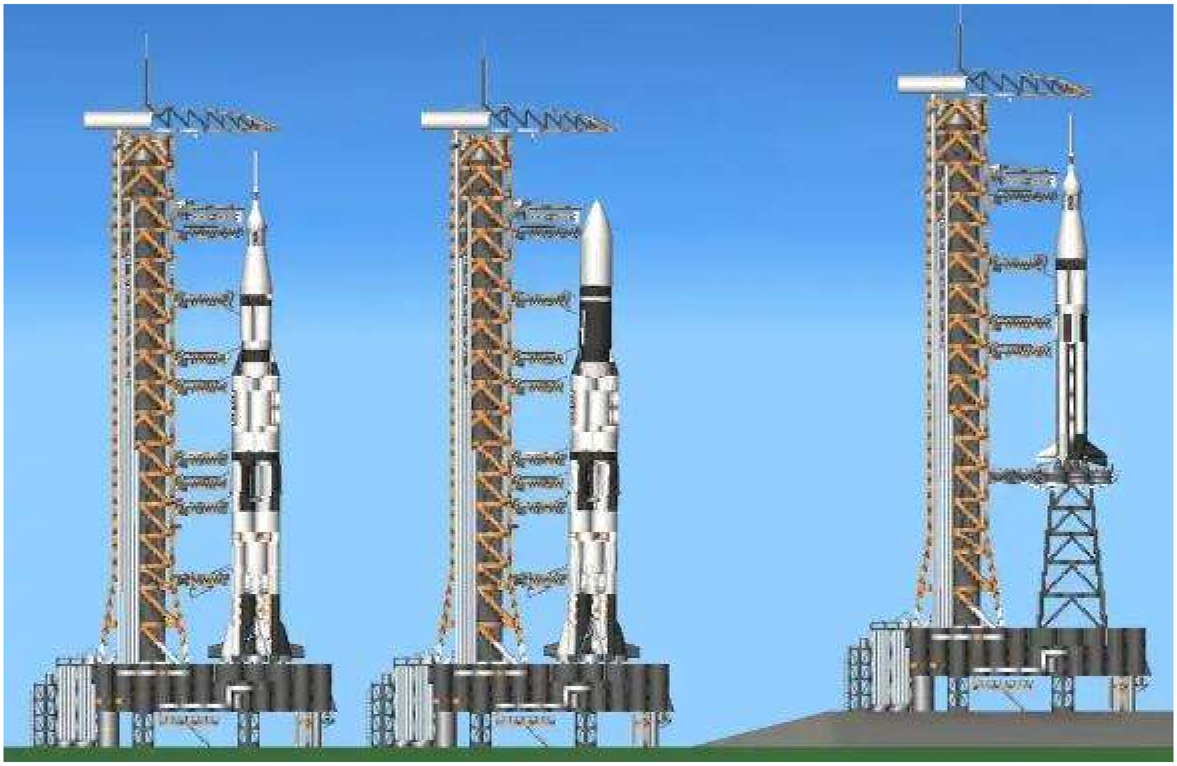
The LOB is built into a berm and houses monitoring and radio frequency test equipment for the vehicle's telemetry system.

LAUNCH OPERATIONS BUILDING | MOBILE SERVICE TOWER | UMBILICAL TOWER | LAUNCH SUPPORT BUILDING | FIX P

The MST is a 260-foot tall enclosed steel structure that contains retractable LV servicing and checkout platforms. A truck-and-drive system moves the MST 250 feet along rails, from its parked position to the service position around the launch platform. The primary functions of the MST include erecting the Atlas V and Centaur, mating encapsulated satellites, and providing work areas for personnel and equipment during satellite mate and flight readiness checkouts. A 60-ton bridge crane is used to erect the Atlas V CCB, solid rocket boosters, Centaur upper stage, satellite assembly and all associated adapters.

LAUNCH OPERATIONS BUILDING | MOBILE SERVICE TOWER | UMBILICAL TOWER | LAUNCH SUPPORT BUILDING | FIX P

The UT provides a structure to service the LV and satellite with consumables. The LV and satellite electrical, environmental control, and fluid disconnects are installed on the rotating booms (service arms), which are released from the LV during the initial launch release sequence. The UT provides support for two rigid umbilical booms, and a ground wind damper that steadies the LV in high winds. There are also platforms for servicing, a lightning mast that provides a 45-degree cone of protection , and a hydrogen vent stack for the Centaur fuel tank.



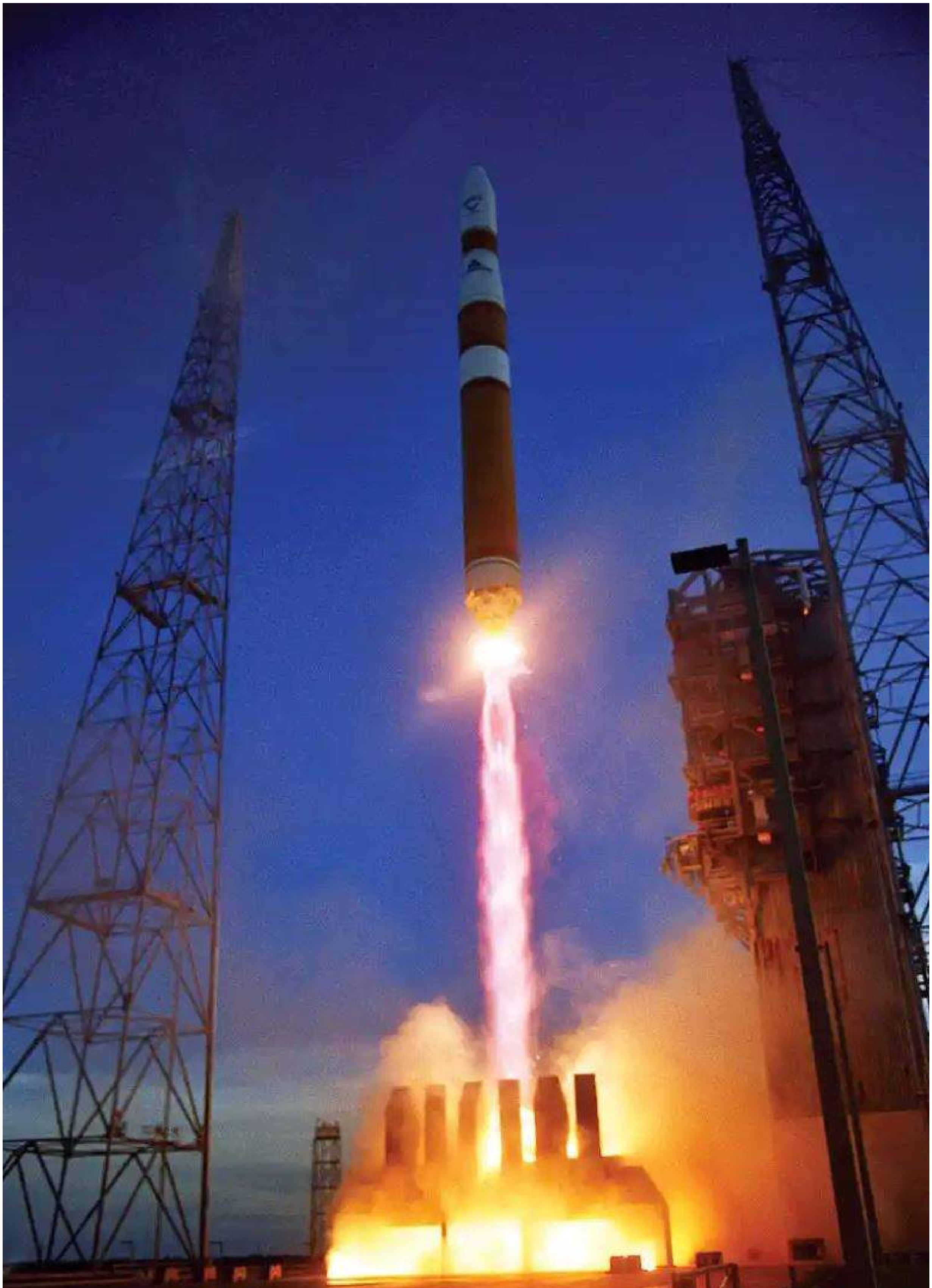
LAUNCH OPERATIONS BUILDING	MOBILE SERVICE TOWER	UMBILICAL TOWER	LAUNCH SUPPORT BUILDING	FIX P

The LSB is a reinforced concrete and steel structure that is the platform where the Atlas V LV is assembled, tested, and launched. A ramp attached to the LSB is used to move the CCB and Centaur upper stage into position to be erected. It also provides a protective shelter for shop areas, storage, locker rooms, environmental control equipment, electrical switch gear, instrumentation, fluid and gas transfer equipment, launch control equipment, and other launch-related service equipment.

LAUNCH OPERATIONS BUILDING	MOBILE SERVICE TOWER	UMBILICAL TOWER	LAUNCH SUPPORT BUILDING	FIX P

The FLP is positioned on top of the LSB launch exhaust duct and supports the LV during integration on the pad, fueling, final preparation, and liftoff. Within the FLP are three retractable launch heads that support the LV using two-inch diameter breakable bolts. The launch heads are designed to extend to the LV, and then to retract out of the way immediately upon liftoff.

Complete the content above before moving on to learn about the Delta IV vehicle configuration and infrastructure.



Delta IV Vehicle Configuration and Infrastructure

The Delta family of expendable launch systems has provided spacelift capability to the US since 1960 and was designed by the Boeing Company to emphasize reliability rather than performance. Numerous upgrades and modifications over its 375+ launch history, as well as the need to reduce the cost and effort required to launch payloads into orbit, led Boeing and Lockheed Martin to merge into United Launch Alliance (ULA) in 2006. Delta IV vehicles are currently produced at a facility in Decatur, Alabama.

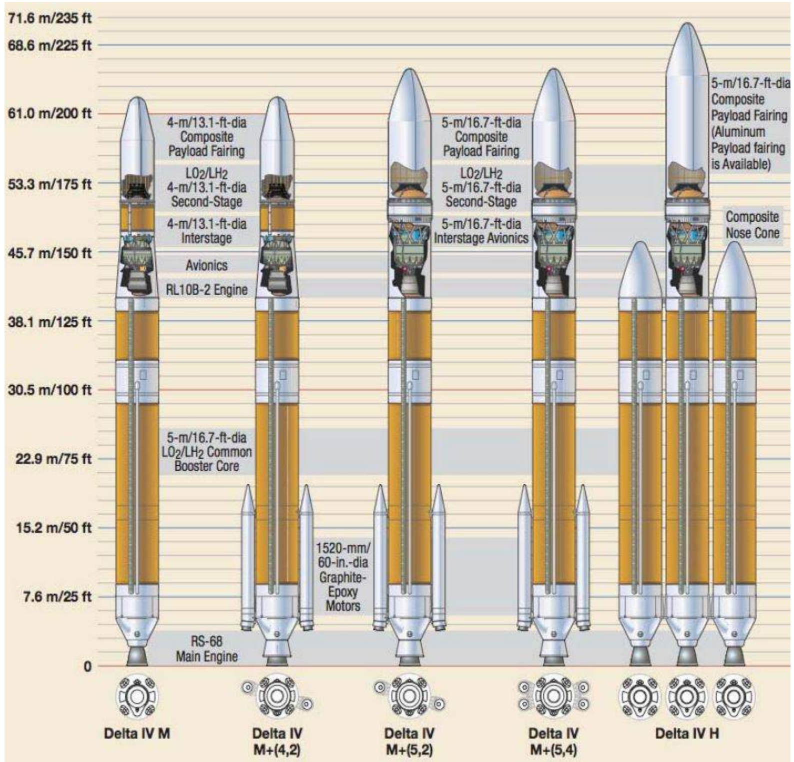
Click on each plus (+) listed below to learn about the mission and configuration of the Delta IV.

Mission

The Delta IV LV was designed specifically for the USAF EELV program and the commercial satellite business and is intended to reduce the cost and effort needed to launch payloads into orbit. The Delta IV is primarily designed to satisfy the requirements of the US military.

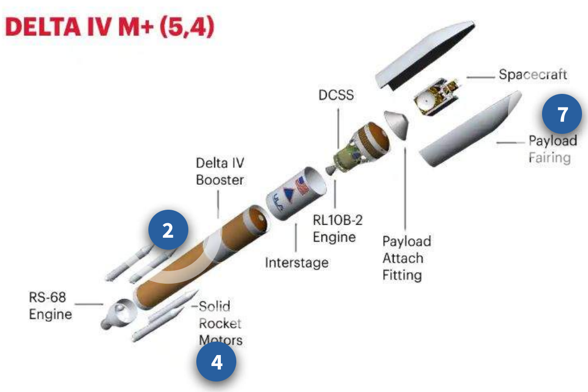
Configuration

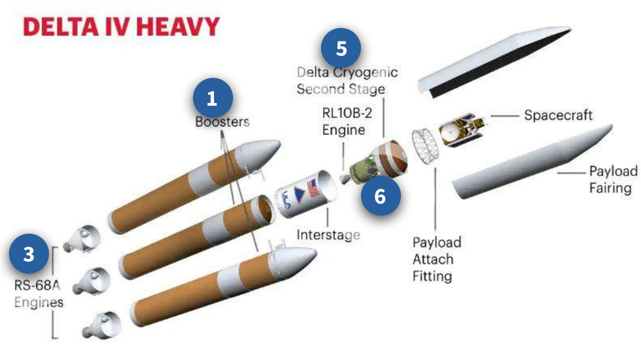
The Delta IV has five different configurations that each have a common booster core (CBC) first stage, second stage, and PLF (fig 1–6).

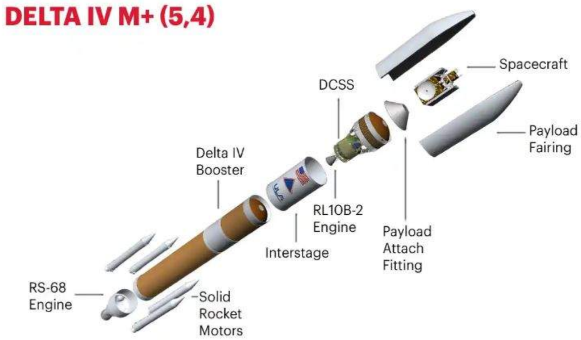


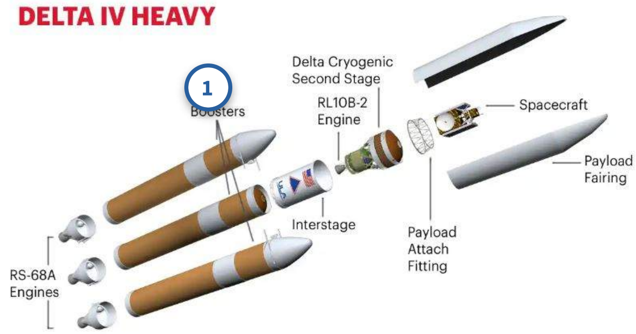
Complete the content above before moving on to learn about the Delta IV vehicle configuration components.

Listed below are the Delta IV M+ and Delta IV Heavy internal components. Click on each number to learn about the functions of the components.





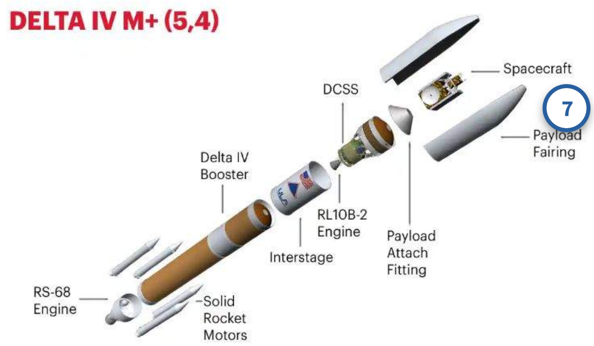


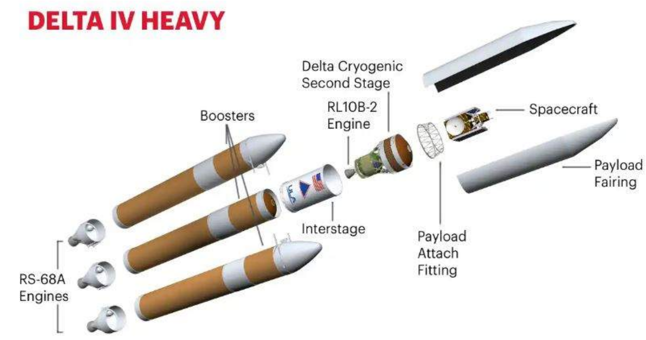


Common Booster Core

A typical first stage of the Delta IV consists of one CBC powered by a Rocketdyne RS–68 engine. The Delta IV "Heavy" configuration uses three CBCs.

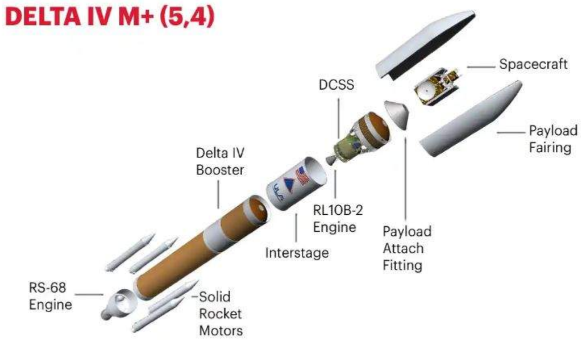
The CBC also provides attachment points for additional strap-on solid rocket motors.

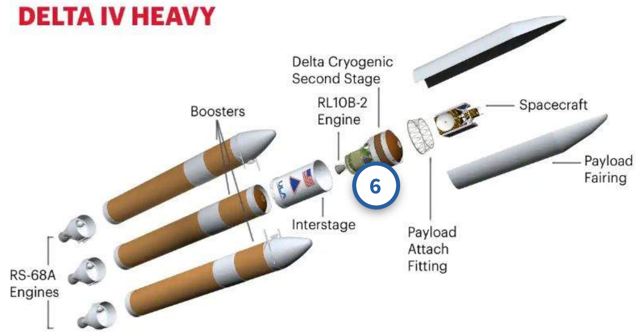




Payload Fairing

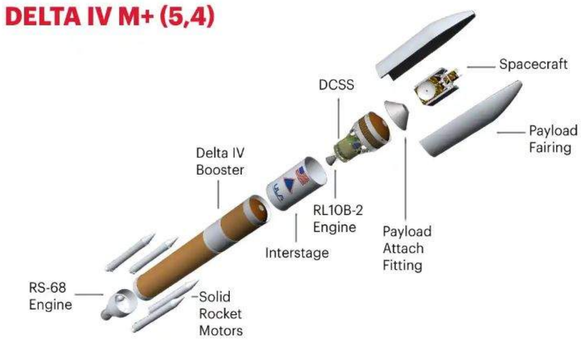
The PLF is an aerodynamic shroud that protects the payload and/or second stage from external environments and contamination. It provides acoustic, radio frequency, and static protection from the time the satellite is encapsulated until the Delta IV exits Earth's atmosphere.13-foot and 16.5-foot variants are used, and both are constructed from composite materials.

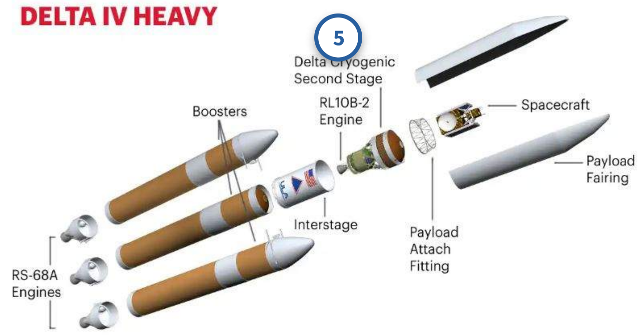




Engine (RL10B–2)

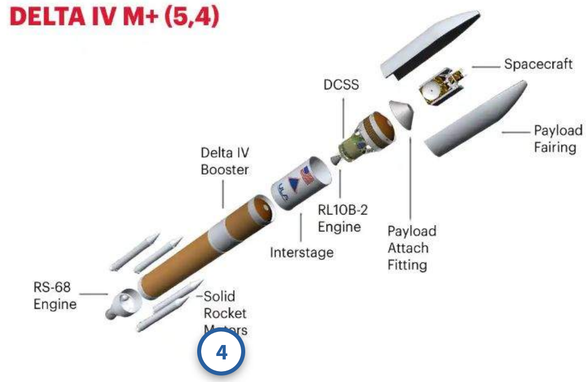
The RL10B–2 is a cryogenic liquid hydrogen fueled rocket engine, with an extendable carbon nozzle that improves specific impulse. Electro–mechanical gimbaling is used to reduce weight and increase reliability.

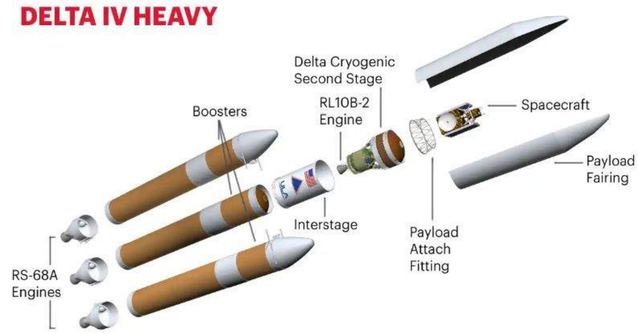




Second Stage

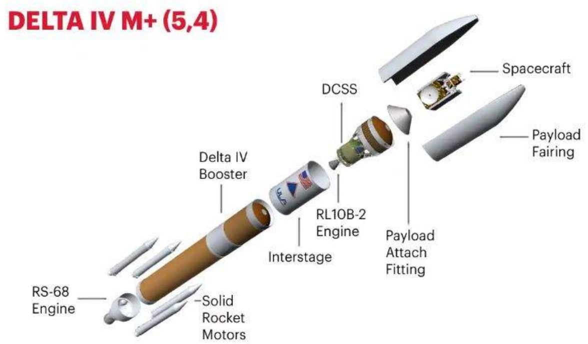
The second stage is powered by a Pratt & Whitney RL10B–2 engine. Depending on the LV configuration (13-foot or 16.5-foot PLF), two different inter-stages are used to mate the first and second stages.

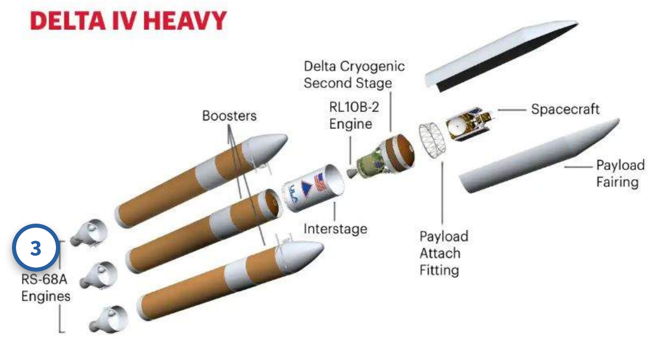




Solid Rocket Motors

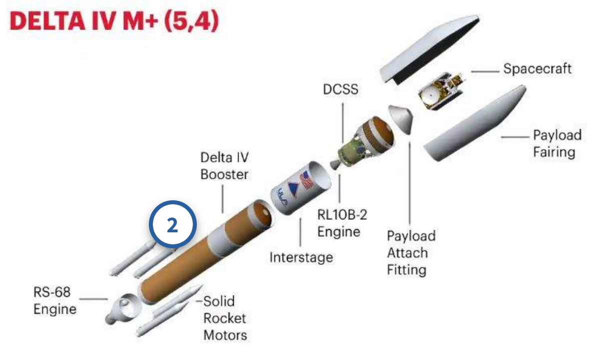
High performance solid rocket motors, known as graphite epoxy motors (GEM), provide additional thrust for the medium + class of LV. Either two or four GEMs can be added to the vehicle, depending on the mission requirements. Primary components of the GEM are a nose cone, a casing filled with solid propellant, and a nozzle. The GEM is 53 feet long and 5 feet in diameter.

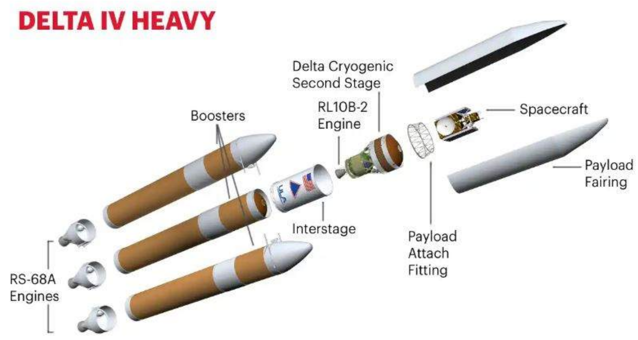




Engine (RS–68)

The RS–68 is a liquid hydrogen/liquid oxygen engine that uses a gas generator, two turbopumps, a regeneratively cooled combustion chamber, and a single nozzle.





Propellant Tanks

Two propellant tanks are used; one for liquid hydrogen and one for liquid oxygen. The primary tank structure is built from an aluminum isogrid, and the two tanks are separated by a composite cylinder called the centerbody.

Complete the content above before moving on to learn about the Delta IV infrastructure.

Delta IV Infrastructure

The Delta IV is launched from Launch Complex 37 at CCAFS, and from SLC–6 at VAFB. Launch facilities on both coasts are similar, and include the:

Mobile Service Tower (Vandenberg SFB SLC–6 only)

The MST provides service access a weather protection to the rocket, and the crane at the top of the MST allows the payload and solid rocket motors to be attached to the LV. The MST moves over rail tracks on hydraulically powered trucks, and then meets with the fixed umbilical tower (FUT) and mobile assembly shelter (MAS) to form an environmental enclosure for the LV. The MST is rolled away from the Delta IV rocket several hours before launch.

Mobile Assembly Shelter (VSFB SLC–6 only)

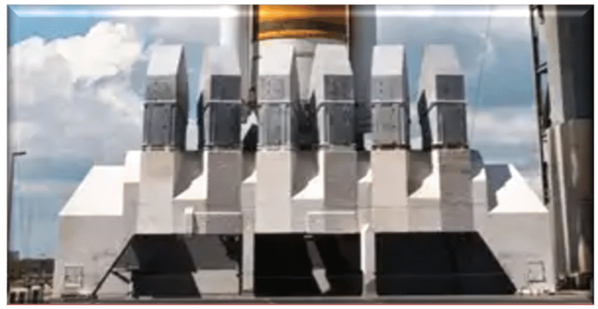
The MAS is a large structure that meets with the FUT and MST that completely surrounds and provides an environmental enclosure for the LV.

Fixed Umbilical Tower

The FUT is directly adjacent to the LV, and has large swing arms that provide electrical, hydraulic, environmental control, and other support functions to the vehicle through umbilical lines. The swing arms retract in less than 12 seconds in order to prevent them from coming in contact with the vehicle during launch.

Launch Table

The LV sits on top of the launch table, which is equipped with six tail service masts that are capable of meeting the needs of all five vehicle configurations. The launch table supports the vehicle on the pad, and the tail service masts provide additional support and fueling functions for the CBCs.


Launch Mate Unit (LMU)

The LMU is a large steel platform that provides a foundation for the rocket and connects the LV to the launch table. The two structures are attached with pyrotechnic bolts that will sever at launch.

Fixed Pad Erector (FPE)

The FPE is located in front of the launch table and utilizes two 4-stage telescoping hydraulic erector cylinders to erect the assembled LV from a horizontal position to a vertical position on the launch table. The FPE is capable of lifting in excess of 200 tons.

Horizontal Integration Facility (HIF)

The HIF is a large building that allows the Delta IV CBC and second stages to be mated and tested before they are moved to the launch pad. It consists of a two-bay booster processing area and an office area. HIF activities include receipt and inspection of boosters, ordnance installation, 2nd stage nozzle extension deployment system (NEDS) checkout, and 2nd stage-to-CBC integration and checkout.

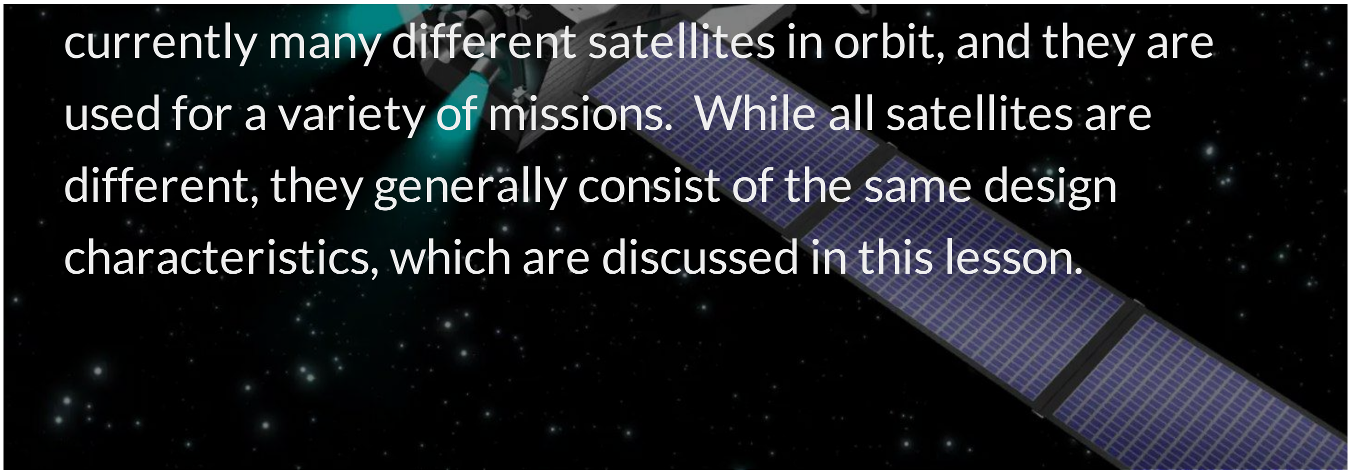
Elevating Platform Transporter (EPT)

The EPT moves the Delta IV among the various facilities at the pad using large rubber tires powered by either diesel engines or electric power. Diesel EPTs are used for moving the vehicles from the HIF to the launch pad, while electric EPTs are used in the HIF since precise movements are important.

Click here to learn about the spacecraft systems.

Spacecraft Systems

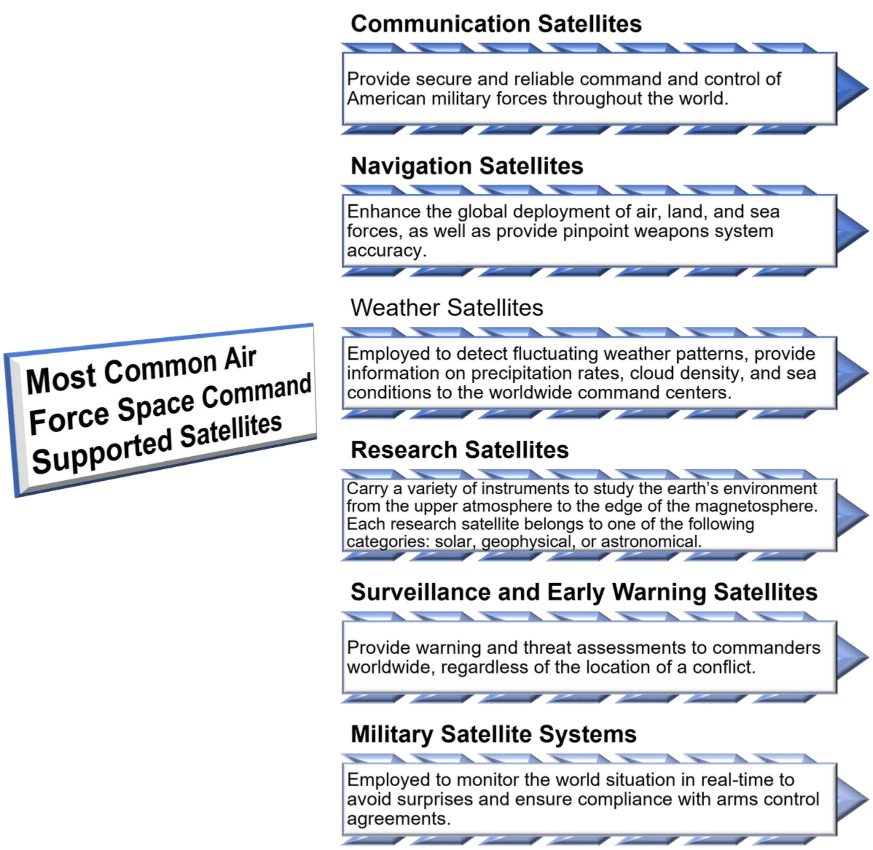
Spacecraft are specialized satellites that consist of a payload and an array of different subsystems. There are



currently many different satellites in orbit, and they are used for a variety of missions. While all satellites are different, they generally consist of the same design characteristics, which are discussed in this lesson.

Mission

The mission and importance of satellite systems is unquestionable in today's military environment. While you are reading this text, numerous satellites are in orbit performing a wide variety of missions. AFSPC operates the Air Force Satellite Control Network (AFSCN)—the largest and most sophisticated military space network in the world. The AFSCN is tasked with maintaining a multitude of DoD satellites that provide the national command authorities, armed forces, and government agencies with voice, video, and data services. Remote tracking stations handle hundreds of satellite contacts daily. These satellites provide information that is vital to the defense of the United States. Listed in the table below are the most common AFSPC-supported satellites and the mission each performs.



Characteristics

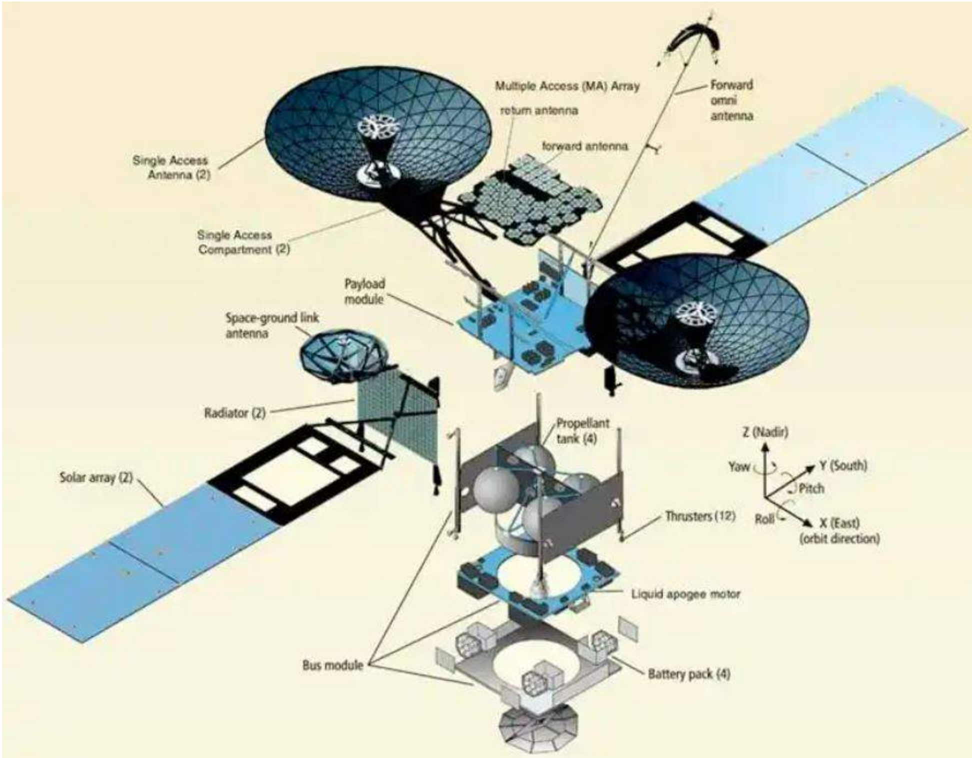
Satellites are designed to meet mission requirements, and nearly all satellites utilize the following subsystems:

- Structural
- Electrical
- Thermal control
- Propulsion
- Attitude control and telemeter
- Tracking
- Command

Structural

A satellite's structure is designed to provide a strong and stable platform for the payload instruments and subsystems. It also provides a mechanical interface with the LV, sustains launch loads, and serves as a precision alignment platform for components like antennas, sensors, actuators, and thruster jets.

A satellite's structure is designed to provide a strong and stable platform for the payload instruments and subsystems. It also provides a mechanical interface with the LV, sustains launch loads, and serves as a precision alignment platform for components like antennas, sensors, actuators, and thruster jets.

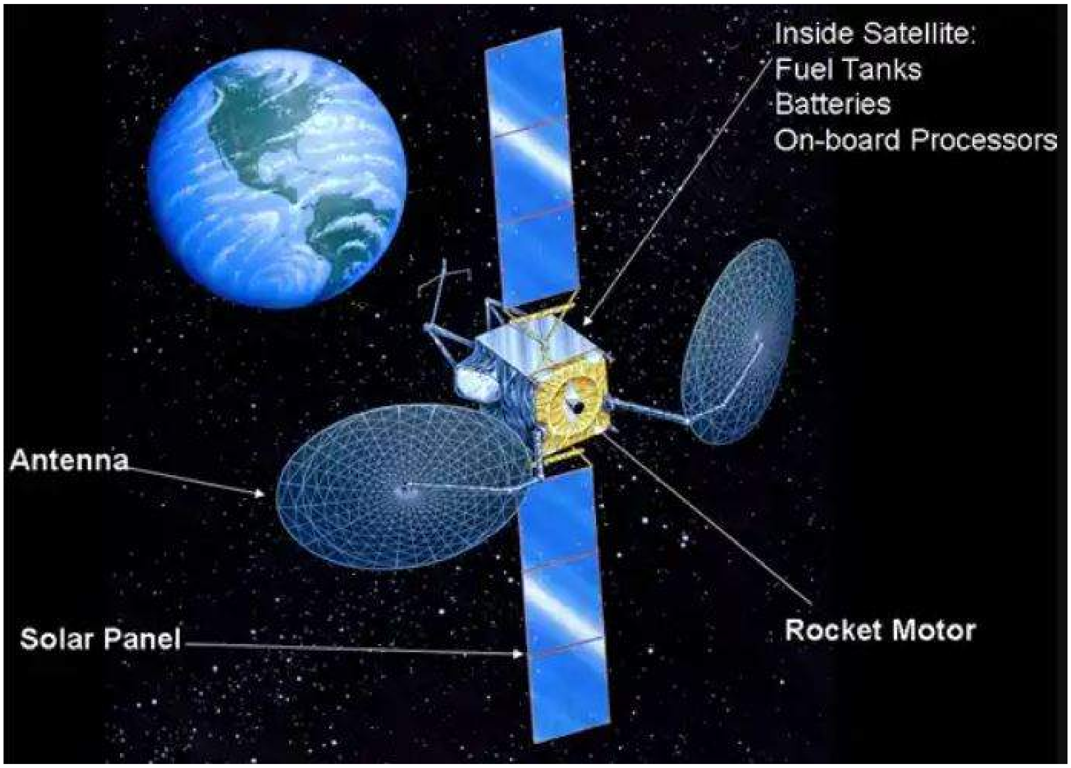


Electrical

The electrical subsystem is by far the most important subsystem on the satellite. Its main purpose is to generate, store, control, and distribute electrical power to all other satellite subsystems. There are three sources of electrical power that are used on satellites:

- Solar
- Battery
- Nuclear

It is important to note that nuclear power has seen only limited use in space so far. It is primarily used with missions that are lengthy, have increased power requirements, or will operate at a great distance from the sun.

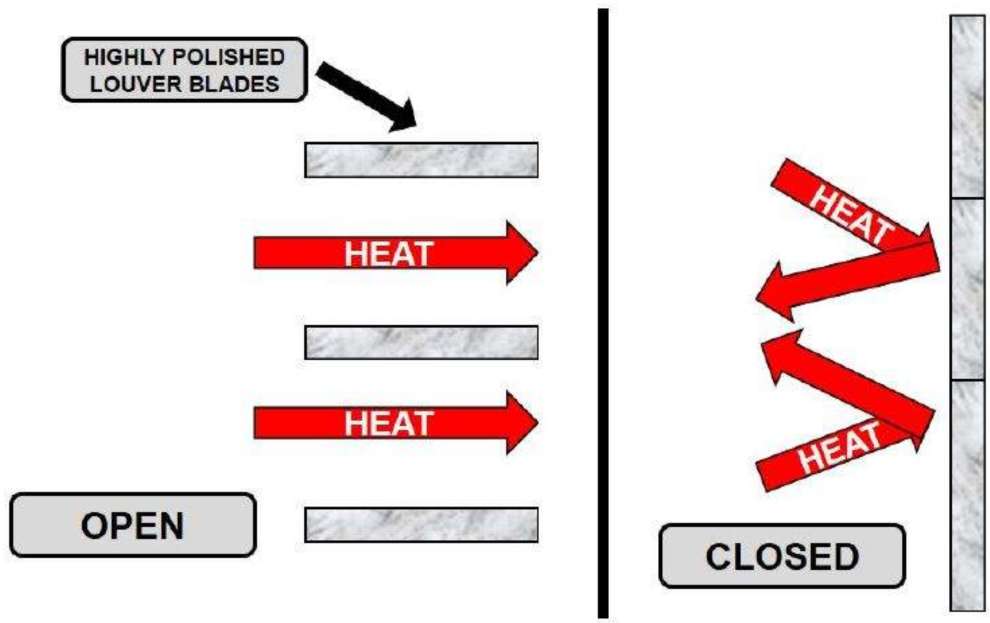


Thermal Control

The thermal control subsystem is how the satellite maintains its temperature. Significant variations in temperature occur within a satellite due to heat generated by its own components, friction of the vehicle leaving the atmosphere, and heating effects of the sun. Conversely, a satellite cold soaks when it is not exposed to sunlight. Thermal controls can be broken into two categories: passive and active.

Thermal Controls	
Type	**Description**
Passive	

Conduction, reflection, and radiation are used to maintain a satellite's temperature. These controls can be thermal coatings, thermal insulation, or heat sinks.	
Thermal coatings	Conduct or reflect heat.
Thermal insulation	Controls the amount of heat lost or gained.
Heat sinks	Conduct heat to or away from specific components that require temperature control.
Active	
With active controls, satellite temperatures are continuously monitored. When specific temperatures are reached, mechanical devices are actuated or electric heaters are cycled on or off to maintain the temperature. Active controls can be broken down as follows:	
Heat pipes	Transport heat energy from internal equipment to a radiator surface using a chemical fluid, usually methanol or ammonia.
Thermal louvers	Highly polished. Open or close to allow heat to enter or escape from the satellite (fig 1–7).
Electric heaters	Turns off or on depending on temperature.



Propulsion

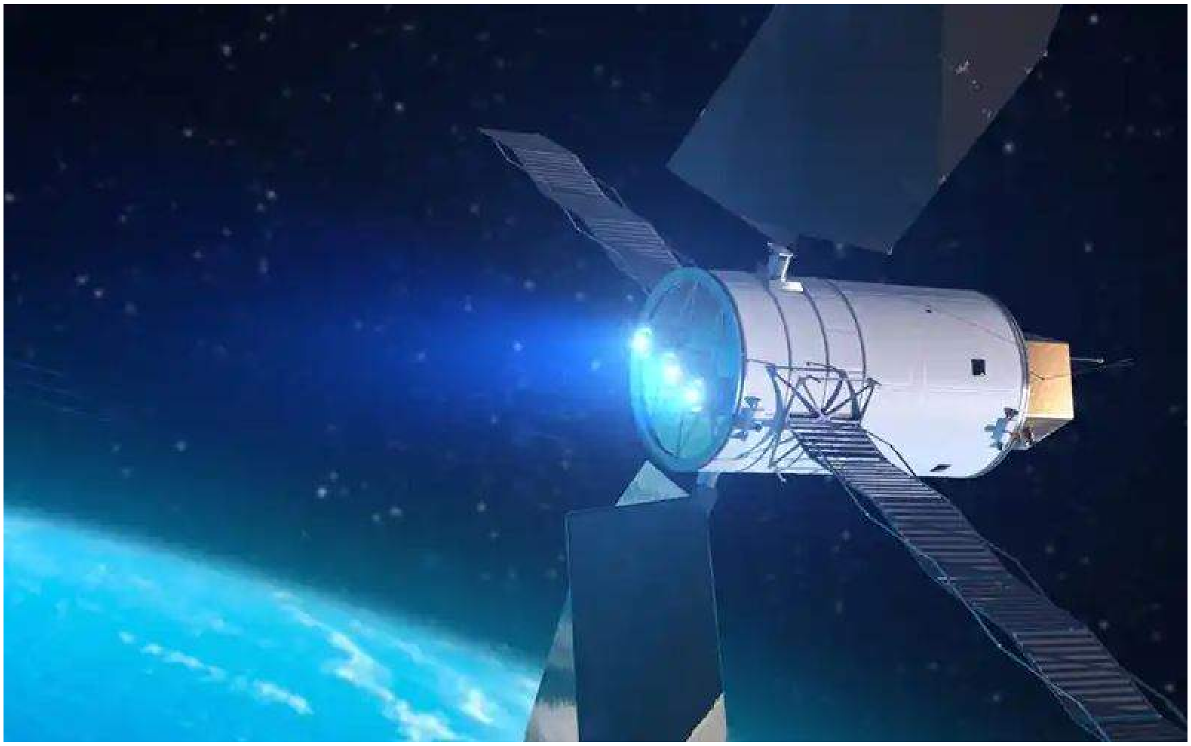
The satellite's propulsion system normally takes over after it separates from the LV and provides the thrust necessary for orbit changes, adjustments, and orientation of the satellite's rotation. The propulsion system also helps control the attitude, spin rate, and nutation. Nutation is the irregular "nodding" motion that is sometimes a part of a body's spin motion on its axis.

A typical propulsion system consists of propellant tanks and thrusters that are interconnected and isolated by latching valves. The mission profile in the design phase of a satellite determines what propulsion system or combinations of propulsion systems are employed.

Propulsion Systems	
Type	**Description**
Liquid Propellant	

Expensive and used more commonly than other systems. Allows precise control of the satellite's thrust and can be fired multiple times.
Electrical Propulsion
Uses electrical energy to generate or increase the force of the propulsive jet. Three types of electrical propulsion systems are used:

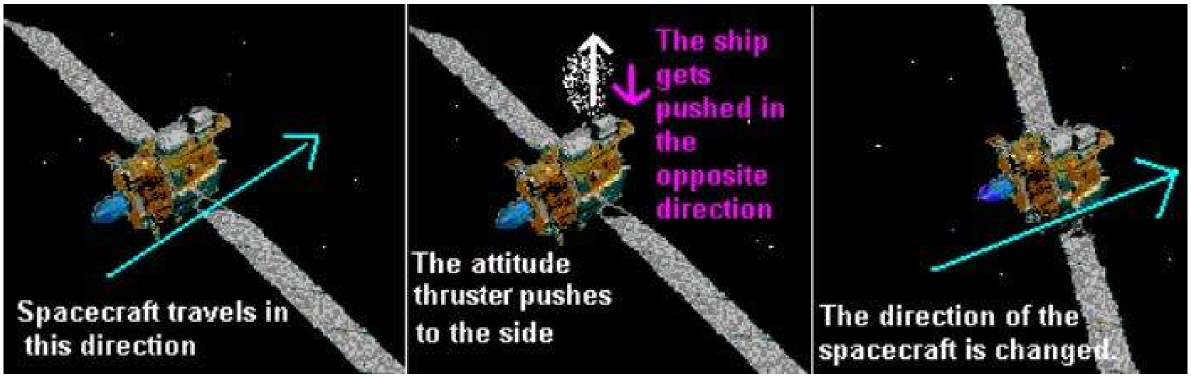
Electro-thermal	Uses electrical energy to heat a gaseous propellant.
Electrostatic	Uses electrical energy to ionize a gaseous propellant and an electrostatic field to accelerate positive ions to produce thrust.
Electromagnetic	Uses an electromagnetic field to accelerate neutral, gaseous plasma to produce thrust.



Attitude Control

Attitude control is required to ensure sensors, communications antennas, optics, and other satellite instruments remain pointing in the proper direction. Do not confuse "attitude" with "altitude." The attitude is which direction the satellite is pointing, not the height of an object above the earth. Attitude control systems serve two functions:

- Station keeping – overcomes the motion of the satellite generated by atmospheric drag, gravity, and solar winds.
- Stabilizing – rotates the satellite to orient it in the correct direction.

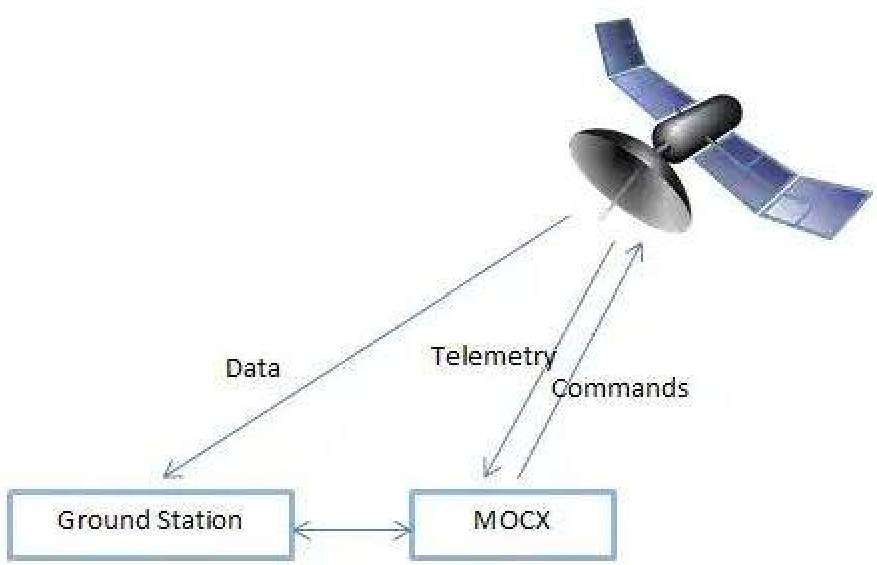


Telemetry, Tracking, and Command Elements

Once a satellite has reached its desired orbit, radio and microwave signals are used to monitor and control the satellite from the ground.

Satellite Monitoring and Controlling Elements	
Element	**Description**
Telemetry	Transmits whatever data the satellite was designed to gather (i.e., meteorological or astronomical data). Transmits data on the general health of the satellite, such as pressures, temperatures, flowrates, voltages, electrical currents, and other events present in the satellite's subsystems.
Tracking	Gathers telemetry data and establishes a

	link for commanding the satellite.
Commanding	Commands are up-linked to the vehicle to maintain satellite health, execute attitude and orbit adjustments, calibrate and adjust payloads and clocks, and perform other tasks needed for the success of the satellite's mission.



You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the Atlas V vehicle configuration and infrastructure.

1. What are the major assemblies of the Atlas V launch vehicle?

Type your answer here

SUBMIT

2. What components are in the common core booster's engine (RD–180)?

Type your answer here

SUBMIT

13

3. What are the major structural elements of the Centaur upper stage?

Type your answer here

SUBMIT

14

4. What structure contains enclosures that have retractable launch vehicle servicing and checkout platforms?

- Launch support building.
- Umbilical tower.
- Mobile service tower.
- Payload fairing.

SUBMIT

15

5. What is the platform where the Atlas V launch vehicle is assembled, tested, and launched?

- Payload fairing.
- Umbilical tower.

Mobile service tower.

Launch support building.

SUBMIT

16

6. What platform supports the launch vehicle during fueling and final preparation for launch?

Umbilical tower.

Fixed launch platform.

Mobile service tower.

Launch support building.

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to the Delta IV vehicle configuration and infrastructure.

1. What two liquids are contained in the common booster core propellant tanks?

Type your answer here

SUBMIT

2. What powers the Delta IV second stage?

Type your answer here

SUBMIT

18

3. What are the two varieties of Delta IV payload fairings?

Type your answer here

SUBMIT

19

4. When is the mobile service tower rolled away from the Delta IV?

Type your answer here

SUBMIT

20

5. What completely encloses the launch vehicles within the fixed umbilical tower and mobile service tower?

- Mobile assembly shelter (MAS).
- Launch table (LT).
- Fixed pad erector (FPE).
- Horizontal Integration Facility (HIF).

SUBMIT

21

6. What supports the launch vehicles on the pad?

Mobile assembly shelter (MAS).

Launch table (LT).

Fixed pad erector (FPE).

Mobile service tower (MST).

SUBMIT

7. Where are the Delta IV common booster core and second stages mated and tested before being moved to the launch pad?

Mobile assembly shelter (MAS).

Launch table (LT).

Horizontal integration facility (HIF).

Mobile service tower (MST).

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to the spacecraft systems.

1. Match the satellite mission in column A with their category in column B. Items in column B maybe used once.

1. Provides secure and reliable command and control.	Communications.
2. Provide pinpoint weapons system accuracy.	Navigation.

3. Provide information on sea conditions.	Weather.
4. Solar, geophysical, or astronomical.	Research.
5. Provide warning and threat assessment to commanders worldwide.	Surveillance and early warning.
6. Ensure compliance with arms control agreements.	Military.

SUBMIT

23

2. What sources of electrical power are utilized on satellites?

Type your answer here

SUBMIT

24

3. What chemical fluids are usually used in heat pipes to transport heat energy from internal equipment to a radiator surface?

Type your answer here

SUBMIT

25

4. What are the types of electrical propulsion systems?

Type your answer here

SUBMIT

26

5. Define station keeping.

Type your answer here

SUBMIT

27

6. What two sources of information are included in telemetry data?

Type your answer here

SUBMIT

Click here to learn about the research and development of the weapon systems.

Research and Development

Research and development plays a pivotal role in keeping our weapon systems on the cutting edge of technology and keeping the nation one step ahead of our adversaries. Through two different agencies, the AF modernizes and tests weapon systems and spacelift capabilities to ensure that we can continue to meet the demands of the highly complex operational environment that our nation's military exists in.

Air Force Research Laboratory (AFRL) Mission: To explore, prototype, and demonstrate high-impact, game changing technologies that enable the Air Force and Nation to maintain its superior technical advantage.

AFRL Vision: To lead the Air Force and Nation in command, control, communications, computers, and intelligence (C4I) and cyber science, technology, research and development.

Mission of Research and Development Organizations

The AFRL and AFOTEC modernize our current weapon systems as well as develop and test new weapon systems. This lesson will focus on the mission of each of these prestigious organizations.

Air Force Research Laboratory

The AFRL is headquartered at Wright-Patterson AFB, Ohio, but maintains several laboratories throughout the country. It was created in 1997 by combining the Air Force Office of Scientific Research (AFOSR) with four other major laboratories.

Click on the play button to watch the video below on the Air Force Research Laboratory.

Watch the video before moving forward in the lesson to learn about the mission and organization of the AFRL.

Mission

The AFRL's mission is to lead in the discovery, development, and integration of warfighting technologies for America's Air, Space, and Cyberspace Forces. It has a full spectrum of laboratories responsible for planning and executing the Air Force's science and technology program. Together with industrial and academic experts, the AFRL develops and delivers a wide range of revolutionary technologies that ensure we have the world's best Air, Space, and Cyberspace Forces.

Organization

The AFRL contains a HQ division located at Wright-Patterson AFB, but also contains nine separate directorates responsible for different weapon system components. The directorates are listed and described in the following table.

Air Force Research Laboratory Directorates	
Directorate	**Responsibilities**
Air Force Office of Scientific Research (AFOSR)	AFOSR, operating out of Arlington, Virginia, specializes in long-term, broad-based research in aerospace-related science and engineering to further aid the efforts of other directorates.

Directed Energy Directorate	The Directed Energy Directorate, headquartered at Kirtland AFB, New Mexico, focuses on directed energy and optical technologies, including high-energy microwaves, lasers, adaptive optics, and imaging, as well as the effects of each.
Information Directorate	The Information Directorate operates out of Rome, New York, and specializes in the exploitation of information and defensive information warfare, as well as the development of intelligent operating systems.
Materials and Manufacturing Directorate	Operating from Wright-Patterson AFB and Tyndall AFB, Florida, the Materials and Manufacturing Directorate researches technologies to support aerospace component manufacturing and materials. They support current systems by finding better materials and ways to make the same product.
Munitions Directorate	The Munitions Directorate, based at Eglin AFB, Florida, develops, demonstrates and transitions science and technology for air-launched munitions used for defeating ground fixed, mobile/relocatable, air and space targets to assure pre-eminence of US air and space forces.

Aerospace Systems Directorate	Operating out of Wright-Patterson AFB and Edwards AFB, California, this directorate develops air and space vehicle propulsion and power technologies. Focus areas include turbine and rocket engines, advanced propulsion systems, and the associated fuels and propellants.
Sensors Directorate	Headquartered at Wright-Patterson AFB, and operating out of Hanscom AFB, Massachusetts, and Rome, New York, the Sensors Directorate works on new technologies that US warfighters need to find and engage the enemy and eliminate their ability to hide or threaten our forces. Its core technology areas include: radar, active and passive electro–optical targeting systems, navigation aids, automatic target recognition, sensor fusion, threat warning, and threat countermeasures.
Space Vehicles Directorate	The Space Vehicles Directorate, with operating locations at Kirtland AFB and Hanscom AFB, develops and transitions space technologies. Primary focus areas include: radiation-hardened electronics, space power, space structures and control, space-based sensing, space environmental effects, autonomous maneuvering, and balloon and satellite flight experiments.

Human Performance Wing	The 711th Human Performance Wing is stationed at Wright-Patterson AFB. It is the first human–centric warfare wing to consolidate research, education, and operational consultation under one roof. The wing's primary mission areas are aerospace medicine, and science and technology, as well as how humans are integrated with different weapon systems.

Click on the play button to watch the video below on the Air Force Operational Test and Evaluation Center (AFOTEC).

Watch the video before moving forward in the lesson to learn about the mission and organization of AFOTEC.

Air Force Operational Test and Evaluation Center

The AFOTEC is located at Kirtland AFB, New Mexico and is a direct reporting unit under HQ USAF; it does not fall under a MAJCOM or NAF. It is the AF's independent test agency responsible for testing new systems being developed for the AF and other services and agencies under operationally realistic conditions.

The AFOTEC employs more than 600 personnel in five detachments located at Edwards AFB, California; Peterson SFB, Colorado; Eglin AFB, Florida; Nellis AFB, Nevada, and Kirtland AFB, New Mexico, as well as many other operating locations throughout the nation.

Mission

AFOTEC's mission is to test and evaluate new warfighting capabilities. They do this in the most operationally realistic environment possible to get the most accurate test results. These tests inform national agencies about new systems and influence the decision to divert national resources to their development. Test teams conduct tests at selected sites then collect, analyze, evaluate the data, and prepare formal reports. The teams are managed by AFOTEC, but tests are conducted by personnel from the operating and support commands that will eventually employ these systems.

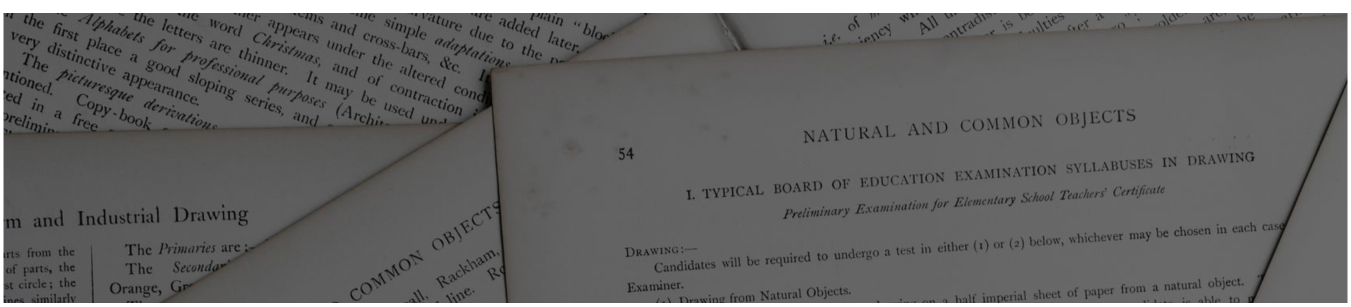
Test Program

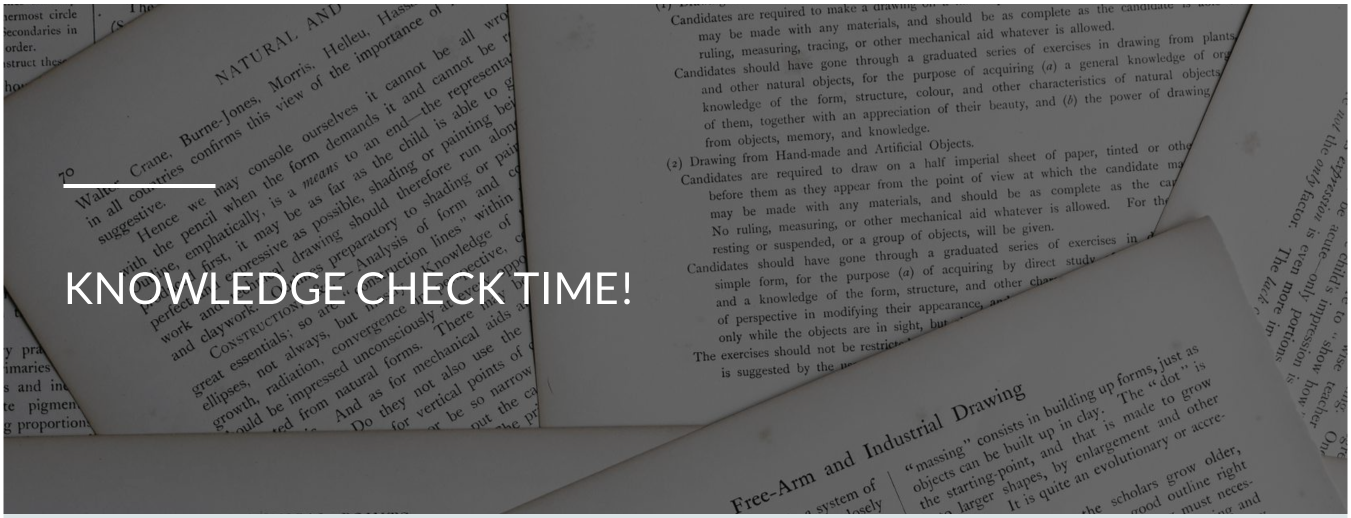
The AFOTEC performs independent and objective evaluations of how well systems will meet operational requirements and provides a vital link between the developer and the user. They are a key element of the system acquisition approval process.

Operational tests are designed to address critical issues regarding a system's performance in combat–like environments when operated by field personnel. They seek to answer questions about how safe, effective, reliable, maintainable, compatible, and supportable new systems will be.

The AFOTEC's tests are normally conducted on prototype and pre-production models and play an important role in acquisition and identifying deficiencies.

This lesson focused on the mission of Air Force research and development organizations, which are largely responsible for modernizing current weapon systems, as well as developing new ones.





KNOWLEDGE CHECK TIME!

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the mission of research and development organizations.

1. Match the description in column A with the Air Force Research Laboratory Directorate in column B. Items in column B may be used once.

1. Specializes in long-term, broad-based research in aerospace science and engineering.	Air Force Office of Scientific Research.
2. Focuses technologies on optical technologies.	Directed Energy.
3. Develops intelligent operating systems.	Information.
4. Supports current systems by finding better ways to make the same product.	Materials/Manufacturing.

5. Specializes in defeating ground fixed, mobile/relocatable, and air and space targets.	Munitions.
6. Develops air and space vehicle propulsion and power technologies.	Aerospace systems.
7. Specializes in aerospace medicine, science, and technology.	Human Performance.

SUBMIT

28

2. Who does the AFOTEC report to?

Type your answer here

SUBMIT

29

3. What is AFOTEC's mission?

Type your answer here

SUBMIT

30

4. What are operational tests conducted by AFOTEC designed to address?

Type your answer here

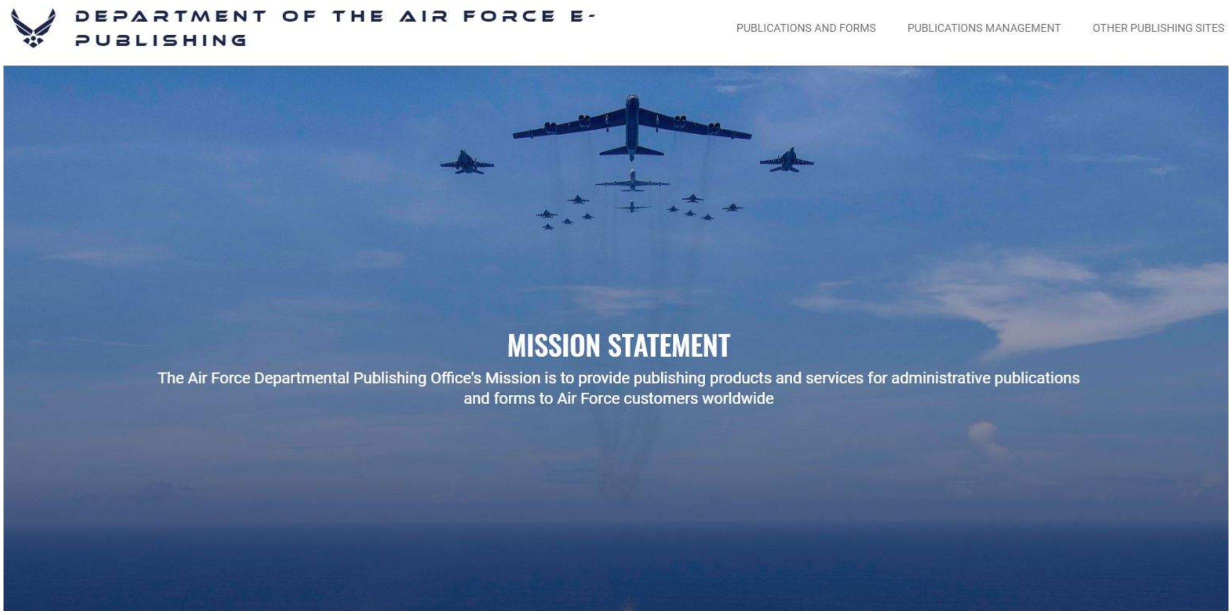
SUBMIT

This completes Lesson 1. You can find the answers to the self-test questions in the Module 2 table of contents.

Lesson 2. Publications

Main Points

1. Standard Publications and Technical Orders
   a. Categories and types of standard publications
   b. Description of the technical order system
   c. Typical technical order format
   d. Technical order improvement report
2. Civil Engineering Manuals
   a. Description of civil engineering manuals
   b. Format of civil engineering systems and equipment manuals
   c. Submitting civil engineering manual improvement reports



https://www.e-publishing.af.mil/

https://www.e-publishing.af.mil/

Publications are the primary method the AF uses to document how the mission will be accomplished. Often, you unknowingly comply with requirements you have never personally read because your supervisor has instructed you to do so or you have been trained to do so. Compliance with publications and directions is a habit in the AF, but it is vital that you understand where this direction comes from as it can change frequently.

As you learned in your technical training, you cannot perform your duties as a technician without a technical order (TO) or civil engineering manual (CEM), so it is very important that you learn to navigate your way through these publications to ensure you are doing your job safely and effectively. Through time, you will figure out that there are sometimes better or more efficient ways of accomplishing a task than what the TO or CEM directs, which is when you will submit a change request.

This lesson will introduce you to standard publications and guide you through the AF's TO system and CEM system and this lesson will also include instructions on how to complete and submit TO or CEM improvement reports.

Click here to begin Lesson 2.

There are literally thousands of publications within the DoD and the AF. Most standard publications can be found at the click of a mouse, but the TO system is different.

This section of the lesson will familiarize you with standard publications and will examine the TO system and the layout of a typical TO. This section concludes with a look at the TO improvement program.

Categories and Types of Standard Publications

All standard publications are divided into two main categories: directive and non-directive. This simply tells you whether a publication contains information that must be adhered to or simply used as a guide to accomplishing a task. We will break down each category then see how these publications are numbered to make it easier for you to find one. Most publications can be found on the Air Force Publications website, so we will look at what that website can offer.

Directive

Directive publications are those necessary to meet the requirements of safety, security, or other areas where common direction and standardization benefit the AF. Air Force personnel must comply with these publications and the heading of each of these publications normally contains the following statement: "COMPLIANCE WITH THIS PUBLICATION IS MANDATORY."

Directive

Supplements

Before we discuss other types of directive publications, it is prudent to discuss supplements first. Supplements are publications that extend or add material to other publications issued by higher HQ or agencies. The key idea to remember about supplements is that they cannot contain guidance that is less restrictive than the parent publication they supplement.

For example, Department of the Air Force Instruction (DAFI)36–2903, *Dress and Personal Appearance of United States Air Force and United States Space Force Personnel*, requires you to wear ribbons and all devices on your service coat. Policy directives and memorandums cannot be supplemented.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

AIR FORCE MANUAL 21-202

29 AUGUST 2019

Incorporating Change 1, 2 September 2020

AIR FORCE GLOBAL STRIKE COMMAND Supplement

15 JULY 2020

Incorporating Change 1, 3 May 2021

Certified Current 3 May 2021

Maintenance

MISSILE MAINTENANCE MANAGEMENT

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

ACCESSIBILITY: Publications and forms are available for downloading or ordering on the ePublishing website at **www.e-Publishing.af.mil**

RELEASABILITY: There are no releasability restrictions on this publication.

OPR: HQ AF/A4LW

Certified by: AF/A4L (Col McElroy)

Supersedes: AFI21-202V1, 18 January 2017, AFI21-202V2, 29 October 2014

Pages: 104

Directive

Policy Directives

Air Force policy directives (AFPD) are orders from the Secretary of the Air Force (SECAF) that contain directive policy statements to initiate, govern, and/or regulate actions within specified areas of responsibility or activities. The SECAF is the only approval authority for AFPDs and thus, they cannot be supplemented by subordinate units. An example of an AFPD is AFPD 21–1, *Maintenance of Military Materiel*. This AFPD simply establishes policy and assigns responsibilities for the maintenance of air and space equipment.

BY ORDER OF THE
SECRETARY OF THE AIR FORCE

AIR FORCE POLICY DIRECTIVE

21-1

1 AUGUST 2018

Maintenance

MAINTENANCE OF MILITARY MATERIEL

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

ACCESSIBILITY: This publication is available on the e-Publishing web site at publishing.af.milpublishing.af.mil

RELEASABILITY: There are no releasability restrictions on this publication

OPR: SAF/AQD

Certified by: SAF/AQ (Dr. William Roper)

Supersedes: AFPD 21-1, 29 October 2015

Pages: 8

Directive

Policy Memorandum

The difference between an Air Force policy directive (AFPD) and an Department of the Air Force policy memorandum (DAFPM) is simple—a memorandum is published when there is insufficient time to process a directive. These address critical issues such as national security or safety when action must happen immediately, but there is not enough time to finish the directive. DAFPMs expire 180 days after publication, so an AFPD must be in development.

DEPARTMENT OF THE AIR FORCE
WASHINGTON, DC

OFFICE OF THE SECRETARY

DAFPM2021-36-01
30 April 2021
Extended Date: 28 April 2022

MEMORANDUM FOR DISTRIBUTION C
MAJCOMs/FLDCOMs/FOAs/DRUs

SUBJECT: Department of the Air Force Policy Memorandum *Accessions and In-Service Transition for Persons Identifying as Transgender*

This Department of the Air Force (DAFPM) Policy Memorandum immediately establishes specific Air Force and Space Force policy and provides guidance associated with the accession and in-service transition of Service members identifying as transgender. Compliance with this memorandum is mandatory. To the extent the memorandum's directions are inconsistent with other DAF publications, the information herein prevails, in accordance with Department of the Air Force Instruction 33-360, *Publications and Forms Management.*

Directive

Instructions

Department of the Air Force instructions (DAFI) are what you will see most of the time. DAFIs are orders from the SECAF and are certified and approved by HQ Air Force staff. DAFIs direct action, ensure compliance, and/or give detailed procedures to standardize actions across the entire AF. DAFIs may be supplemented at any level; however, as you have learned, supplements can only make the DAFI more restrictive. An example of a DAFI is DAFI 91-101, *Air Force Nuclear Weapons Surety Program.*

Other units below the Air Force level have the freedom to establish their own instructions as well. For example, Air Education and Training Command Guidance Manual (AETCGM) 2018-36-03, Interim Guidance for the Instructional Design of Basic Military and Technical Training, directs how technical training will be developed and managed. There is no Air Force-level instruction to govern technical training development, which means there is no document to supplement; therefore, AETC developed its own guidance.

BY ORDER OF THE
SECRETARY OF THE AIR FORCE

DEPARTMENT OF THE AIR FORCE
INSTRUCTION 91-101

26 MARCH 2020
Incorporating Change 1, 6 April 2022

Safety

AIR FORCE NUCLEAR WEAPONS
SURETY PROGRAM

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

ACCESSIBILITY: Publications and forms are available for downloading or ordering on the e-Publishing website at **www.e-Publishing.af.mil**.

RELEASABILITY: There are no releasability restrictions on this publication.

Directive

Manuals

Air Force manuals (AFMAN) are usually extensions of DAFIs that provide additional guidance for performing standard tasks or supporting education and training programs. An AFMAN does not necessarily have to fall under an AFI, and can stand alone. A good example is AFMAN 36–2203, *Drill and Ceremonies*, which contains extensive instructions with illustrations on how to perform drill. Your military training instructor at basic training used this publication extensively.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

AIR FORCE MANUAL 21-204

13 JANUARY 2023

Maintenance

NUCLEAR WEAPONS MAINTENANCE

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

ACCESSIBILITY: This publication is available for downloading from the e-Publishing website at **www.e-Publishing.af.mil**

RELEASABILITY: There are no releasability restrictions on this publication.

OPR: AF/A4LW

Certified by: AF/A4L (Maj Gen Linda S. Hurry)

Supersedes: AFMAN 21-204, 13 August 2019

Pages: 46

Directive

Operating Instructions

Operating instructions (OI) are developed for the same purpose of instructions; however, OIs are only developed by a particular unit for use only in that unit. An OI is very similar to an AFI, but an OI is only applicable to the unit that created and published it. They are directive and are mandatory for all personnel in that unit and/or subordinate units.

Now that you have learned about directive publications, click through each tab before moving forward in the lesson to learn about the non-Air Force publications.

Non-directive

Non-directive publications are informational and suggest guidance that you can modify to fit the circumstances. Complying with non-directive publications is expected, but not mandatory. AF personnel use these publications as reference aids or "how-to" guides. The following are some examples of non-directive publications.

PAMPHLET	HANDBOOK	VISUAL AIDS	DOCTRINE DOCUMENTS

Air Force pamphlets (AFPAM) are informational, "how-to" publications that may include information for implementing AF guidance. They may provide guidance regarding reports, but may not prescribe reports. They may reference forms and provide guidance on completing them, but cannot prescribe the use of the form.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

DEPARTMENT OF THE AIR FORCE PAMPHLET 34-1203

13 SEPTEMBER 2022

Services

DRILL AND CEREMONIES

ACCESSIBILITY: Publications and forms are available for downloading or ordering on the e-Publishing website at www.e-Publishing.af.mil

RELEASABILITY: There are no releasability restrictions on this publication

OPR: AF/A1S

Certified by: SAF/MR

Supersedes: AFMAN36-2203, 19 June 2018

Pages: 107

PAMPHLET	HANDBOOK	VISUAL AIDS	DOCTRINE DOCUMENTS

Handbooks are reference books of a particular subject or a compilation of factual data and instructional material not subject to frequent change. A good example of an Air Force handbook (AFH) is AFH 1, The Airman Handbook.
This handbook contains information on Air Force history, doctrine, values, customs and courtesies, and is the study material for the Promotion Fitness Examination or United States Air Force Supervisory Examination.

AIR FORCE HANDBOOK 36-2643

17 MAY 2019

Personnel

AIR FORCE MENTORING PROGRAM

ACCESSIBILITY: Publications and forms are available on the e-Publishing website at **www.e-Publishing.af.mil** for downloading or ordering.

RELEASABILITY: There are no releasability restrictions on this publication.

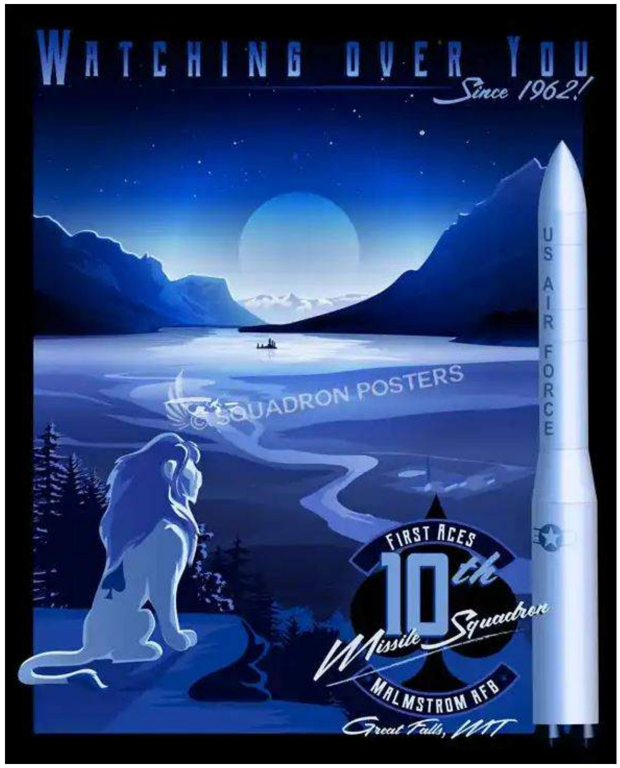
OPR: AF/A1D Certified by: SAF/MR

Supersedes: AFMAN36-2643, 4 May 2017 Pages: 21

PAMPHLET	HANDBOOK	VISUAL AIDS	DOCTRINE DOCUMENTS

Visual aids are posters or graphic illustrations. They are issued for display on walls, bulletin boards, desks, or other base facilities. There are two kinds of visual aids, permanent and temporary. Permanent visual aids explain or instruct, such as a chart portraying military insignia.

Temporary visual aids are used to inform or motivate, and might include a poster that promotes safe driving. As a rule, temporary visual aids should only be displayed 180 calendar days or less, and this expiration date should be printed at the bottom.



PAMPHLET	HANDBOOK	VISUAL AIDS	DOCTRINE DOCUMENTS

Doctrine documents are statements of officially sanctioned beliefs and warfighting principles that describe and guide the proper use of air, space, and cyberspace forces in military action. These documents are authoritative but broad in nature and require judgment in applying them. They can be either doctrine documents or tactics, techniques, and procedures documents.


AIR FORCE DOCTRINE PUBLICATION 1
THE AIR FORCE
U.S. AIR FORCE
10 March 2021

Click on each tab above before moving on in the lesson.

Non-Air Force Publications

Non-Air Force publications are produced by federal agencies outside of the AF and are directive, or of interest, to the AF. They do not include commercial, foreign, state, or local government publications. Sources of non-Air Force publications include the DoD, Department of Health and Human Services, Department of Labor, other military branches, and the Joint Staff.

Air Force Publications Website

Today, most Air Force publications can be found on the internet in electronic format, which eliminates the need to maintain paper copies. The Air Force publications website is located at https://www.e-publishing.af.mil/.

This site is a powerful reference tool and contains nearly every Air Force standard publication you are looking for, as well as thousands of blank forms prescribed by those publications. It also contains several Air Force supplements to DoD publications. The most current version of each publication is maintained on the website. Whenever possible, obtain the newest version rather than using a copy found on your computer or network drive, as these versions may not be up to date.

Some publications will not be available in electronic format because they contain sensitive information that should not be disclosed to the general public. When you need one of these publications, simply contact the office of primary responsibility that is listed on the website.

Description of the Technical Order (TO) System

TOs provide clear, concise instructions on how to perform maintenance safely and effectively. They also provide a wealth of other information that will help guide you through your maintenance activities. In this lesson, we will look at the different types of TOs, how TOs are numbered, and some general policies for using a TO.

Types of Technical Orders

There are several different types of TOs that you will encounter throughout your career. Figure 2–1 shows a diagram depicting each of the different types.

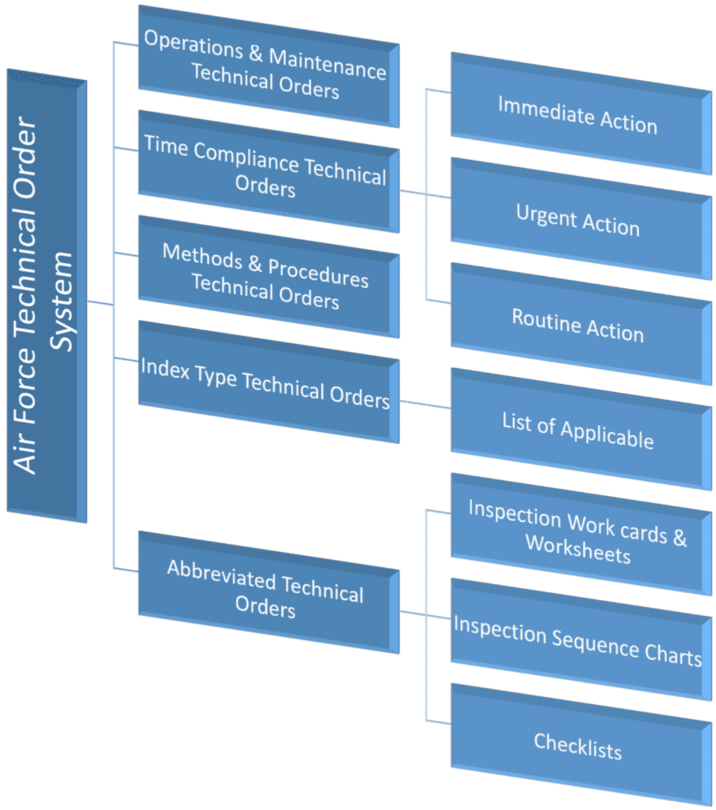
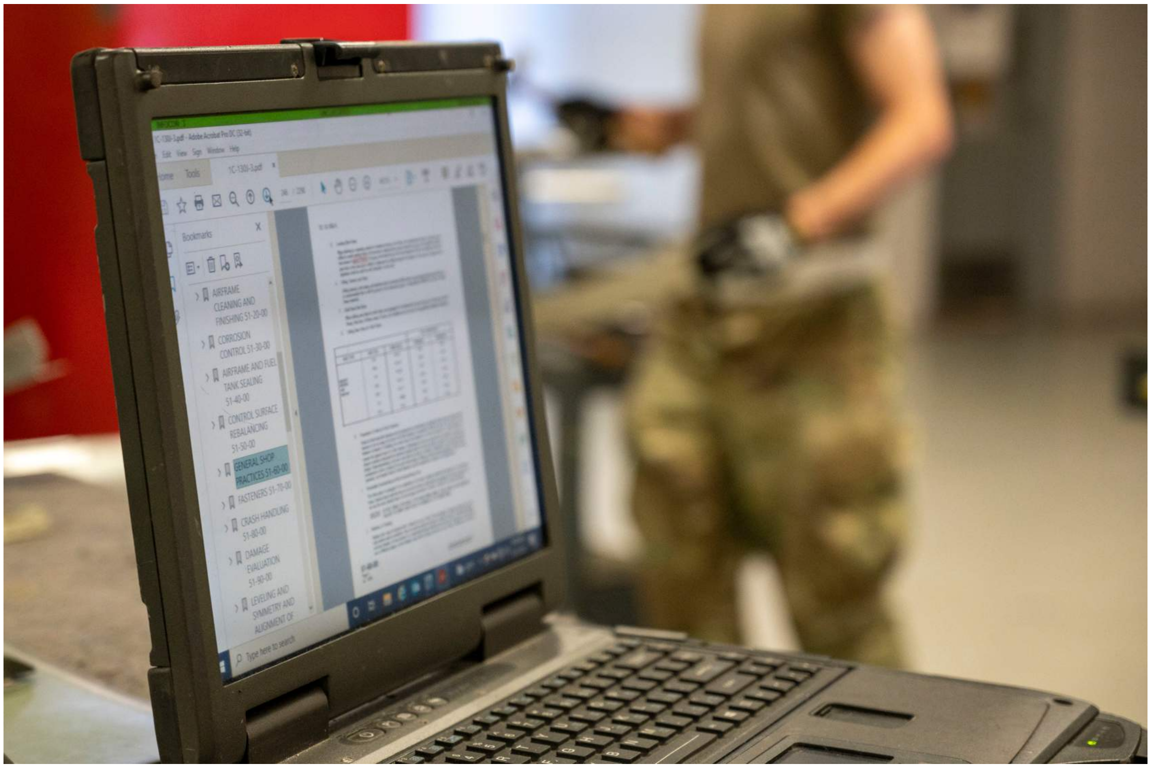


Figure 2–1. Types of technical orders.

Click on each (+) sign below to learn about the different types of technical orders.

Operations and Maintenance (O&M)

Operations and maintenance (O&M) TOs provide step-by-step procedures for performing tasks. They cover the installation, operation, troubleshooting, repairing, removing, calibrating, servicing, or handling of Air Force military systems and end items. O&M TOs must be available and used wherever maintenance is being performed.



Methods and Procedures (M&P)

Methods and procedures (M&P) TOs contain information that applies to more than one type of weapon system. They are general in nature and might have specific information on how to accomplish a task, but they are not required to be available and used on the job site.

Index

Indexes identify needed TOs, group TOs pertaining to specific items of equipment, and show the status of all TOs. The TO index is the quickest and easiest method to find a TO if you do not know the TO number. Using a list of applicable publications index will help you find any TO applicable to a specific weapon system as well as the items related to that weapon system.

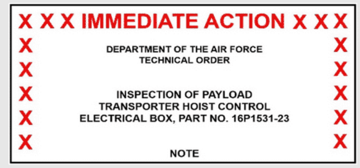
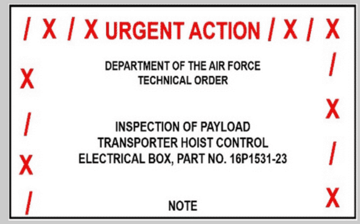
Abbreviated

Abbreviated TOs are excerpts from one or more basic TOs, and their purpose is to organize and simplify instructions. Examples are inspection work cards, inspection sequence charts, and checklists.

Abbreviated Technical Orders	
Type	**Description**
Inspection work cards	You used work cards during technical training that told you what periodic inspections needed to be done on the weapon system. Work cards provide the required guidance, including applicable safety warnings and cautions, and provides specific pass or fail criteria.
Inspection sequence charts	Sequence charts break down an inspection work card and show a planned work. Schedule or sequence in which inspection work cards can be used.
Checklists	Checklists provide abbreviated step-by-step procedures for performing maintenance on the weapon system. **A checklist will cover not every task or maintenance practice.**

Time Compliance Technical Orders (TCTOs)

Time compliance technical orders (TCTO) direct and provide instructions for modifications and one time inspections (OTI) of the weapon system. Any modification or upgrade will be directed by a TCTO. TCTOs are grouped according to their importance and urgency. The three levels of TCTO urgency are: Immediate, Urgent, and Routine action.

Levels of TCTOs		
Level	**Description**	**Image**
Immediate	Immediate action TCTOs (fig. 2–2) are issued to prevent the use of equipment or procedures until a hazardous safety condition can be resolved and are the highest level of TCTOs issued. The words "IMMEDIATE ACTION" are printed in red at the top center of the page and a series of red Xs are printed around the border of the first page.	Figure 2–2. Immediate action TCTO cover page. 
Urgent	These are issued when potentially unsafe conditions exist that could result in personnel injury or damage to property, or when the condition could reduce combat efficiency if not properly attended to. If an urgent action TCTO is not complied with within its set time limit, the equipment or item must be removed from service until the TCTO for that piece of equipment has been accomplished. Urgent action TCTO have the words "URGENT ACTION" printed on the top of the page with a series of red diagonals and red Xs around the border of the first page (fig. 2–3).	Figure 2–3. Urgent action TCTO cover page. 
Routine	All other TCTOs not covered by immediate or urgent action fall under the routing category. These can be issued for a system upgrade or to address deficiencies that if not corrected, could eventually develop into something more serious. Routine actions TCTOs have no significant identifying marking like those that identify Immediate and Urgent actions.	

Preliminary

While not classified as a type of technical order, it is important to address the preliminary TO. When a new piece of equipment or procedure is developed, the tech data is called a preliminary TO. It cannot be used to perform the task yet because the procedures that it contains still need to be verified. Operational personnel with oversight from the technical content manager (TCM) accomplish the verification. At some point in your career you may have the opportunity to conduct a validation verification (val-ver or "val-ver") with 20 AF and the TO manager. Once the procedures have been tested and approved, the preliminary TO will become an O&M TO that can be used to perform maintenance on the weapon system.

Complete the content above before moving on.

Technical Order Numbering System

Understanding how TOs are numbered will go a long way when it comes to finding the right TO. Each TO category has its own numbering pattern, so we will not be covering all possible numbering combinations. TO numbers are composed of groups separated by dashes; each group is then further divided into parts, and each part consists of one or more numbers or letters. Figure 2–4 shows an example of the numbering system. The table in figure 2–4 provides additional information about the grouping of numbers used in the TO numbering system.

Technical Order Numbering System

Use T.O. **21M-LGM30G-2-7-8** as an example.

21M-

21	Identifies that this T.O. belongs to Category 21, *Guided Missiles*
M	Identifies that this T.O. is for a *missile system*

LGM30G-

L	Identifies that the launch environment is *silo-launched*
G	Identifies the basic mission is *ground attack*
M	Identifies that the type of vehicle is a *missile or drone*
30G	Identifies the missile *model* and *series*

2-7-8

2	Identifies the type of manual, i.e., *O&M, abbreviated, index, etc.*
7	Identifies the major subsystem is the *Environmental Control System*
8	Identifies the T.O. series number

Figure 2–4. Technical Order Numbering System.

Figure 2–4. Technical Order Numbering System.

Technical Order Numbering System	
Group	**Description**
1	The first set of numbers/letters before the first dash identifies the category of TO and will set the standard for how the rest of the TO is numbered. This number corresponds to the supply code assigned to the major system that it applies to. This is how an index TO is built; it will give you all the TOs under that category. Other TO categories you will encounter are 32 (special tools) and 33 (test equipment). We will focus on how category 21 is broken down. Category 21 is for guided missiles and will always be accompanied by an "M" for missile.
2	Under category 21, the first digit in-group 2 identifies the launch environment, second digit identifies the basic mission of the missile, and the third identifies the missile vehicle type. Ours is LGM30G; "L" means silo launch, "G" means its mission is ground attack, and "M" means guided missile or drone. 30G identifies the model number and production series of the missile. "30" indicates minuteman and "G," starting from A, indicates it is the seventh in the minuteman production series.
3	Under category 21, group 3 identifies the type of inspection, instruction, or procedure. In our case, the "–2" indicates an organizational maintenance manual, an O&M TO. Substitute a "–4" for an illustrated parts breakdown (IPB), or "–06" for work unit code (WUC) manuals.
4 & 5	Groups 4 and 5 are series numbers used to identify different technical orders in a series. Our numbers, "–7" tells us it is for the environmental control system and "–8" is last code to identify its place in the series.

Looking back at our example, 21M–LGM30G–2–7–8, we know that it pertains to a guided missile that is silo launched, and is a ground attack mission by a Minuteman missile. We know it is an O&M TO used to work on the ECS. Refer to TO 00–5–18, AF Technical Order Numbering System, for more information on breaking down other publication categories or what other identifiers under category 21 mean.

Technical Order Use

The last items of business we will cover in this lesson are compliance, what to do if there is a conflict between publications, and waivers to TOs.

Click on each tab below to learn about the different ways technical orders are utilized.

COMPLIANCE	CONFLICTS	TECHNICAL ORDER (TO) WAIVERS

As stated earlier, compliance with TOs is mandatory. They are just what they are called: "orders." They are published under the authority of the SECAF and failure to comply with a TO could be considered failure to obey a lawful order under Article 92 of the Uniform Code of Military Justice (UCMJ).

All TOs except for M&Ps must be available and used in the work area. Your TO should be open to the procedure you are performing, and you should refer to it and know exactly what step you are on. Sometimes this is not possible when working in a tight space and for other safety reasons you might be working with another person. In this case, use the command and response technique: one technician reads the step; the other performs the step, and then verbally responds that the step was complied with. This ensures steps are not missed and the technician performing the task knows what step in the TO they are on.

Lastly, before completing a task, read through the procedure one additional time to ensure that you completed all of the steps. This can save countless headaches and helps to ensure that the job was done completely.

COMPLIANCE	CONFLICTS	TECHNICAL ORDER (TO) WAIVERS

Sometimes you might come across information that is contradicted by another publication, and the following are some rules to remember when dealing with conflicts:

- If a TO contradicts information in an AFI, the TO always has precedence. AFIs should not contain procedures on how to perform tasks.
- If a TO contradicts Air Force Occupational Safety and Health (AFOSH) standards, use whichever guidance is more restrictive. This will ensure the highest safety standards are followed to prevent personnel injury.
- If a specific system TO contradicts a general TO, the specific system TO always has precedence.
- Inspection work cards take precedence over TOs for accept/reject criteria. For example, if the TO states that your #2 pencil should be at least four-inches long, but the work card states that it must be at least five-inches long, your #2 pencil needs to be at least five-inches long. If you sharpen it anymore after that, it will no longer meet the work card criteria.

COMPLIANCE	CONFLICTS	TECHNICAL ORDER (TO) WAIVERS

A TO waiver is used when you encounter a situation where the TO is incorrect. Inform your supervisory personnel, who will up channel it to the proper authorities. In most cases, the NAF can issue TO waivers. All TO waivers have an expiration date, so a TO change also needs to be submitted.

Complete the content above before moving forward in the lesson.

Typical Technical Order Format

TOs are divided into organized sections that make it easy to find the information you need to successfully complete your maintenance. This lesson will illustrate how TO 21M–LGM30G–2–7–8, Launch Facility Environmental Control System, is broken down.

Opening Pages

There are several administrative items that you will see when you first open a TO, and it's important to understand them. The following paragraphs will help you understand the specific layout of a TO, where to find information, how to use it, and safety precautions that must be observed while performing maintenance.

Title Page

This is the first page, and it provides information such as the TO number and title which will ensure that you are using the correct book. The basic date tells you when the TO was first published, and is found in the bottom left-hand corner of the title page. The latest change number is located in the bottom right-hand corner, and this tells you the latest change number of the book and the date that the change was published. Knowing this is important because it ensures that you have the most recent version of the book. Figure 2–5 shows a title page and its contents.

As you can see from the basic date in the bottom-left corner, this TO was first published on 4 June 2010. The information in the bottom-right corner states that it is on its third change, the newest of which was published on 7 July 2011.

T.O. 21M-LGM30G-2-7-8

TECHNICAL MANUAL

OPERATION, SERVICE, AND REPAIR INSTRUCTIONS

ORGANIZATIONAL AND DEPOT LEVEL MAINTENANCE

LAUNCH FACILITY
ENVIRONMENTAL CONTROL SYSTEM

EAS80001 AND EAS80003

WINGS I (SQUADRONS I, II, AND III), III AND V
USAF SERIES LGM30G MISSILE

Basic and all changes have been merged to make this a complete publication.

F42610-98-C-0001

DISCLOSURE NOTICE: This information is furnished upon the condition that it will not be released to another nation without the specific authority of the Department of the Air Force of the United States; it will be used for military purposes only; individual or corporate rights originating in the information, whether patented or not, will be respected; the recipient will report promptly to the United States any known or suspected compromise; and the information will be provided substantially the same degree of security afforded it by the Department of Defense of the United States. Also, regardless of any other markings on the document, it will not be downgraded or declassified without written approval of the originating United States agency.

DISTRIBUTION STATEMENT D: Distribution authorized to the Department of Defense and U.S. DoD contractors only, for Intercontinental Ballistic Missile (ICBM) administrative or operational use, determined 16 June 2008. Other requests shall be referred to ICBM TOMA, AFNWC / NWIEV, Hill AFB, UT 84056-5816.

WARNING: This document contains technical data whose export is restricted by the Arms Export Control Act (Title 22, U.S.C., Sec 2751, et seq.) or the Export Administration Act of 1979, as amended, Title 50, U.S.C. App. 2401, et seq. Violations of these export laws are subject to severe criminal penalties. Disseminate in accordance with the provisions of AFI 61-204.

HANDLING AND DESTRUCTION NOTICE: Comply with distribution statement and destroy by any method that will prevent disclosure of the contents or reconstruction of the document.

Published under authority of the Secretary of the Air Force

4 JUNE 2010 CHANGE 3 7 JULY 2011

Figure 2–5. Technical order title page.

List of Effective Pages

The list of effective pages lists every single page in the TO and tells you the correct change number for the page (fig 2–6). When you want to see what was changed in the latest change, you can reference the change number for each page by looking in the "Change No." column. This is particularly important because it helps to ensure that you are familiar with any changes to tasks or additional tools and test equipment you may need. Your work center should inform you of applicable changes, but if you are not sure how to perform a task with the changes in it, you need to find out before performing the task.

T.O. 21M-LGM30G-2-7-8

INSERT LATEST CHANGED PAGES. DESTROY SUPERSEDED PAGES.

LIST OF EFFECTIVE PAGES

NOTE The portion of the text affected by the changes is indicated by a vertical line in the outer margin of the page. Changes to illustrations are indicated by shaded or screened areas, or by miniature pointing hands.

Dates of issue for original and changed pages are:

Original . . . . 0 . . . . 4 June 2010 Change . . . . 2 . . . . . 2 December 2010
Change . . . . 1 . . . . . 2 September 2010 Change . . . . 3 . . . . 7 July 2011

TOTAL NUMBER OF PAGES IN THIS PUBLICATION IS 742 CONSISTING OF THE FOLLOWING:

Page No.	*Change No.	Page No.	*Change No.	Page No.	*Change No.
Title	3	3-20.1 Added	1	4-46	1
A - C	3	3-20.2 Blank	1	4-47 - 4-56	0
D Added	3	3-21	3	4-57	1
E Blank	3	3-22 - 3-24	0	4-58	3
i - iii	0	3-25 - 3-27	3	4-59 - 4-71	0
iv	3	3-28	1	4-72	3
iv.1 Added	3	3-29 - 3-30	0	4-72.1 Added	3

Figure 2–6. List of effective pages.

TO 00-25-107

TABLE OF CONTENTS

Chapter Page

Technical Order table of contents for TO 00-25-107.

Table of Contents

The table of contents tells you where to find the information that you're looking for. There is also a list of tables and a list of illustrations to show you where the tables and pictures are. This is particularly helpful since most of your periodic inspections are located in tables. When you need to perform other maintenance, you are normally directed to the appropriate location from a periodic inspection or a table in the maintenance chapter that breaks down each component. We will discuss this more later.

Foreword

These pages tell you how to use the TO and give you specific information on what different terms in the book mean and how to interpret them, and also show how a TO is laid out. Not all TOs are formatted in the way described in this lesson. The foreword also provides a list of publications related to the one you are using.

TO 00-20-1

FOREWORD

1 PURPOSE.

This technical manual provides a description of the Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures. Instructions for safe and proper storage, handling, inspection, testing, maintenance, and preparation for use are also provided.

2 USE OF THIS MANUAL.

The table of contents indicates chapter, paragraph, title, and page numbers to facilitate location of information. Illustrations, tables, and diagrams, when applicable, are located throughout the publication to supplement the text material. A list of illustrations and a list of tables indicate the number, title, and location. Abbreviations, phrases, and words which are on a decal, a placard or an engraving are set forth in the text exactly as they appear on the decal, the placard or the engraving.

3 DEFINITIONS.

The word SHALL is used to express a provision that is binding. The words SHOULD and MAY are used when it is necessary to express nonmandatory provisions. WILL may be used to express a mandatory declaration of purpose or when it is necessary to express a future event.

4 ABBREVIATIONS AND ACRONYMS.

All abbreviations used in this manual are in accordance with abbreviations per ASME Y14.38M, Abbreviations and Acronyms for use on drawings and related documents: Use acronym list from Appendix B.

NOTE

Acronyms used only once in the TO are not included in this list.

5 LIST OF RELATED PUBLICATIONS.

These publications contain information in support of this technical manual. Use List of Related Publications from Appendix A.

6 IMPROVEMENT REPORTS.

All changes to this TO must be forwarded through users MAJCOM. Submit change requests using AFTO Form 22, IAW TO 00-5-1.

Technical Order forward for TO 00-20-1.

Safety Summary

Almost every TO contains a safety summary with broad safety precautions to follow, which are not identified further in the TO. A summary of all cautions and warnings throughout the TO might also be listed, which will identify safety requirements related to your specific task. This section must be reviewed before starting any maintenance task.

Description

Most TOs have a description section that will explain how a system operates. Reading this section while simultaneously following a diagram will help you gain a better understanding of the system and develop your system knowledge.

Special Tools and Test Equipment

This section will show you what tools or test equipment you will need for your task. Here you will find a table that lists the special tool, its part number, and what it is used for. A list of test equipment (fig 2–7) will tell you the same information, as well as what other equipment is authorized to be used in its place if the original is not available. A list of consumables tells you the chemicals that you might use as well as what other supplies you need to have available.

Lastly, this section also provides specific instructions on the use of some specific pieces of equipment. If you are directed to install the manifold and gauge assembly, for example, you would refer to this section of the TO to find specific steps on how to install it.

T.O. 21M-LGM30G-2-7-8

Table 2-1. Special Tools

Item	Nomenclature	Specification, Part Number, or NSN	Use
1.	Adapter, Crowsfoot (7/16-inch)	PN FC014A Snap-On (or equivalent)	Applying torque to emergency fan mounting hardware.
2.	Apron, Rubber	8415-00-082-6108 or 8415-00-634-5023 (or equivalent)	Servicing ECS.
3.	Extension Cord (25-ft)	6150-00-485-6149 (or equivalent)	Applying power to ECS test equipment.
4.	Eyewash Bottle (32-oz)	PN 5BB-121842 Lab Safety (or equivalent)	Flushing eyes.
5.	Faceshield	4240-00-542-2048 (or equivalent)	Servicing ECS.

Figure 2–7. Special Tools and Test Equipment.

Operation and Checkout

This section lists what procedures it contains and gives you a reference to where they are located. This is where you will find procedures on operating the weapon system or component as well has how to perform checkouts on it, and this is where most periodic inspections are located. The tables in this section are in a four–column format as shown in figure 2–8. Perform the procedure; if you get a normal indication, perform the next step. If you get an abnormal indication, perform the corrective action. The corrective action will normally direct you to complete maintenance or troubleshooting actions because a component is malfunctioning and needs to be repaired.

T.O. 21M-LGM30G-2-7-8

Table 3-2. ECS Emergency Mode Checkout

Step	Procedure	Normal Indication	Abnormal Indication	Corrective Action
1.	Ensure the ECS is in normal operation IAW Paragraph 5.3.1.			
	CAUTION Loss of airflow to electronic racks will result in rack failure. If loss of emergency ECS occurs and air handler fan is inoperative, electronic racks shall be shut down immediately (refer to T.O. 21M-LGM30G-2-10). Failure to comply may result in equipment damage.			
1A.	In LDB panel, set circuit breaker CB-25, 27, 29 to OFF.			
2.	Check air handler fan (**[1]** FO-14, 53 **[3][5]** FO-27, 55<) status.	Not operating	Operating	Check and repair facility electrical system (refer to CEM 21-SM80X-2-21-X).

Figure 2–8. A procedure in four-column format.

Trouble Analysis

The trouble analysis section provides step-by-step instructions on how to locate a malfunction. Other procedures will typically refer you to a specific trouble analysis step. If not, the alarm indications section will provide a good starting point. The tables in this section are in a four-column format as well. Sometimes when troubleshooting, a normal indication on a step eliminates the need to perform the next several steps. One other concept to remember about these procedures is that they should be used in conjunction with the diagrams. A tricky electrical problem is easier to find if you know where the procedure is directing you to check and why.

Maintenance

The maintenance section breaks down all the maintenance tasks that can be performed on nearly every component in the system you are working on, and you can typically skip directly to this section if you already know what maintenance you need to perform. For example, if you know that you have to replace the fiber optic repeater adapter in the brine chiller control panel, then look up the procedures in this chapter and press on. Here is how:

1. Find the component replacement and adjustment table (fig 2–9).
2. Find the component designator you are looking for in the table.
3. Determine what mode of operation the system must be in to perform maintenance on that component, and then establish that mode of operation.
4. Proceed to either the replacement or the adjustment paragraph listed on the table and complete the procedure.
5. Perform a functional checkout to verify that the problem was fixed.

You can remove, install, adjust, or service nearly all components in the system using these procedures. Your maintenance actions are not considered complete until you verify that the system is fully operational, so always be sure to perform a functional checkout even if the maintenance procedure does not direct you to do so.

Table 5-1. Component Replacement and Adjustment - Continued

			Establish Operational Mode and Remove Facility Power (attach Danger Tag) at...			
Ref Des	Short Name	Figure Location	Operational Mode/Para	Facility Power Source	Replace Para	Adj Para
FOR-1	Fiber Optic Repeater	FO-7, 5	Emergency Paragraph 5.3.3	CCP-1; CB-1	Paragraph 5.40	None
FOR-2	Fiber Optic Repeater	FO-10, 37	Emergency Paragraph 5.3.3	Launch Tube Heater Control Panel; SW-5 Disconnect cable W673 from J-1 (FO-10, 11); then, attach shorting plug (Table 2-1, 25) to cable W673	Paragraph 5.41	None
FRA-1	Fiber Optic Repeater Adapter	FO-7, 4	Emergency Paragraph 5.3.3	CCP-1; CB-1	Paragraph 5.42	None
FRA-2	Fiber Optic Repeater Adapter	FO-10, 38	Emergency Paragraph 5.3.3	Launch Tube Heater Control Panel;	Paragraph 5.43	None

Figure 2–9. Component Replacement and Adjustment Table.

Diagrams

This section contains illustrations of components, schematic diagrams, and wiring diagrams that cover all aspects of the system, and these can be used in a variety of situations. Schematics can be followed to aid in troubleshooting and understanding system operation. Figures usually contain a reference from a procedure to show you where to find a particular part of a component or where a component is located. The wiring diagrams are useful when you need to ensure that a component is wired correctly.

One important note is that you are not authorized to troubleshoot the system using schematic diagrams alone. Schematics must be used in conjunction with operation and checkout procedures or trouble analysis procedures. Failure to comply could result in death or injury to personnel or damage to equipment.

Technical Order Changes

Technical order changes are a result of improvement reports (which we will see later) that are submitted by technicians such as yourself. You were shown the list of effective pages earlier in the unit, but how do you know what content within that page was changed? Changes are annotated with a vertical black line printed in the outside margin next to the content that changed (fig 2–10). When familiarizing yourself with the task prior to departing for the field, pay close attention to these lines, and make sure that you are familiar with how to perform the changed procedure.

This lesson focused on the organization and contents of TO 21M–LGM30G–2–7–8, Launch Facility Environmental Control System. Be sure to reference the foreword on any TO you are using to see how that particular TO is broken down. All TOs contain the same general content, but not always in this particular order. Understanding the format of one type of TO will make finding information in other TOs much easier.

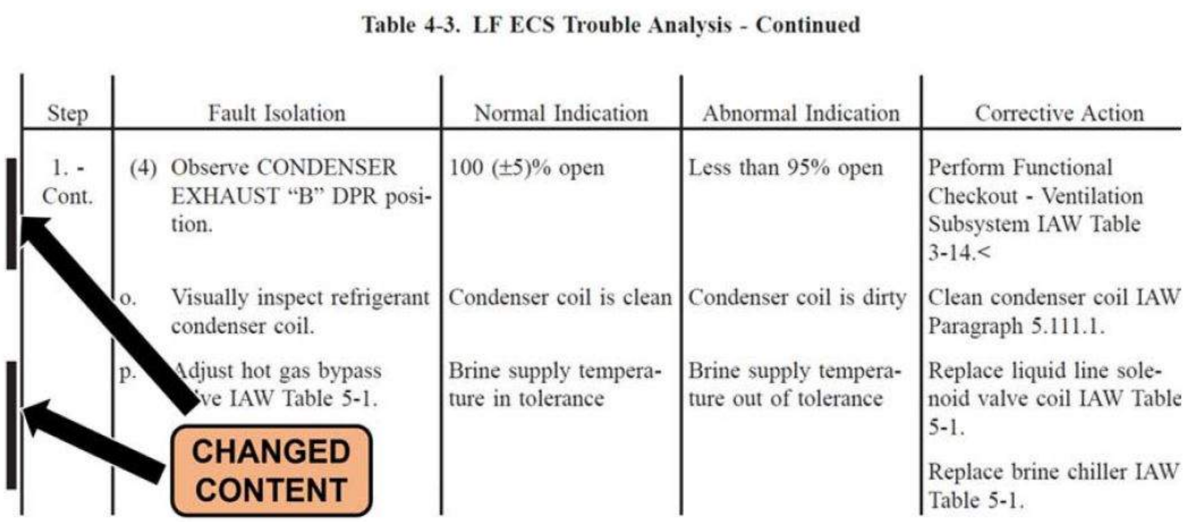


Table 4-3. LF ECS Trouble Analysis - Continued

Step	Fault Isolation	Normal Indication	Abnormal Indication	Corrective Action
1. - Cont.	(4) Observe CONDENSER EXHAUST "B" DPR position.	100 (±5)% open	Less than 95% open	Perform Functional Checkout - Ventilation Subsystem IAW Table 3-14.<
	o. Visually inspect refrigerant condenser coil.	Condenser coil is clean	Condenser coil is dirty	Clean condenser coil IAW Paragraph 5.111.1.
	p. Adjust hot gas bypass valve IAW Table 5-1.	Brine supply temperature in tolerance	Brine supply temperature out of tolerance	Replace liquid line solenoid valve coil IAW Table 5-1.
				Replace brine chiller IAW Table 5-1.

Figure 2–10. Identifying changed content.

The previous section covered the typical technical order format. Click here to learn about the technical order improvement report.

Technical Order Improvement Report

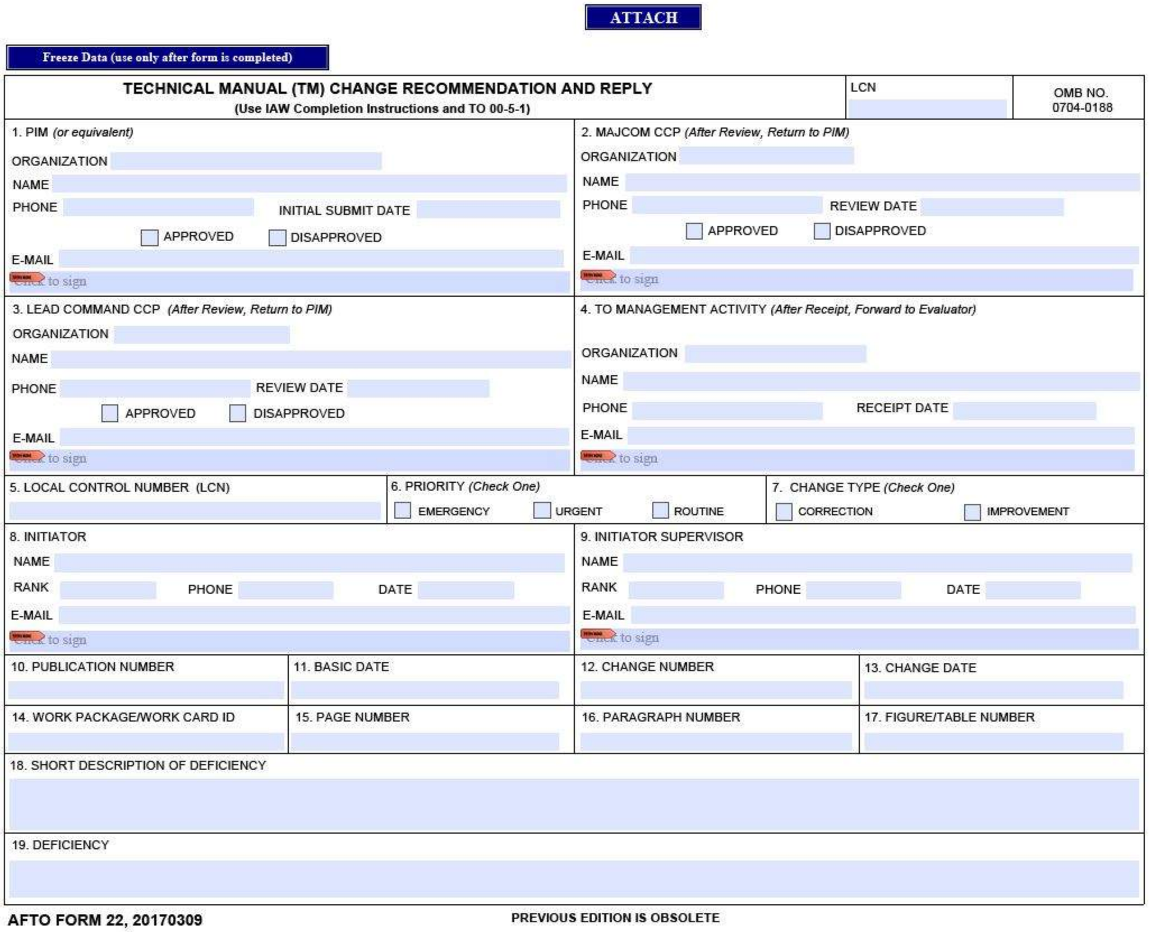
You may find guidance in a TO that is incorrect, unclear, incomplete, or improperly sequenced—or you might have a more efficient way of completing a procedure. The Air Force Technical Order (AFTO) Form 22, Technical Manual (TM) *Change Recommendation and Reply*, provides a way to correct, clarify, delete, or include the correct information. This lesson will focus on the purpose, report categories, and procedures for submitting an AFTO Form 22, or AFTO 22.

Purpose

Figures 2–11, 2–12, and 2–13 illustrate the three pages of an AFTO 22, and this form is submitted to correct errors or omissions of a technical nature, which prevent adequate performance of functions required for mission accomplishment. You can also submit an AFTO 22 to correct minor inaccuracies of a nontechnical nature that affect the meaning of instructions. Do not submit an AFTO 22 to correct typographical or printing errors that do not cause confusion, or errors that would normally be corrected during scheduled reviews.

Your supervisor will review your form before you submit it to ensure it is a valid recommendation. Next, the AFTO 22 will be sent to the designated review authority within the unit—which is usually your local quality assurance (QA)—where it will be checked for proper category and disapproved if necessary. Depending on the category of the report, you can expect to get a response from the control point within 60 days.

Below is a copy of the AFTO 22. Scroll through the images to see the document. Always check the Department Air Force E-Publishing site to ensure the most current form is being utilized.



ATTACH

Freeze Data (use only after form is completed)

TECHNICAL MANUAL (TM) CHANGE RECOMMENDATION AND REPLY (Use IAW Completion Instructions and TO 00-5-1)	LCN	OMB NO. 0704-0188

1. PIM *(or equivalent)* ORGANIZATION NAME PHONE INITIAL SUBMIT DATE APPROVED DISAPPROVED E-MAIL Click to sign	2. MAJCOM CCP *(After Review, Return to PIM)* ORGANIZATION NAME PHONE REVIEW DATE APPROVED DISAPPROVED E-MAIL Click to sign
3. LEAD COMMAND CCP *(After Review, Return to PIM)* ORGANIZATION NAME PHONE REVIEW DATE APPROVED DISAPPROVED E-MAIL Click to sign	4. TO MANAGEMENT ACTIVITY *(After Receipt, Forward to Evaluator)* ORGANIZATION NAME PHONE RECEIPT DATE E-MAIL Click to sign

5. LOCAL CONTROL NUMBER (LCN)	6. PRIORITY *(Check One)* EMERGENCY URGENT ROUTINE	7. CHANGE TYPE *(Check One)* CORRECTION IMPROVEMENT

8. INITIATOR NAME RANK PHONE DATE E-MAIL Click to sign	9. INITIATOR SUPERVISOR NAME RANK PHONE DATE E-MAIL Click to sign

10. PUBLICATION NUMBER	11. BASIC DATE	12. CHANGE NUMBER	13. CHANGE DATE
14. WORK PACKAGE/WORK CARD ID	15. PAGE NUMBER	16. PARAGRAPH NUMBER	17. FIGURE/TABLE NUMBER

18. SHORT DESCRIPTION OF DEFICIENCY

19. DEFICIENCY

AFTO FORM 22, 20170309 PREVIOUS EDITION IS OBSOLETE

Figure 2–11. AFTO Form 22, Page 1.

	LCN:
20. RECOMMENDED TM CHANGE	
21. SAVINGS/YR - DOLLARS	22. SAVINGS/YR-MANHOURS
23. EVALUATOR *(After evaluation, forward to supervisor)* NAME RANK PHONE RECEIPT DATE EVALUATION DATE E-MAIL Click to sign	24. EVALUATOR/SUPERVISOR *(After review, return to TO Management Activity)* NAME RANK PHONE REVIEW DATE E-MAIL Click to sign

25. DISPOSITION	26. DISPOSITION/REMARKS
☐ APPROVED ☐ DEFERRED ☐ ABEYANCE ☐ ADVISEMENT ☐ DUPLICATE ☐ DISAPPROVED ☐ OTHER	VERIFICATION REQUIRED BY ☐ PERFORMANCE ☐ DESK-TOP ANALYSIS 27. IDEA BENEFITS ARE ☐ INTANGIBLE ☐ TANGIBLE - AMOUNT
28. CONTINUATION	

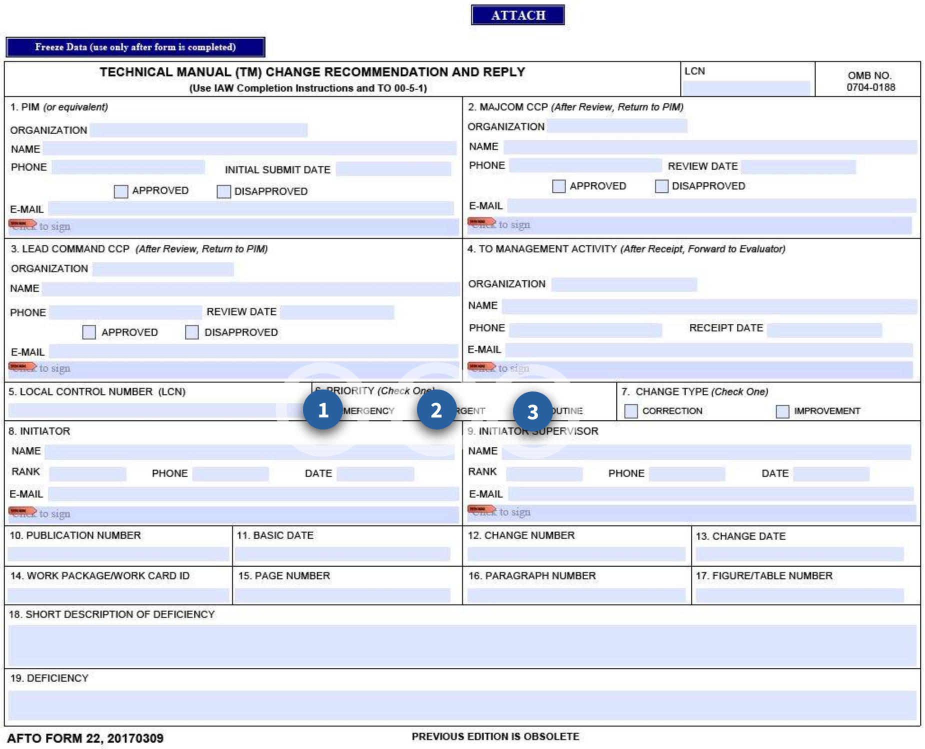
AFTO FORM 22, 20170309

ROLE	AFTO 22 ABBREVIATED COMPLETION INSTRUCTIONS*
WUC/LCN	WUC or LCN if applicable.
INITIATOR (Block 8)	• Complete blocks 6-7 and 10-20. Complete blocks 21, 22 and 27, if applicable. • Complete block 8 and digitally sign. Forward signed form and any required attachments to supervisor •
Initiator Supervisor (Block 9)	• Review blocks 6-7, 10-22 and 27 for validity, accuracy and completeness. Make necessary changes and enter corresponding comments in block 28. • Complete block 9, and digitally sign • Forward signed form and all attachments to PIM (or equivalent).
PIM (or Equivalent) (Block 1)	• Review blocks 6-7, 10-22 and 27 for validity, accuracy and completeness. Make appropriate changes and enter corresponding comments in block 28 • Enter Local Control Number in block 5. • Enter organization information and e-mail address (preferably an organizational e-mail) into block 1, 2, and 3. • See routing information, via AFNET at https://cs3.eis.af.mil/sites/00-TO-00-59/default.aspx • Enter the Initial Submit Date and digitally sign block 1 • Forward signed form, and all attachments, to the first reviewer • Enter dates of subsequent reviews in block 28. • Forward to the TO Management Activity in block 4. Note: Follow up with the TO Management Activity if a disposition is not received within 48 hours for an Emergency recommendation
MAJCOM and Lead Command CCP Reviewer (Blocks 2 and 3)	• Review blocks 6-7, 10-22 and 27 for validity, accuracy and completeness. Make appropriate changes and enter comments in block 28 • Complete block 2 or 3, as appropriate, including review date. Digitally sign • Returned signed form, and all attachments, to PIM (or equivalent) (block 1)
TO Management Activity (Block 4)	• Complete block 4 and digitally sign • Forward signed form, and all attachments, to evaluator (block 23)
Evaluator (Block 23)	• Enter receipt date in block 23 • Review blocks 6, 7, 10-22, and 27 for validity, accuracy and completeness. Make appropriate changes and enter corresponding comments in block 28 • Change type (block 7) will not be changed without the approval of the submitting MAJCOM CCP • Recommended disposition in block 25 • Provide appropriate verification and disposition remarks in block 26 • Complete block 23, including entering evaluation date, and digitally sign • Forward completed form and all attachments, to supervisor
Evaluator Supervisor (Block 24)	• Review recommended disposition, complete block 24 and digitally sign. • This authority may be delegated to the evaluator. If so delegated, document in block 28, along with the first level supervisor's name and e-mail address. • Return completed form to the TO Management Activity, initiator, PIM, and other activities.

*** FOR AFTO FORM 22 DETAILED COMPLETION INSTRUCTIONS, SEE TO 00-5-1**

Figure 2–13. AFTO Form 22, Page 3.

The three priorities for submitting an AFTO 22 are emergency, urgent, and routine. Below is a copy of the AFTO 22. Click on each number to learn about the different report priorities.



ATTACH

Freeze Data (use only after form is completed)

TECHNICAL MANUAL (TM) CHANGE RECOMMENDATION AND REPLY
(Use IAW Completion Instructions and TO 00-5-1)

LCN

OMB NO. 0704-0188

1. PIM *(or equivalent)*
ORGANIZATION
NAME
PHONE
INITIAL SUBMIT DATE
APPROVED
DISAPPROVED
E-MAIL

2. MAJCOM CCP *(After Review, Return to PIM)*
ORGANIZATION
NAME
PHONE
REVIEW DATE
APPROVED
DISAPPROVED
E-MAIL

3. LEAD COMMAND CCP *(After Review, Return to PIM)*
ORGANIZATION
NAME
PHONE
REVIEW DATE
APPROVED
DISAPPROVED
E-MAIL

4. TO MANAGEMENT ACTIVITY *(After Receipt, Forward to Evaluator)*
ORGANIZATION
NAME
PHONE
RECEIPT DATE
E-MAIL

5. LOCAL CONTROL NUMBER (LCN)

6. PRIORITY *(Check One)*
1 EMERGENCY
2 URGENT
3 ROUTINE

7. CHANGE TYPE *(Check One)*
CORRECTION
IMPROVEMENT

8. INITIATOR
NAME
RANK
PHONE
DATE
E-MAIL

9. INITIATOR SUPERVISOR
NAME
RANK
PHONE
DATE
E-MAIL

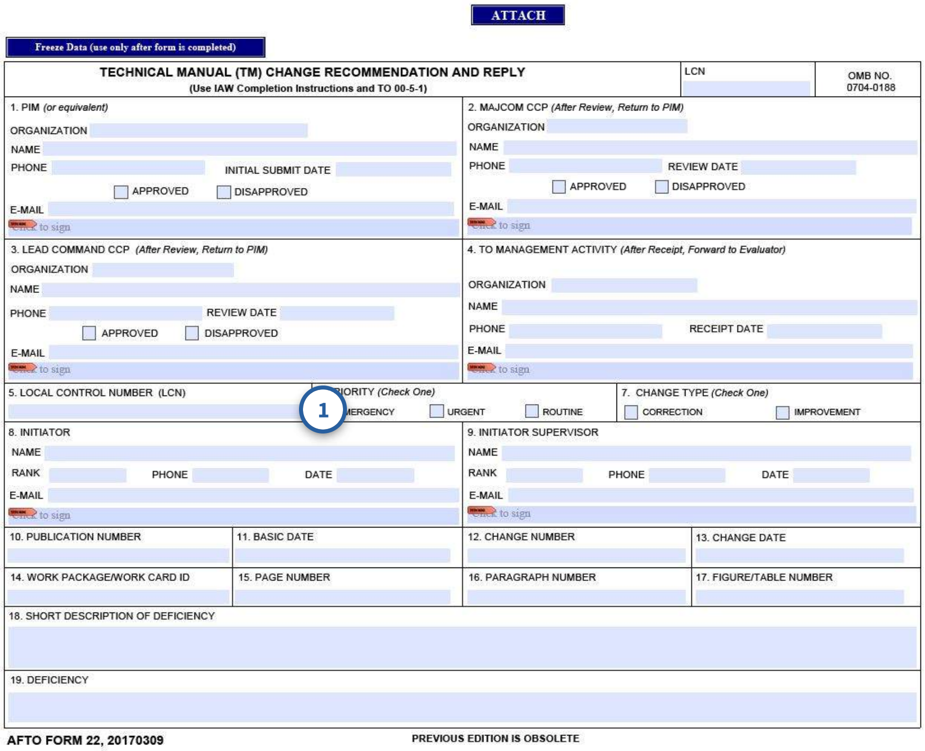
10. PUBLICATION NUMBER	11. BASIC DATE	12. CHANGE NUMBER	13. CHANGE DATE
14. WORK PACKAGE/WORK CARD ID	15. PAGE NUMBER	16. PARAGRAPH NUMBER	17. FIGURE/TABLE NUMBER

18. SHORT DESCRIPTION OF DEFICIENCY

19. DEFICIENCY

AFTO FORM 22, 20170309

PREVIOUS EDITION IS OBSOLETE



ATTACH

Freeze Data (use only after form is completed)

TECHNICAL MANUAL (TM) CHANGE RECOMMENDATION AND REPLY
(Use IAW Completion Instructions and TO 00-5-1)

LCN

OMB NO. 0704-0188

1. PIM *(or equivalent)*
ORGANIZATION
NAME
PHONE
INITIAL SUBMIT DATE
APPROVED
DISAPPROVED
E-MAIL
Click to sign

2. MAJCOM CCP *(After Review, Return to PIM)*
ORGANIZATION
NAME
PHONE
REVIEW DATE
APPROVED
DISAPPROVED
E-MAIL
Click to sign

3. LEAD COMMAND CCP *(After Review, Return to PIM)*
ORGANIZATION
NAME
PHONE
REVIEW DATE
APPROVED
DISAPPROVED
E-MAIL
Click to sign

4. TO MANAGEMENT ACTIVITY *(After Receipt, Forward to Evaluator)*
ORGANIZATION
NAME
PHONE
RECEIPT DATE
E-MAIL
Click to sign

5. LOCAL CONTROL NUMBER (LCN)

1

RIORITY *(Check One)*
MERGENCY
URGENT
ROUTINE

7. CHANGE TYPE *(Check One)*
CORRECTION
IMPROVEMENT

8. INITIATOR
NAME
RANK
PHONE
DATE
E-MAIL
Click to sign

9. INITIATOR SUPERVISOR
NAME
RANK
PHONE
DATE
E-MAIL
Click to sign

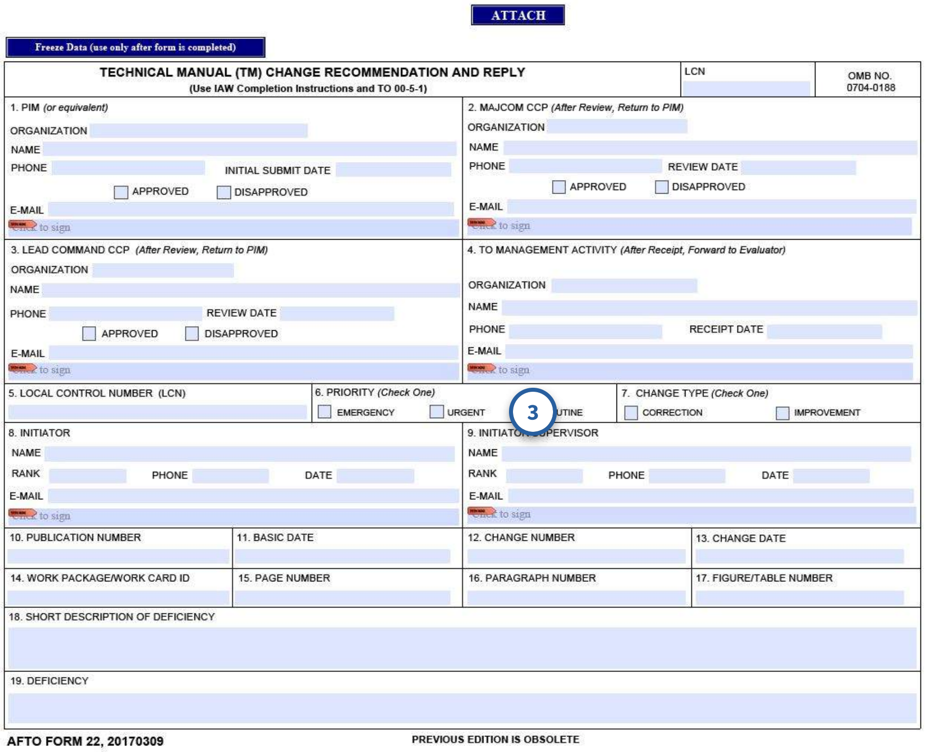
10. PUBLICATION NUMBER
11. BASIC DATE
12. CHANGE NUMBER
13. CHANGE DATE
14. WORK PACKAGE/WORK CARD ID
15. PAGE NUMBER
16. PARAGRAPH NUMBER
17. FIGURE/TABLE NUMBER
18. SHORT DESCRIPTION OF DEFICIENCY
19. DEFICIENCY

AFTO FORM 22, 20170309
PREVIOUS EDITION IS OBSOLETE

Emergency

Emergency reports require immediate action to correct a TO deficiency which, if not corrected, WOULD result in a fatality or serious injury to personnel, or extensive damage or destruction of equipment or property.

This type of recommendation demands immediate action. The TCM will issue either an interim TCTO or rapid action change within 48 hours (72 hours for a work stoppage) of receiving the AFTO 22.



ATTACH

Freeze Data (use only after form is completed)

TECHNICAL MANUAL (TM) CHANGE RECOMMENDATION AND REPLY
(Use IAW Completion Instructions and TO 00-5-1)

LCN | OMB NO. 0704-0188

1. PIM *(or equivalent)*
ORGANIZATION
NAME
PHONE | INITIAL SUBMIT DATE
APPROVED | DISAPPROVED
E-MAIL
Click to sign

2. MAJCOM CCP *(After Review, Return to PIM)*
ORGANIZATION
NAME
PHONE | REVIEW DATE
APPROVED | DISAPPROVED
E-MAIL
Click to sign

3. LEAD COMMAND CCP *(After Review, Return to PIM)*
ORGANIZATION
NAME
PHONE | REVIEW DATE
APPROVED | DISAPPROVED
E-MAIL
Click to sign

4. TO MANAGEMENT ACTIVITY *(After Receipt, Forward to Evaluator)*
ORGANIZATION
NAME
PHONE | RECEIPT DATE
E-MAIL
Click to sign

5. LOCAL CONTROL NUMBER (LCN)

6. PRIORITY *(Check One)*
EMERGENCY | URGENT | 3 ROUTINE

7. CHANGE TYPE *(Check One)*
CORRECTION | IMPROVEMENT

8. INITIATOR
NAME
RANK | PHONE | DATE
E-MAIL
Click to sign

9. INITIATOR'S SUPERVISOR
NAME
RANK | PHONE | DATE
E-MAIL
Click to sign

10. PUBLICATION NUMBER | 11. BASIC DATE | 12. CHANGE NUMBER | 13. CHANGE DATE

14. WORK PACKAGE/WORK CARD ID | 15. PAGE NUMBER | 16. PARAGRAPH NUMBER | 17. FIGURE/TABLE NUMBER

18. SHORT DESCRIPTION OF DEFICIENCY

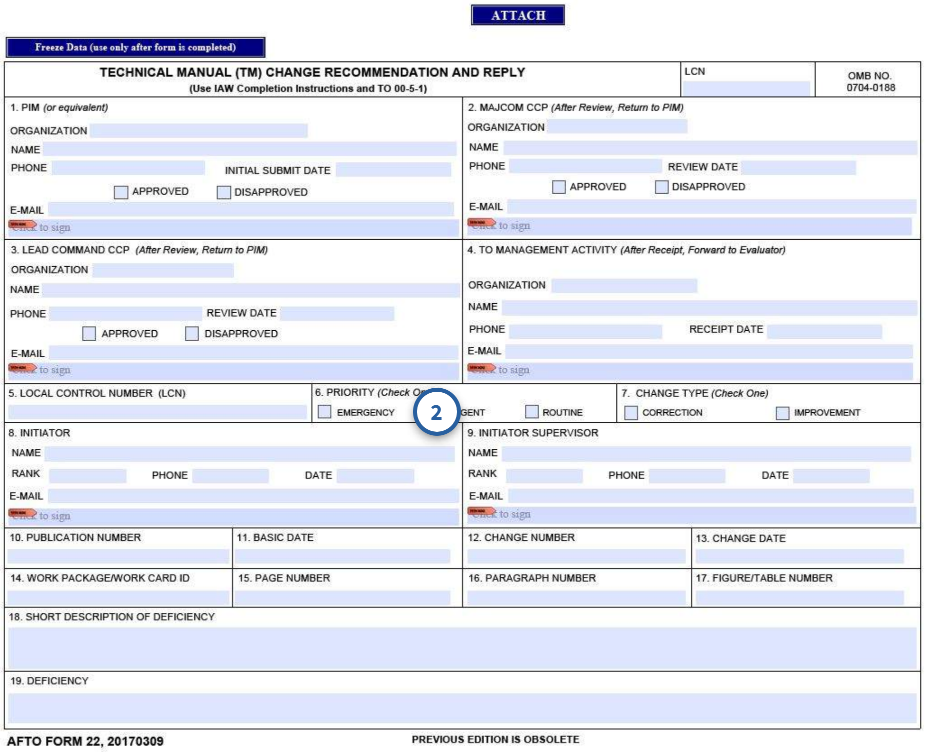
19. DEFICIENCY

AFTO FORM 22, 20170309 | PREVIOUS EDITION IS OBSOLETE

Routine

Routine reports require action on TO deficiencies which do not fall into emergency or urgent categories. These can even include minor typographical errors, word omissions or printer errors, but only if they cause a critical misinterpretation or affect the meaning of instructions that would impede the mission.

The TCM will respond to all routine reports within 45 calendar days. Generally, updates will be published (including printing and distribution) by the responsible agency within one year of receipt of the report.



ATTACH

Freeze Data (use only after form is completed)

TECHNICAL MANUAL (TM) CHANGE RECOMMENDATION AND REPLY
(Use IAW Completion Instructions and TO 00-5-1)

LCN

OMB NO. 0704-0188

1. PIM (or equivalent)
ORGANIZATION
NAME
PHONE
INITIAL SUBMIT DATE
APPROVED
DISAPPROVED
E-MAIL
to sign

2. MAJCOM CCP (After Review, Return to PIM)
ORGANIZATION
NAME
PHONE
REVIEW DATE
APPROVED
DISAPPROVED
E-MAIL
to sign

3. LEAD COMMAND CCP (After Review, Return to PIM)
ORGANIZATION
NAME
PHONE
REVIEW DATE
APPROVED
DISAPPROVED
E-MAIL
to sign

4. TO MANAGEMENT ACTIVITY (After Receipt, Forward to Evaluator)
ORGANIZATION
NAME
PHONE
RECEIPT DATE
E-MAIL
to sign

5. LOCAL CONTROL NUMBER (LCN)

6. PRIORITY (Check O
EMERGENCY
2
GENT
ROUTINE

7. CHANGE TYPE (Check One)
CORRECTION
IMPROVEMENT

8. INITIATOR
NAME
RANK
PHONE
DATE
E-MAIL
to sign

9. INITIATOR SUPERVISOR
NAME
RANK
PHONE
DATE
E-MAIL
to sign

10. PUBLICATION NUMBER

11. BASIC DATE

12. CHANGE NUMBER

13. CHANGE DATE

14. WORK PACKAGE/WORK CARD ID

15. PAGE NUMBER

16. PARAGRAPH NUMBER

17. FIGURE/TABLE NUMBER

18. SHORT DESCRIPTION OF DEFICIENCY

19. DEFICIENCY

AFTO FORM 22, 20170309

PREVIOUS EDITION IS OBSOLETE

Urgent

Urgent recommendations require action on a TO deficiency which, if not corrected, COULD cause personnel injury or damage to equipment or property.

All TCTO deficiencies are submitted as an urgent priority. Identification of, or replacements for, Environmental Protection Agency (EPA) hazardous material and ozone depleting chemicals are submitted as urgent as well.

Click on each priority before moving forward in the lesson.

Procedures

As with any other digital form you use, always be sure that you're using the most current version of the AFTO 22 by visiting http://www.e-publishing.af.mil. Since each recommended improvement must be evaluated individually, only one improvement per AFTO Form 22 is usually submitted. An exception to this is when the same error occurs more than once in the same TO.

If this is the case, identify the location of each error on a single AFTO 22, and an AFTO 22 that is submitted for an inspection manual (–6 TO) can also include all locations that need to be changed. Brief summaries of the deficiency and recommended change are required in the narrative section of the form. Complete the

AFTO 22 digitally and submit via e-mail. Your reviewing authority will handle it from there andprovide you feedback on the process as it occurs.

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the categories and types of standard publications.

1. In regard to a supplement's parent publication, a supplement must meet what key condition?

Type your answer here

SUBMIT

2. What is the main difference between a policy directive and policy memorandum?

Type your answer here

SUBMIT

2

3. Who are operating instructions directive and mandatory for?

Type your answer here

SUBMIT

3

4. What rules apply when posting temporary visual aids?

Type your answer here

SUBMIT

4

5. If a publication you are looking for contains sensitive information that should not be disclosed to the general public, where could you obtain an electronic copy?

Type your answer here

SUBMIT

Answer all of the self-test questions above before moving on to the technical order system questions.

Click here to answer the self-test questions pertaining to the description of technical order system.

1. What publications must be used whenever maintenance is being performed?

Type your answer here

SUBMIT

5

2. What is the main difference between operations and maintenance technical order and methods and procedures technical orders?

Type your answer here

SUBMIT

6

3. What information does a list of applicable publications index provide?

Type your answer here

SUBMIT

7

4. What are time compliance technical orders used for?

Type your answer here

SUBMIT

8

5. How can you identify immediate action time compliance technical orders?

Type your answer here

SUBMIT

9

6. What action must occur if an urgent time compliance technical order is not complied with before its time limit?

Type your answer here

SUBMIT

10

7. What has to happen before a preliminary technical order becomes an operations and maintenance technical order?

Type your answer here

SUBMIT

11

8. What type of information would you find in a category 32 technical order?

Type your answer here

SUBMIT

12

9. Describe the command and response technique.

Type your answer here

SUBMIT

13

10. Inspection work cards take precedence over technical orders for what type of criteria?

Type your answer here

SUBMIT

14

11. How do you proceed if you find a technical order is incorrect and you cannot perform the task correctly?

Type your answer here

SUBMIT

Answer all of the self-test questions above before moving on to the typical technical order format.

Click here to answer the self-test questions pertaining to the typical technical order format.

1. How does knowing when a technical order was last changed help you?

Type your answer here

SUBMIT

2. Why is it important to review technical order changes prior to a dispatch?

Type your answer here

SUBMIT

3. When is the safety summary section of the technical order reviewed?

Type your answer here

SUBMIT

17

4. How will following along in diagrams while reading system descriptions help you?

Type your answer here

SUBMIT

18

5. In a four-column format checkout procedure, how do you proceed if you get a normal indication?

End the operational check.

Annotate the corrective action.

Perform the next step.

Annotate the malfunction.

SUBMIT

6. Where should you start trouble analysis if you were not referred to a specific step by another procedure?

At the beginning of the procedural process.

Alarm indications section.

○ The first series of steps.

SUBMIT

20

7. What procedure must be performed prior to actually performing a maintenance or adjustment procedure?

Type your answer here

SUBMIT

21

8. When can you use schematic diagrams for troubleshooting?

Type your answer here

SUBMIT

22

9. How can you identify changed content on a technical order page?

Type your answer here

SUBMIT

Answer all of the self-test questions above before moving on to the technical order improvement report

Click here to answer the self-test questions pertaining to the technical order improvement report.

1. An Air Force Technical Order AFTO Form 22 is submitted for what reason?

Type your answer here

SUBMIT

23

2. What should quality assurance do if an AFTO Form 22 is categorized incorrectly or is inaccurate?

Type your answer here

SUBMIT

24

3. What must a technical content manager issue within 48 hours of receiving an AFTO Form 22 in the emergency category?

Type your answer here

SUBMIT

25

4. When would typographical errors be corrected with an AFTO Form 22?

Type your answer here

SUBMIT

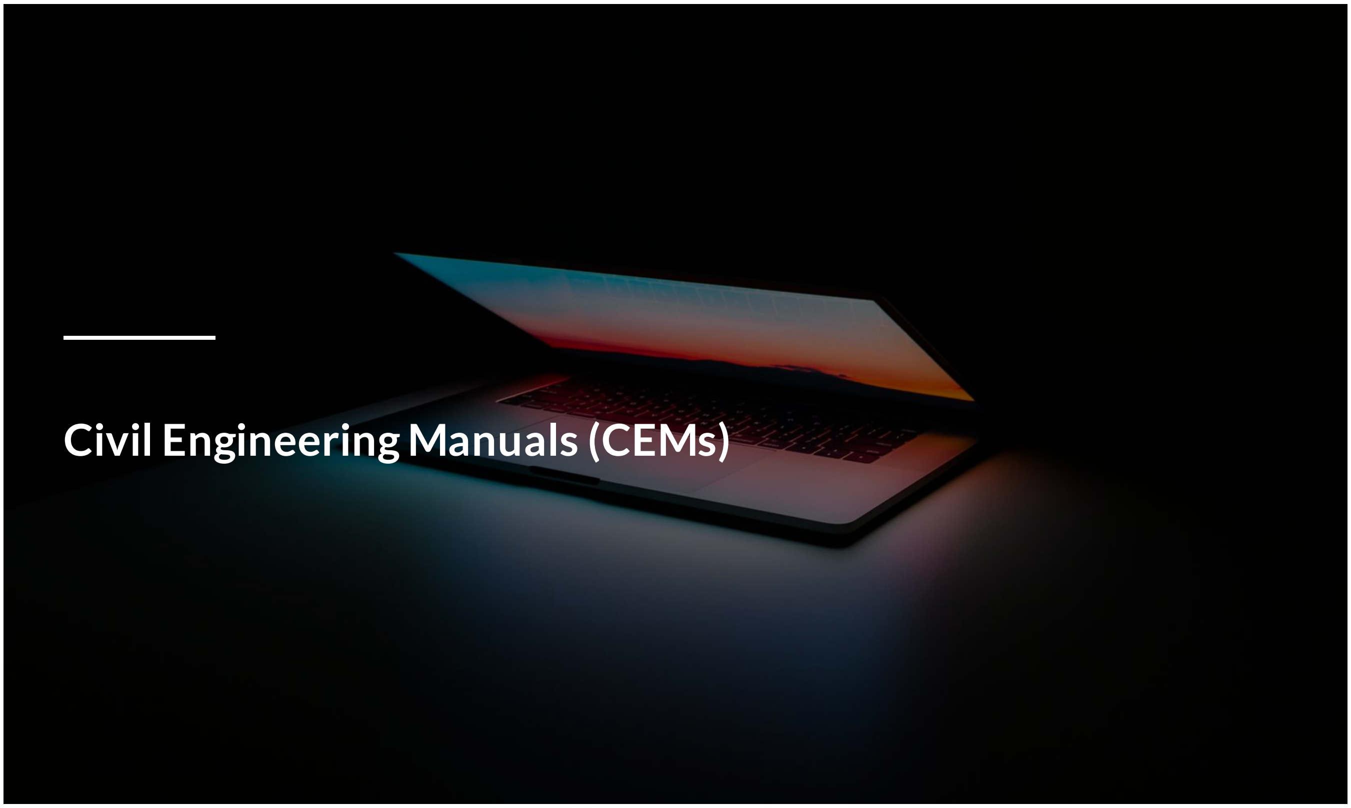
26

5. What information is required in the narrative section of the AFTO Form 22?

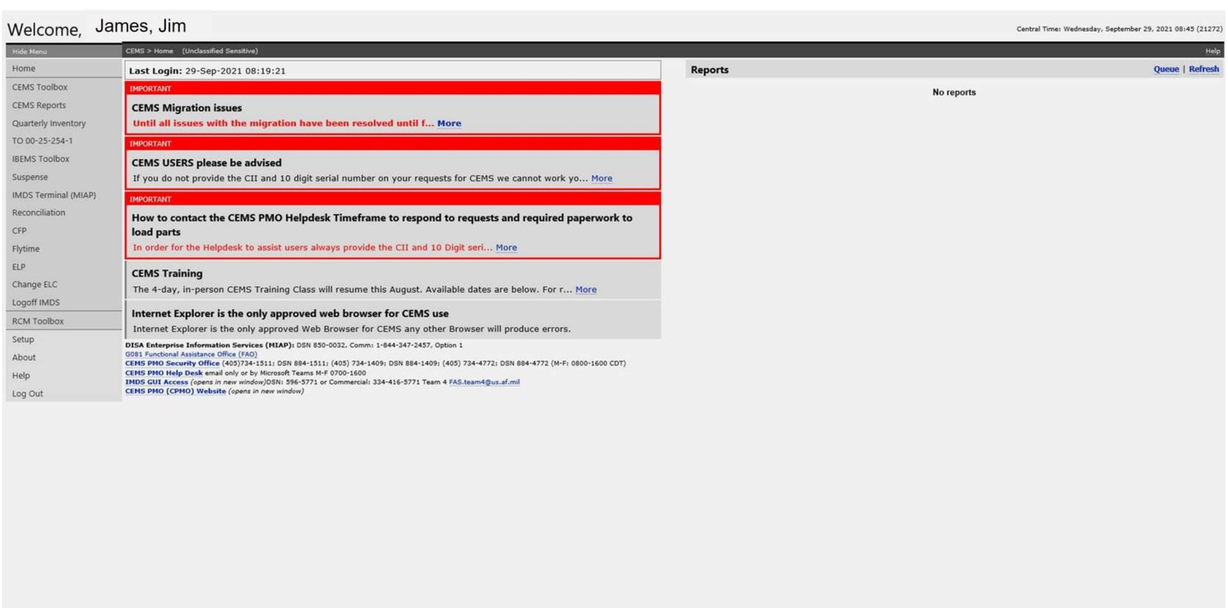
Type your answer here

SUBMIT

Complete all of the self-test questions above before moving on to learn about Civil Engineering Manuals (CEMs).



Civil Engineering Manuals (CEMs)



CEMs Home screen

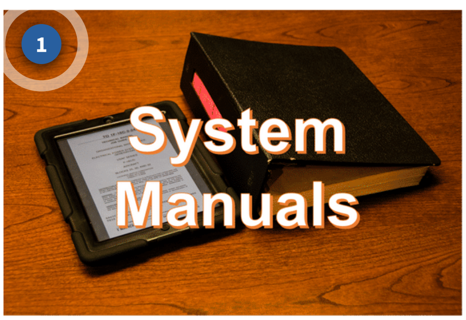
Real property installed equipment (RPIE) is government-owned equipment physically attached to or built into an Air Force facility. Normally, RPIE is manufactured for commercial use, but is procured through the military construction efforts of various contractors.

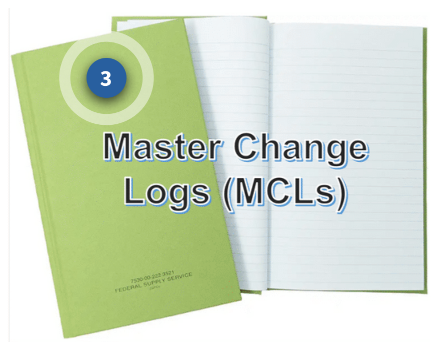
In this section, we will discuss the civil engineering manuals (CEM) that provide O&M instructions for RPIE. Although similar in format to TOs, CEMs are written to cover RPIE at a specific wing. We will also discuss the purpose and specific procedures for submitting an AFGSC Form 272, *RPIE Improvement Report*.

Description of Civil Engineering Manuals

Knowing where to find the information you need to perform a task or order a replacement part is essential. The information you gain in this lesson will help you understand the different types of CEMs. You will also learn the CEM numbering system, which can save a lot of time when trying to find information on the component you are working with.

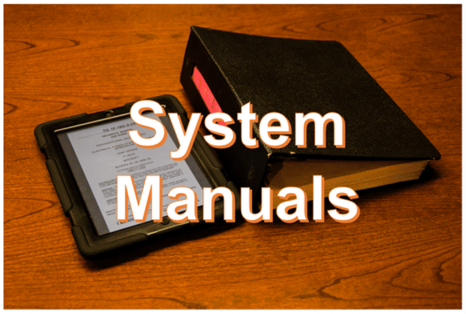
Below are the different types of CEMs. The three are system manuals, equipment manuals, and master change logs (MCL). The system and equipment manuals are closely related and are used together in most cases. An MCL is the CEM version of a TCTO and serves the same purpose. Click on each number to learn more about each manual.

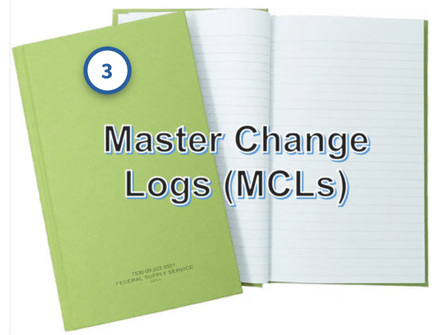




System Manuals

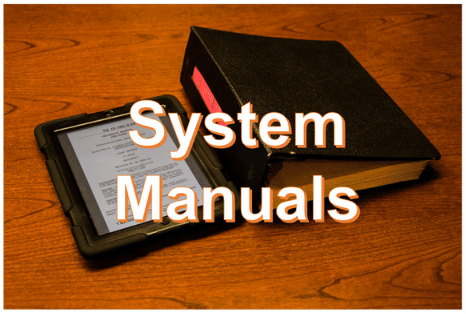
System manuals provide instructions for O&M of an RPIE system, and are laid out similar to TOs. System manuals are prepared for experienced maintenance personnel, meaning that standard maintenance practices are not included. Detailed information specific to a component, unit, or subsystem is located in the equipment manual, but may also appear in the system manual, and this is where you will find particular information about a component.

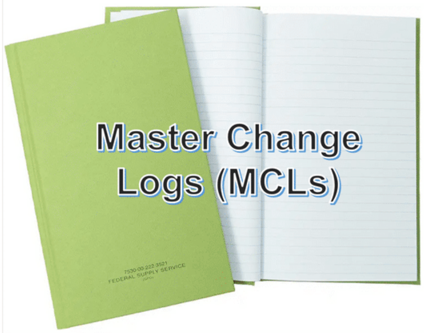




Master Change Logs (MCL)

An MCL serves the same purpose as a TCTO. While there are not different levels of MCLs like there are for TCTOs, the urgency is clearly communicated through command channels if needed. MCLs will contain all of the information needed to complete a modification or OTI, including what parts to procure and how to procure them, and the step-by-step procedures for performing the modification or inspection. An MCL's progress is tracked in the Integrated Maintenance Data System (IMDS) exactly like a TCTO, and command authorities will be formally notified via a completion package when an MCL is completed.





Equipment Manuals

You should recall that the system manual is used for O&M of an entire system. When you isolate a fault to a component and need further information on that component to make a better determination, you need to refer to the equipment manual. The combination of system and equipment CEMs provides complete coverage for the RPIE system. Most manufacturers prepare operational and maintenance data sheets on the equipment they build. The Air Force saves money by using this available data. Think of an equipment manual as a collection of commercial owner's manuals. Since equipment manuals contain the commercial data provided by the manufacturer, they are also a good place to research replacement parts. Not all, but most, of the commercial data in the equipment manual will provide replacement part numbers. If they do not have this information, at least you have a place for materiel control personnel to look when helping you research needed parts.

Click on each number before moving forward to learn about the identifying numbers of the CEMs.

Identifying Numbers

You may have noticed that the identifying numbers of the CEMs are similar to those of TOs. Each CEM number is divided into three or more parts, and each part is separated by a dash. Let's look at the parts of the identifying numbers for CEM 21–SM80A–2–21–2, Launch Facility Power Generation and Distribution and CEM 35R–1–451–2, Power Generation and Distribution.

NOTE: A system manual uses a two-digit number to identity the system, while the equipment manual has a three–digit number. The equipment manuals are not coded to the ICBM or model. Remember, the equipment manuals are written for the commercial equipment.

This brief lesson provided a description of the types of CEMs as well as what their identifying numbers mean, which will come in handy when you need to select the correct book for performing maintenance.

CEM Identifying Number Parts			
System manual: Type 21–SM80A–2–21–2		**Equipment Manual:** Type 35R–1–451–2	
Element	**Identifies**	**Element**	**Identifies**
CEM 21	System manual (Minuteman)	35R	Equipment Manual (Minuteman)
-SM80A	The missile model, design, and series	-1	The missile model, design, and series
-2	The type of manual (that is., Description, Operation, and Maintenance)	-451	The weapon system: (Power Generation and Distribution)
-21	A specific system (that is, Power generation and distribution)	-2	The wing or squadron (Malmstrom) **This does not correspond directly to the wing number.**
-2	The wing or squadron (Malmstrom) **This does not correspond directly to the wing number.**		

CEM Identifying Number Parts

Format of Civil Engineering Systems and Equipment Manuals

CEMs use a standardized format; however, the format of a system manual is very different than that of an equipment manual. Understanding the differences and understanding how to use each type of manual will help you locate and interpret information quickly and efficiently. Let's see how both manuals are organized.

Format of a Typical System Manuals

You will find the format of most system manuals is much like the format of an O&M TO, but some system manuals may not have every section described here. The first pages of a typical system manual include a title page, a table of contents, an introduction, a list of effective pages, illustrations, tables, and safety precautions that all serve the same function as they do in a TO. We will focus on the individual sections of CEM 21–SM80A–2–21–2 VI, *Launch Facility Power Generation and Distribution*.

Below are the most common format and the CEM you will use the most in your career. Click on each (+) sign to learn more about each item.

Description

The description sections of a CEM and TO are very similar and contain comprehensive information on how the system works. This is extremely useful information that every technician should review often, and reading the description while following a schematic or diagram can save hours of headache and needless troubleshooting.

Component Lists –

A key part of this section is the component lists. Every CEM will have a list of most components, complete with their location, where the illustration of the component is located, and information to help you order replacement parts. Another key piece of information in a component list is the individual sequence number, which is used to locate items in the equipment manual. It is important to note that researching replacement parts can be somewhat difficult because not all components are on these lists.

Illustrations –

There is a section of the CEM for diagrams, but the description section contains broader illustrations. You might find block diagrams to show how an overall system is connected, or you might see some of the major components of the system illustrated. This information will also help you to know how the system operates.

Review the content above before moving on to learn about special tools and test equipment.

Special Tools and Test Equipment

This section contains instructions for operating particular pieces of equipment, as well as a table showing all the special tools, test equipment, and consumables used throughout the manual. You will normally be referred to this table when a procedure directs you to use a certain item. The table will explain what a tool or piece of equipment is used for and provide information on how to order them.

Like the description section, there are illustrations here as well. These illustrations show you particular pieces of equipment and provide additional information on how to fabricate locally manufactured tools or equipment.

Operation and Checkout

The operation and checkout section includes tables that show step-by-step lists of procedures on how to perform a checkout of a subsystem or component. A CEM checkout procedure is written in a three-column format (fig 2–14), where you perform the step and look for a normal indication. An abnormal indication will not be listed—you will perform the corrective action if you receive any indication other than the normal indication.

These corrective actions can be somewhat vague at times. Sometimes they will refer you to other troubleshooting or maintenance procedures, while at other times they provide specific maintenance steps to perform to obtain a normal indication. If it does not refer you to a procedure, it is acceptable to perform the corrective action while complying with standard maintenance practices.

Table 3-20. LFSB DEU Water Temperature Switch Gage Checkout and Adjustment

STEP	PROCEDURE	NORMAL INDICATION	CORRECTIVE ACTION
	CAUTION Water temperature switch gage indicating needle has 24 vdc applied at all times. When adjusting contacts, do not short allen head adjustment screws to ground. **NOTE** All lights reflected in the NORMAL INDICATION column are located on the MPP unless otherwise indicated.		
1.	Set DEU switch on MPP to DISABLE.	DEU .... ON DEU INHIBITED .... ON STBY PWR FAIL .... ON AUTO .... OFF	Replace MPP (table 5-1).
2.	Set DEU immersion heater circuit breaker No. 1 in panel LDN to OFF and attach WARNING tag.		
3.	(Allis-Chalmers only) Drain DEU coolant to a point below water temperature switch gage sensor.		
4.	Remove water temperature switch gage sensor from DEU.	When sensor cools, MAIN FUEL TANK LOW ... ON	Rotate low temperature contact adjustment screw clockwise until light comes ON. Check and repair wiring. Replace MPP (table 5-1).

Figure 2–14. CEM three-column format.

Troubleshooting

This section provides procedures for troubleshooting some of the more common problems that you might encounter, and most procedures are grouped into tables to relate problems with different systems. You can turn directly to those tables to find your problem if another procedure does not tell you to do so.

The 21-SM80A–2–21–2 also includes a fault matrix (fig 2–15) and flow chart, which will guide you to a particular problem. Not all CEMs contain a fault matrix. If yours doesn't, you will simply go to the troubleshooting index and select a trouble number that aligns with the indicators on the MPP. Let's use fault #1 (far left) as an example. An "X" in the column means that the corresponding light on the MPP is illuminated. Therefore, if you were standing in front of the MPP at this site, the following indicator lights would be illuminated:

- **MPP POWER ON**
- **COMMERCIAL POWER FAIL**
- **STANDBY POWER AVAILABLE**
- **STANDBY POWER ON**

These indicators would tell you that the MPP is powered on, that commercial power has failed, and that the diesel electric unit (DEU) is providing power to the site. It is worth noting that you would already have known most of this was happening due to the fact that the diesel generator would have been running when you arrived on site. CEMs without a fault matrix will still provide you with a fault or trouble number, they just won' t have the visual representation as pictured in figure 2–15.

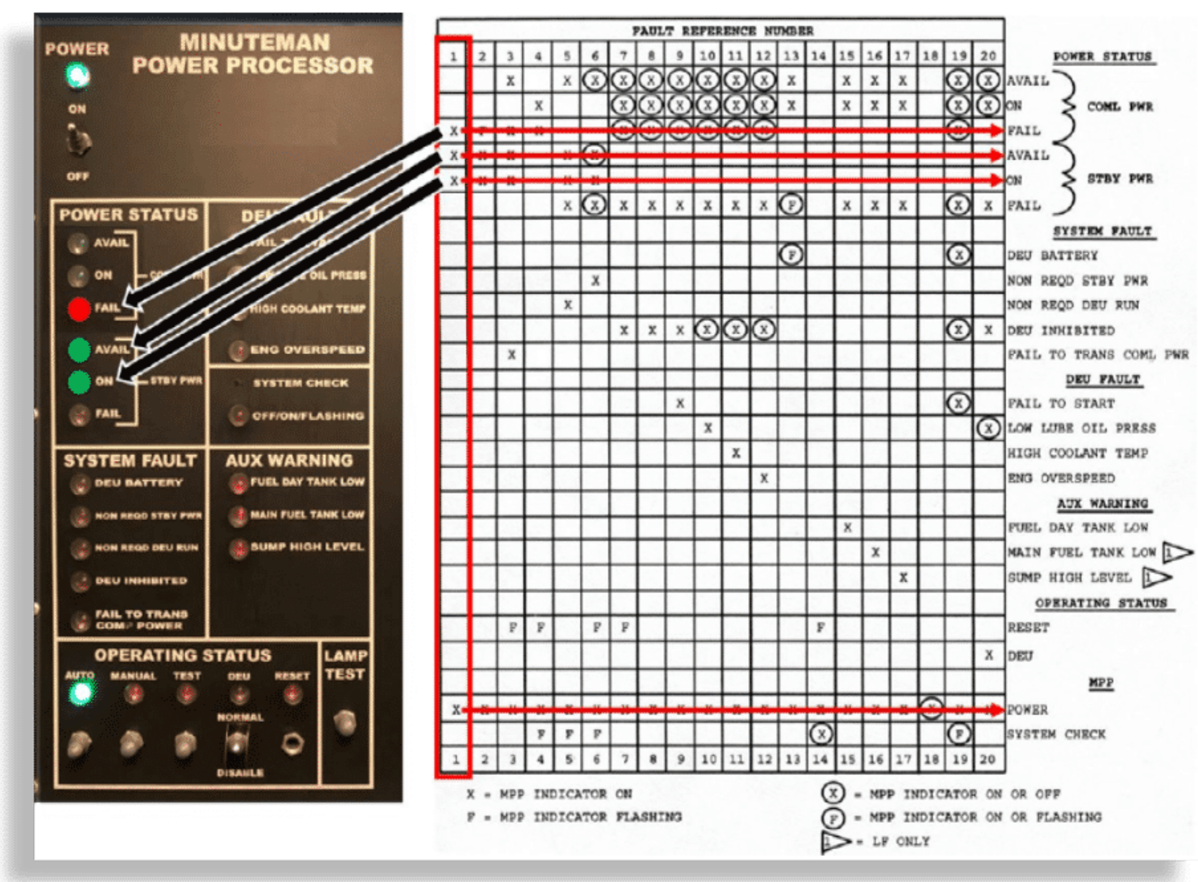


Figure 2–15. Fault matrix.

Maintenance

The maintenance section of the CEM gives instructions for adjusting or replacing components. Some system manuals will not have this section, so you might have to refer to the equipment manual. This CEM has a component replacement and adjustment table that includes the name of the component and where it is located. The table also tells you what power source the facility should be running on, and what mode of operation the system needs to be in. For example, the procedure directs you to disable the DEU because you don't want it to start up while you are performing maintenance on it. Refer to the paragraph listed for a replacement or adjustment and continue with your maintenance. Figure 2–16 shows a snapshot of the component replacement and adjustment table.

This section also contains illustrations that accompany most maintenance procedures. Sometimes, they are placed with the procedure and sometimes they are at the end of the section.

Table 5-1. LCEB and LFSB Component Replacement and Adjustment (Continued)

COMPONENT	LOCATION	ESTABLISH OPERATION MODE FOR MAINTENANCE AND TURN OFF FACILITY ELECTRICAL POWER AS FOLLOWS:		REPLACE PER PARA	ADJ PER PARA/ TBL
Overtemperature Switch	LCEB Diesel Engine	Commercial Power	Set DEU switch on MPP to DISABLE	5-35	TBL 3-8
Overtemperature Switch (Penn Controls Model A70JG-1)	LCEB Diesel Engine	Commercial Power	Set DEU switch on MPP to DISABLE	5-35	TBL 3-9
Radiator (Allis-Chalmers)	LCEB/LFSB Diesel Engine	Commercial Power	Set DEU switch on MPP to DISABLE	5-31	N/A
Radiator (Cummins)	Diesel Engine	Commercial Power	Set DEU switch on MPP to DISABLE	5-78	N/A
Radiator Sight Glass (Cummins)	LFSB Diesel Engine	Commercial Power	Set DEU switch on MPP to DISABLE	5-90	N/A
Relay K1	LCEB/LFSB Automatic Switching Unit	No Power	Obtain sufficient battery-powered lighting	5-8	N/A

Figure 2–16. Component replacement and adjustment table.

Diagrams

The diagrams section contains all of the required schematics and wiring diagrams. There are extensive wiring diagrams to help you to replace components or verify correct wiring while you troubleshoot.

Of special note, unlike a TO, you are authorized to use CEM schematics for troubleshooting without using written procedures from the checkout or troubleshooting sections. One caution on this—you need to follow the procedures first. The complexity of the system means that it can essentially have an infinite number of faults, and it would therefore be impossible to write a CEM that had troubleshooting procedures for every problem that you could encounter. Always remember that your schematics are available as a backup when the procedures are exhausted or have led you astray. When you are performing step-by-step procedures, always trace the steps you are being told to perform through in the schematic so that you can understand how and why the CEM is directing you to check something. The troubleshooting steps might be leading you astray if the written steps in the book don't sync up to the schematic.

Civil Engineering Manual Changes

You may find errors in a CEM that need to be corrected, and there is a good chance that changes have been made to any given CEM that you are using. Here is how to identify them.

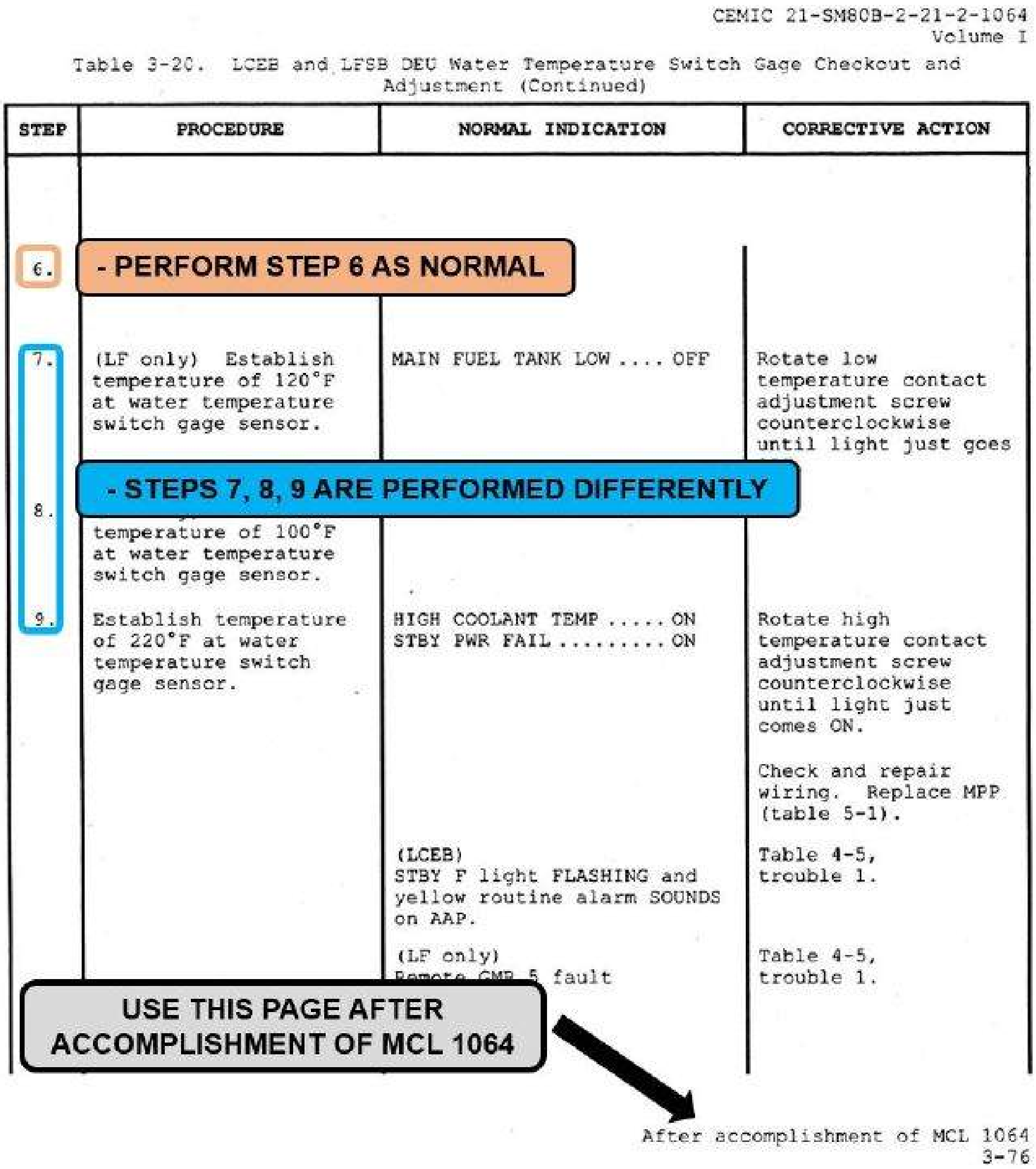
Changed Pages

The list of effective pages is always updated when a CEM is changed. You can see what change each page is on, and there will be a black vertical bar next to any text that has changed on that page.

Interim Changes

Instead of changing a page, sometimes an interim change is posted to the CEM until the book is updated again. A page preceding the title page will show you what interim changes are posted to the CEM, along with the reason for the change and a list of pages added to the CEM by a particular interim change.

If you come across an interim change page opposite the page you are working from, be sure to review it to see if you need to perform the steps on the original page or the ones on the changed page. The bottom of the change page tells you when you should use the change page instead of the original, and figures 2–17 and 2–18 show you an example of this. You can refer to the CEM interim change civil engineering manual interim change (CEMIC) cover page in the front of the CEM to see what the MCL is related to (in this example, diesel replacement program). If the diesel has been replaced on the site you are working on, perform the steps on the change page. If the site you are working at still has an older model diesel, you would use the procedures as normal.



CEMIC 21-SM80B-2-21-2-1064
Volume I

Table 3-20. LCEB and LFSB DEU Water Temperature Switch Gage Checkout and Adjustment (Continued)

STEP	PROCEDURE	NORMAL INDICATION	CORRECTIVE ACTION
6.			
7.	(LF only) Establish temperature of 120°F at water temperature switch gage sensor.	MAIN FUEL TANK LOW .... OFF	Rotate low temperature contact adjustment screw counterclockwise until light just goes
8.	temperature of 100°F at water temperature switch gage sensor.		
9.	Establish temperature of 220°F at water temperature switch gage sensor.	HIGH COOLANT TEMP ..... ON STBY PWR FAIL .... ON	Rotate high temperature contact adjustment screw counterclockwise until light just comes ON.
			Check and repair wiring. Replace MPP (table 5-1).
		(LCEB) STBY F light FLASHING and yellow routine alarm SOUNDS on AAP.	Table 4-5, trouble 1.
		(LF only) Remote GMB 5 fault	Table 4-5, trouble 1.

After accomplishment of MCL 1064
3-76

Figure 2–17. Interim change page.

CEM INTERIM CHANGE

1. TITLE Power Generation and Distribution	4. CEMIC NO. 21-SM80B-2-21-2-1064 (Vol I)
	5. CEMIC ORIGINAL ISSUE DATE 1 February 2009
2. CEM NO. 21-SM80B-2-21-2, Vol I	6. CEMIC CHANGE NO. 1
3. CEM BASIC DATE 15 February 1996	7. CEMIC CHANGE DATE 1 October 2009

8. INSERT ATTACHED CHANGE/ADDED PAGES AS FOLLOWS:

DISTRIBUTION STATEMENT: Distribution authorized to U.S. Government agencies and their contractors for administrative or operational use, dated 1 October 2009. Other requests for this document shall be referred to AFSPC MES, 250 S. Peterson Blvd., Peterson AFB CO 80914-4554.

DESTRUCTION NOTICE--Destroy by any method that will prevent disclosure of contents or reconstruction of the document.

FILING INSTRUCTIONS:

File this CEMIC after hard copy Change 20 has been filed. File CEM Interim Change Notice(s) sequentially in front of latest CEM Change Notice with highest CEMIC number on top. File interim change pages to face affected hard copy pages.

INTERIM CHG PAGE NO.	INTERIM CHG NO.	INTERIM CHG PAGE NO.	INTERIM CHG NO.
v thru vi	0	5-101	0
xi	0	5-103	0
xiA	0	6-25(6-26 Blank)	0
1-7	0	*6-37(6-38 Blank)	1
1-17	0		
1-20 thru 1-21	0		
*1-22	1		
3-24	0		
3-26 thru 3-33	0		
3-35 thru 3-36	0		
3-75 thru 3-77	0		
4-16 thru 4-17	0		
4-45	0		
5-24	0		
5-31 thru 5-32	0		
5-100	0		

9. REMARKS:

10. FINAL RELEASE AUTHORITY		11. VERIFICATION REQUIREMENTS
		☐
		☐ ADDITIONAL VERIFICATION REQUIRED
		☐ VERIFIED AT
		X VERIFICATION NOT REQUIRED

12. REASON FOR CHANGE:

a. To reflect configuration changes required after accomplishment of MCL 1064 (MAF LCEB Diesel Engine Replacement).

b. To incorporate MES Data (1241).

Shows you what the MCL is that would require you to use interim change page

Figure 2–18. Interim change cover page.

Below are the two major components of the equipment manual are the vendor data reference tables and the commercial data. Click on each tab before moving forward in the lesson.

Format of Equipment Manuals

Equipment manuals are a collection of manufacturer's instructions and commercial data sheets for system components, and all equipment manuals have the same layout. The introduction section of the manual is similar to the system manual, and it contains a title page, complete with basic date and change date. It has a list of effective pages showing every page in the manual and what change number it is on.

VENDOR DATA REFERENCE TABLE	COMMERCIAL DATA

The vendor data reference tables show you every component in the system, with the exception of common hardware. You will find a description of the component, part information (part numbers, national stock numbers, or model numbers) and the page number in the equipment manual where you can find the part. The vendor data reference table in the equipment manual and the component list in a system manual both contain sequence numbers. When looking for a specific part in the equipment manual, refer to the list of components from the system manual first. Match the sequence number on the component list in the system manual to the sequence number on the vendor data reference table to help you find the correct part. Figure 2–19 shows you part of a vendor data reference table with the sequence number.

VENDOR DATA REFERENCE TABLE (Continued)

NOMENCLATURE AND DESCRIPTION	SEQUENCE OR REFERENCE DESIGNATOR NO.	IDENTIFICATION NO. (NSN, MODEL, P/N, ETC.)	VENDOR OR MFR CAGE NO. (H4/H8)	PAGE NO.
REGULATOR, Oil Level, DEU	3201-02J 3204-02J	Model RB Model RAB NSN 6680002363996	1PAMO	D-3
REGULATOR, Voltage	3201-18B 3204-08B	P/N 90-39100-100 P/N W10817950GVREG	97520	B-3, R-4, R-7 thru R-11, R-14
RELAY, Auxiliary Cranking (R7)		P/N 4513207 (replace with P/N SAW-4415)		A-205, A-283 A-328C
RELAY, K1		P/N KRP11DG-24VDC	77342	P-39
RELAY SOCKET, K1		P/N 27E122 NSN 5935007638699	77342	P-40

VENDOR DATA REFERENCE TABLE

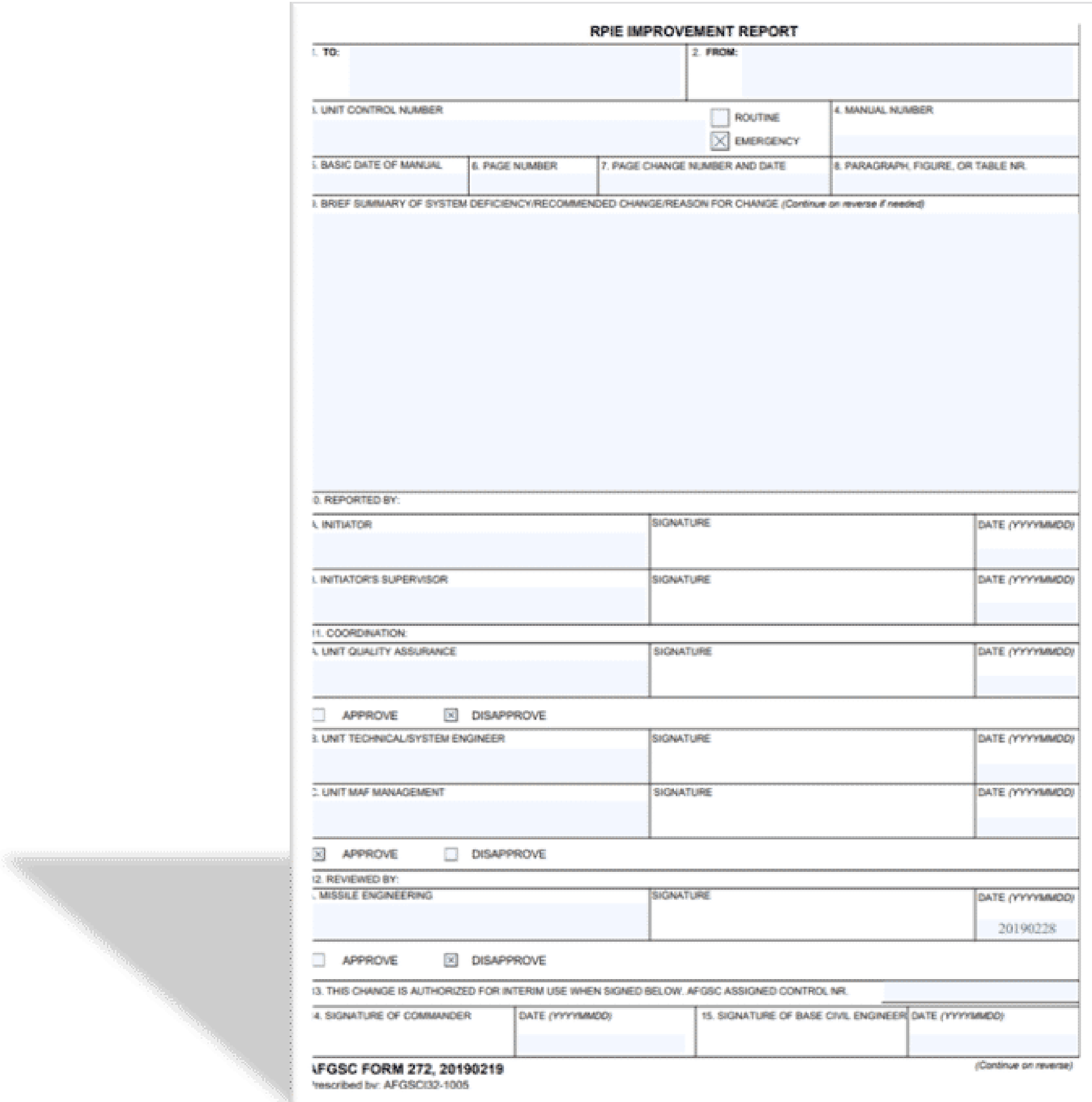
COMMERCIAL DATA

The component information you are looking for in an equipment manual will be in the commercial data portion of the CEM. This data is arranged alphabetically for ease of use. Using the vendor data reference table and sequence numbers, you should be able to find the data sheets you are looking for without any problems.
This lesson focused on the format and different parts of a CEM, and this information will aid you in finding the information you need as fast as possible.

Click on each tab of the content above before moving on t learn about submitting a CEMs improvement report.

Submitting Civil Engineering Manual Improvement Reports

You may find information in a CEM that is incorrect, unclear, incomplete, or improperly sequenced. The AFGSC Form 272 gives you a way to correct or add information. This lesson will focus on the purpose and procedures for submitting an AFGSC 272.



RPIE IMPROVEMENT REPORT

1. TO:
2. FROM:
3. UNIT CONTROL NUMBER
ROUTINE
EMERGENCY
4. MANUAL NUMBER
5. BASIC DATE OF MANUAL
6. PAGE NUMBER
7. PAGE CHANGE NUMBER AND DATE
8. PARAGRAPH, FIGURE, OR TABLE NR.
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*
10. REPORTED BY:
A. INITIATOR | SIGNATURE | DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR | SIGNATURE | DATE *(YYYYMMDD)*
11. COORDINATION:
A. UNIT QUALITY ASSURANCE | SIGNATURE | DATE *(YYYYMMDD)*
APPROVE DISAPPROVE
B. UNIT TECHNICAL/SYSTEM ENGINEER | SIGNATURE | DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT | SIGNATURE | DATE *(YYYYMMDD)*
APPROVE DISAPPROVE
12. REVIEWED BY:
A. MISSILE ENGINEERING | SIGNATURE | DATE *(YYYYMMDD)* 20190228
APPROVE DISAPPROVE
13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR.
14. SIGNATURE OF COMMANDER | DATE *(YYYYMMDD)* | 15. SIGNATURE OF BASE CIVIL ENGINEER | DATE *(YYYYMMDD)*

AFGSC FORM 272, 20190219
Prescribed by: AFGSCI32-1005
(Continue on reverse)

AFGSC Form 272, *RPIE Improvement Report*

Purpose

CEM changes are limited to those essential for weapon system reliability, safety, and protection of personnel and equipment. Changes must be consistent with good judgment, hardware, demand, technician experience, and economy, and CEM changes will not be made to temporarily bypass system components or to change the content of a CEM MCL. The chief missile engineer will ensure close review of recommendations for changes and agree with only those that suggest realistic changes. Submission of an AFGSC 272 is required in the following circumstances:

1. Modifications to missile facilities and equipment that require changes to operating or maintenance instructions, or changes to system descriptions and illustrations contained in an existing CEM.

2. Replacement of equipment or components with items functionally identical to the original item. The item may be of different manufacture date or model, which outdates the manufacturer's brochures or commercial data referenced in existing systems or equipment manuals.

3. Improvements required for emergency war order, emergency procedures, and safety of personnel and equipment.

4. Recommendations to improve clarity or completeness of O&M instructions.

5. Recommendations to correct errors in original data to match the actual as-built configuration of equipment.

Recommendations for CEM improvements may be submitted by anyone.

What You Should Do Beforehand

Before you take the time to complete an AFGSC 272, it would be in your best interest to talk to your supervisor and your local QA evaluators to find out if a change for this content has already been submitted.

Procedures

The following procedures will provide you with a step-by-step walk through on how to complete an AFGSC Form 272, and always ensure that you have the latest version of the form from the Air Force E–Publishing website mentioned earlier. These instructions can also be found on the rear of the form. Reference figures 2–20 and 2–21 as we go along. The "To" block on the latest version of this form has been auto-filled for you. If a newer version of the form is released after this CDC is published, you will need to obtain this information by calling the phone number listed in the instructions on the rear of the form.

RPIE IMPROVEMENT REPORT

1. TO: AFGSC MES/MESI 250 S. PETERSON BLVD PETERSON AFB CO 80914-4554	2. FROM:

3. UNIT CONTROL NUMBER	☐ ROUTINE ☐ EMERGENCY	4. MANUAL NUMBER

5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.

9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*

10. REPORTED BY:

A. INITIATOR	SIGNATURE	DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR	SIGNATURE	DATE *(YYYYMMDD)*

11. COORDINATION:

A. UNIT QUALITY ASSURANCE	SIGNATURE	DATE *(YYYYMMDD)*

☐ APPROVE ☐ DISAPPROVE

B. UNIT TECHNICAL/SYSTEM ENGINEER	SIGNATURE	DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT	SIGNATURE	DATE *(YYYYMMDD)*

☐ APPROVE ☐ DISAPPROVE

12. REVIEWED BY:

A. MISSILE ENGINEERING	SIGNATURE	DATE *(YYYYMMDD)*

☐ APPROVE ☐ DISAPPROVE

13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC MES ASSIGNED CONTROL NR.

14. SIGNATURE OF COMMANDER	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER	DATE *(YYYYMMDD)*

AFGSC FORM 272, 20100119 *(Continue on reverse)*

Figure 2–20. AFGSC Form 272 (front).

RPIE IMPROVEMENT REPORT *(Continued)*

16. REMARKS

RPIE IMPROVEMENT REPORT GENERAL INSTRUCTIONS

a. Block 1: Completed and coordinated form will be mailed to the address in Block 1 or E-mailed to AFGSC MES/MESI. E-mail address can be obtained by calling DSN 692-2720 or DSN 692-2815.

b. Block 2 (Initiator): Enter the Technical Order Distribution Office (TODO) or local Technical Manual Change Monitor office symbol and completed mailing address.

c. Block 3 (Missile Engineer): Enter local control number and mark appropriate block for Routine or Emergency Improvement Report.

d. Block 4 (Initiator): Enter the complete Civil Engineer Manual (CEM) or Civil Engineer Manual Interim Change (CEMIC).

e. Block 5 (Initiator): Enter the basic date appearing on the title page of the CEM. The basic date for a CEMIC is in Block 5 of the cover page for the CEMIC.

f. Block 6 (Initiator): Enter the page number(s) affected.

g. Block 7 (Initiator): If the deficiency involves a page identified with a change date, enter the number and date of the change for the page involved.

h. Block 8 (Initiator): Enter the specific paragraph(s), figure(s), or table(s) number(s) affected.

i. Block 9 (Initiator): Enter whether the AF Form 272 was submitted as a correction or as an IDEA program suggestion. Enter a concise description of the system deficiency, recommended change(s) to eliminate the deficiency or improve the condition, and reason for change. If new vendor or manufacturer brochures are required for equipment manuals, procure one original and submit as an attachment. If necessary, continue in Remarks block or on bond paper, as required. Attach all additional paperwork to Improvement Report.

j. Blocks 10A and 10B (Initiator or Initiator's Supervisor): Enter Name, Grade, Duty Phone, Office Symbol of Initiator or Initiator's Supervisor. Initiator shall sign and date form. Initiator's Supervisor shall review AFGSC Form 272 then sign and date form. Comments may be added in Remarks block.

k. Blocks 11A and 11B (Quality Assurance or Engineering): Enter Name, Grade, and Duty Phone of Quality Assurance or Engineering representative that performed review. Quality Assurance representative shall ensure that local procedures have been complied with for review of AFGSC Form 272 then sign and date form. Engineering representative shall sign and date form. Comments may be added in Remarks block.

l. Block 11C is only used when improvement report affect 21-SM80-10 Series CEMs. Wing Missile Alert Facility Management Representative will review form then enter Name, Grade, Office Symbol, Duty Phone. Representative shall sign and date form. Comments may be added in Remarks block.

m. Block 12A (Missile Engineering): Enter Name, Grade, and Duty Phone of Missile Engineering that performed review. Representative shall sign and date form. Comments may be added in Remarks block.

n. Blocks 13 thru 15: The RPIE Improvement Report may also authorize interim use of a recommended improvement as a local CEMIC. Authorization for interim use requires AFGSC MES (Commander MES or designated representative), Wing Commander (or designated representative), and Base Civil Engineer Commander (or designated representative) approval. Enter AFGSC MES assigned control in Block 13. Wing Commander (or designated representative) and Base Civil Engineer (or designated representative) shall sign and date in Blocks 14 and 15. For further information on local CEMICs refer to AFGSCI32-1005 (CEMs).

o. Block 16: Remarks block may be used as additional space to continue Block 9, to add comments concerning improvement Report, or for any additional comments requiring inclusion on Improvement Report. If additional space is necessary, ensure one copy of any attachment(s) is included with Improvement

AFGSC FORM 272, 20100119 *(REVERSE)*

Figure 2–21. Air Force Global Strike Command Form 272 (rear). Block 1 – To.

In this section, you will click on each number located on the top section of the AFGSC Form 272 to learn what information must be included in the specific blocks.

RPIE IMPROVEMENT REPORT			
1. TO: 1		2. FROM: 2	
3. UNIT CONTROL NUMBER 3		☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER 4
5. BASIC DATE OF MANUAL 5	6. PAGE NUMBER 6	7. PAGE CHANGE NUMBER AND DATE 7	8. PARAGRAPH, FIGURE, OR TABLE NR. 8
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)* 9			

RPIE IMPROVEMENT REPORT			
1. TO: 1		2. FROM:	
3. UNIT CONTROL NUMBER	☐ ROUTINE ☒ EMERGENCY		4. MANUAL NUMBER
5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*			

Block 1 – To

The "To" block on the latest version of this form has been auto-filled for you. If a newer version of the form is released after this CDC is published, you will need to obtain this information by calling the phone number listed in the instructions on the rear of the form.

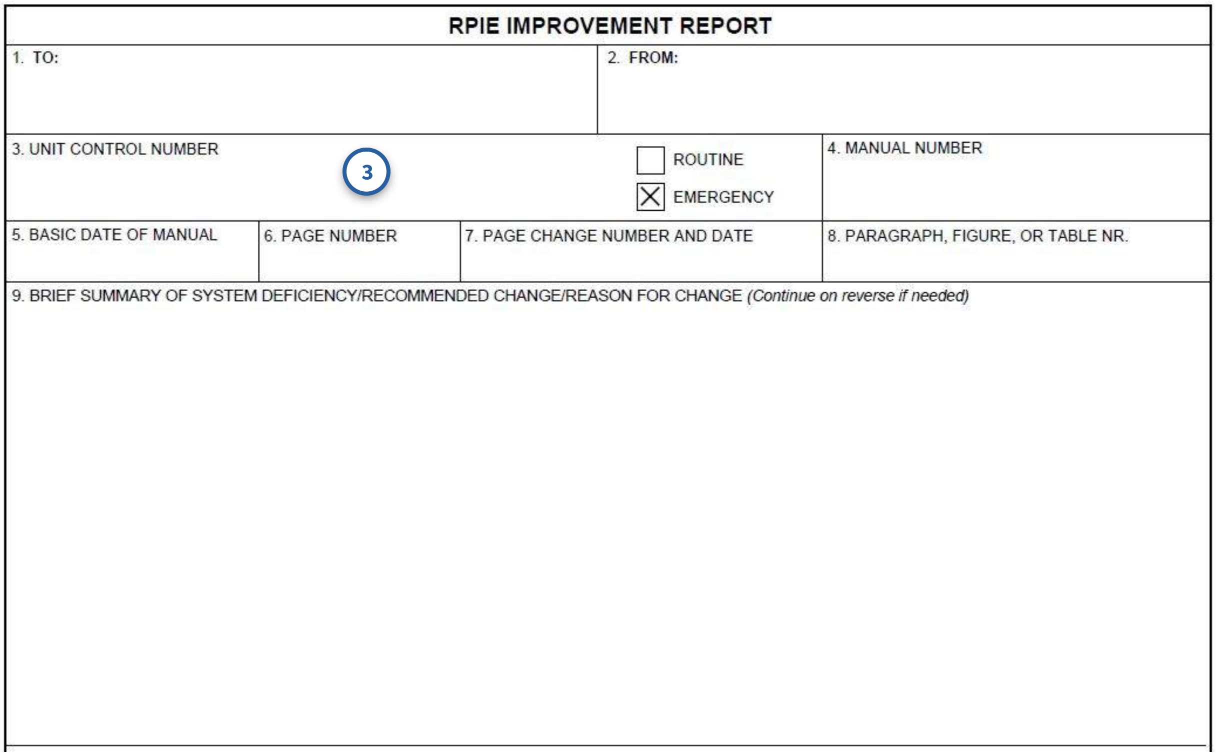
Block 1: Completed and coordinated form will be mailed to AFGSC/A4C,, Bldg 5541,, Barksdale AFB, LA 71110 or E-mailed to AFGSC A4CP workflow (afgsc.a7pworkflow@us.af.mil).

RPIE IMPROVEMENT REPORT			
1. TO:		2. FROM: 2	
3. UNIT CONTROL NUMBER		☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER
5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*			

Block 2 – From

Since you are initiating the report, you might think that your name would be in the "From" block. However, per the instructions on the rear of the form, this is actually the technical order distribution office (TODO) or technical manual change monitor (TMCM). Whichever your organization uses, you will need to obtain their office symbol and mailing address, and enter the information into block 2.

Block 2 (Initiator): Enter the Technical Order Distribution Office (TODO) or local Technical Manual Change Monitor office symbol and completed mailing address.



RPIE IMPROVEMENT REPORT

1. TO:	2. FROM:

3. UNIT CONTROL NUMBER	☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER

5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.

9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*

Block 3 – Unit Control Number

The “unit control number” block is completed by the missile engineer, which will be done after you have authored the AFGSC 272, and your supervisor and QA have both approved it. The missile engineer will add a local control number for tracking the change, as well as decide whether the change should be submitted as routine or emergency.

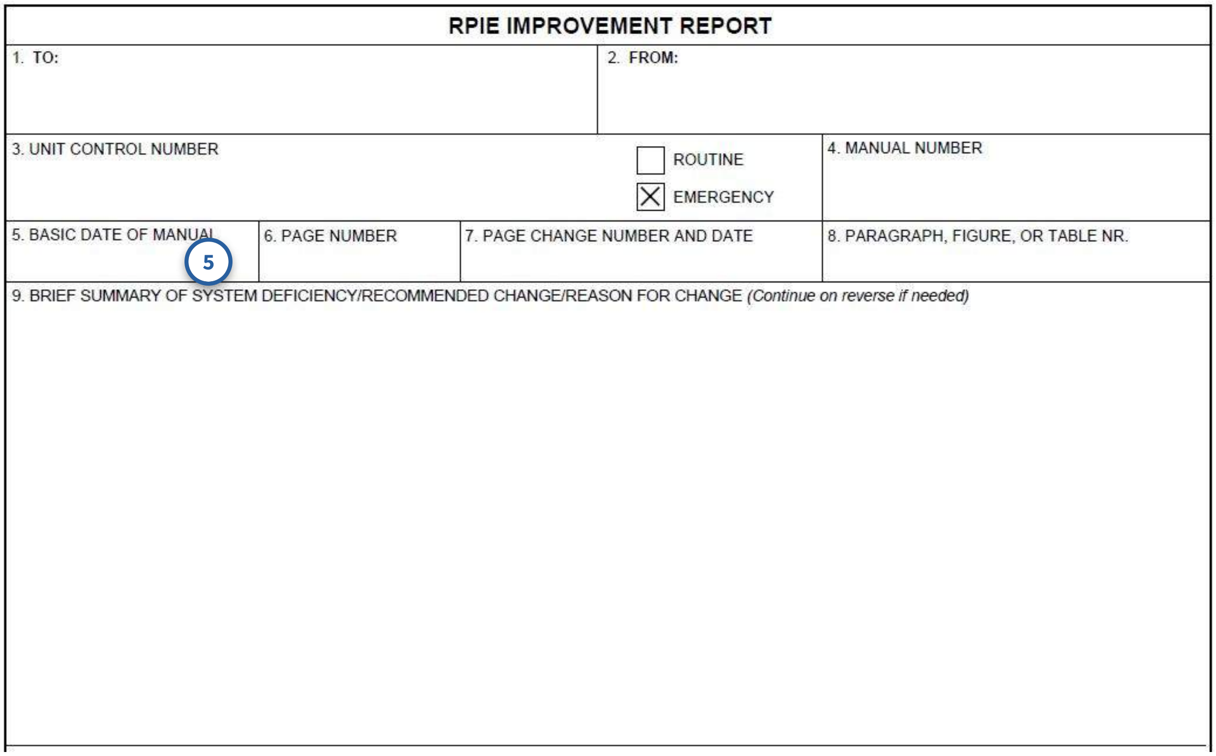
Block 3 (AFGSC): Enter local control number and mark appropriate block for Routine or Emergency Improvement Report.

RPIE IMPROVEMENT REPORT			
1. TO:		2. FROM:	
3. UNIT CONTROL NUMBER		☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER 4
5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*			

Block 4 – Manual Number

The manual number block is where you will enter the complete number of the CEM or CEMIC for which you are submitting the change. This information is extremely easy to find, as it is at the top corner of nearly every printed page in the CEM. Be sure to provide the entire CEM number. For example, "CEM 21–SM80A–2–21–2 Volume II."

Block 4 (Initiator): Enter the complete Civil Engineer Manual (CEM) or Civil Engineer Manual Interim Change (CEMIC).



RPIE IMPROVEMENT REPORT

1. TO:	2. FROM:

3. UNIT CONTROL NUMBER	☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER

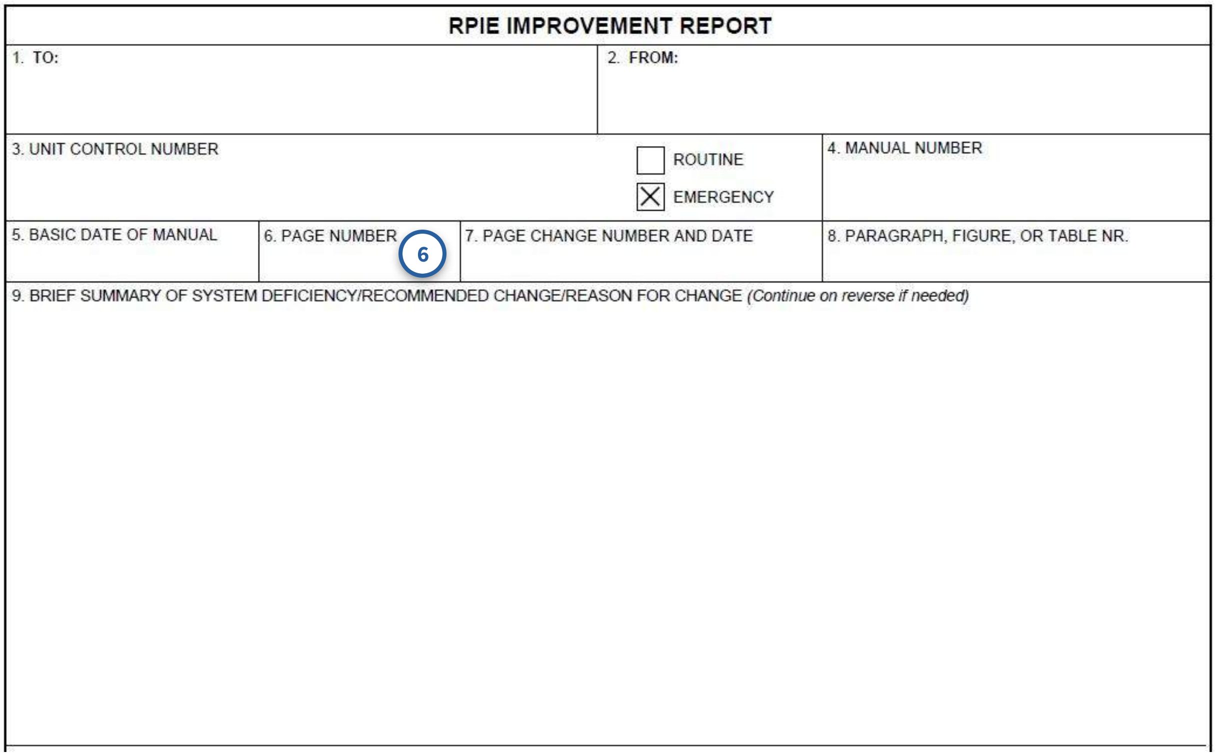
5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.

9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*

Block 5 – Basic Date of Manual (DOM)

Block 5 is where you will enter the basic date of the manual. For a CEM, this information can be found on the title page, which is typically the very first page you will see when you open up the front cover. For a CEMIC, this is the date in block 5 of the first page.

Block 5 (Initiator): Enter the basic date appearing on the title page of the CEM. The basic date for a CEMIC is in Block 5 of the cover page for the CEMIC.

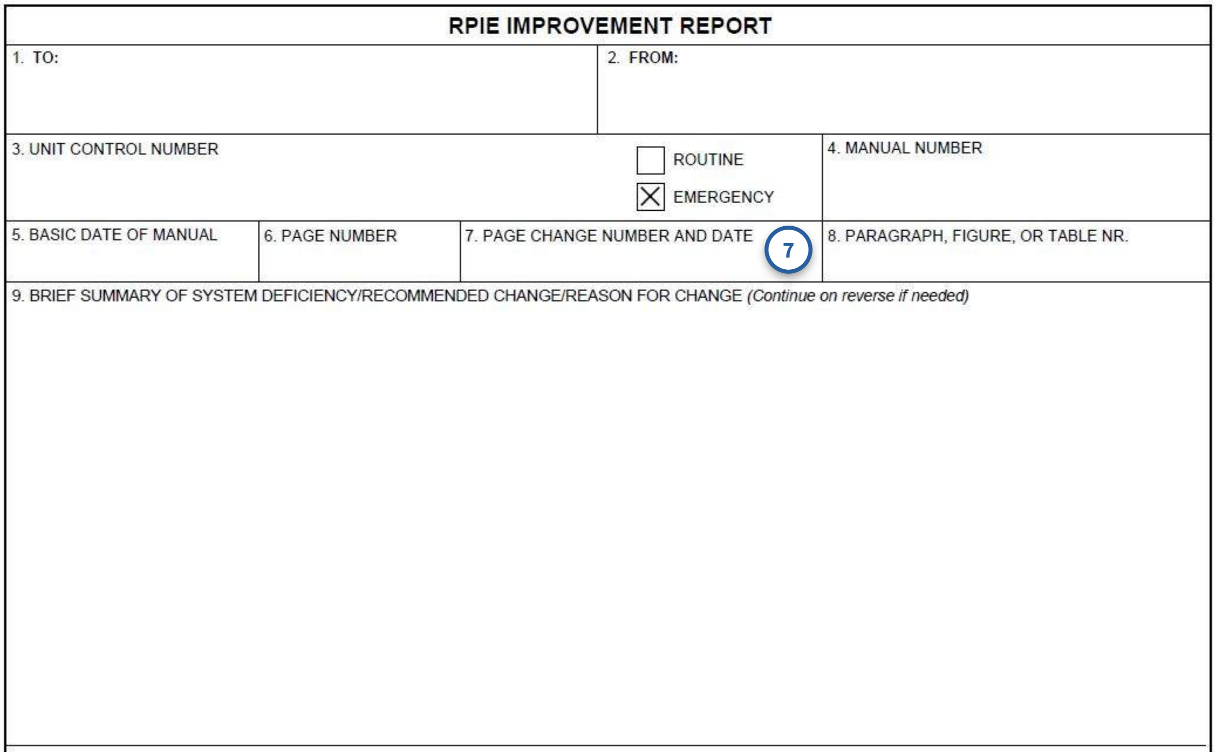


RPIE IMPROVEMENT REPORT			
1. TO:		2. FROM:	
3. UNIT CONTROL NUMBER		☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER
5. BASIC DATE OF MANUAL	6. PAGE NUMBER 6	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*			

Block 6 – Page Number

This is where you will enter the page, or range of pages, that will be affected by the change. If you're only trying to change one step, this will be a single page number. If you are trying to modify an entire procedure, list the entire range of pages that will be affected.

Block 6 (Initiator): Enter the page number(s) affected.



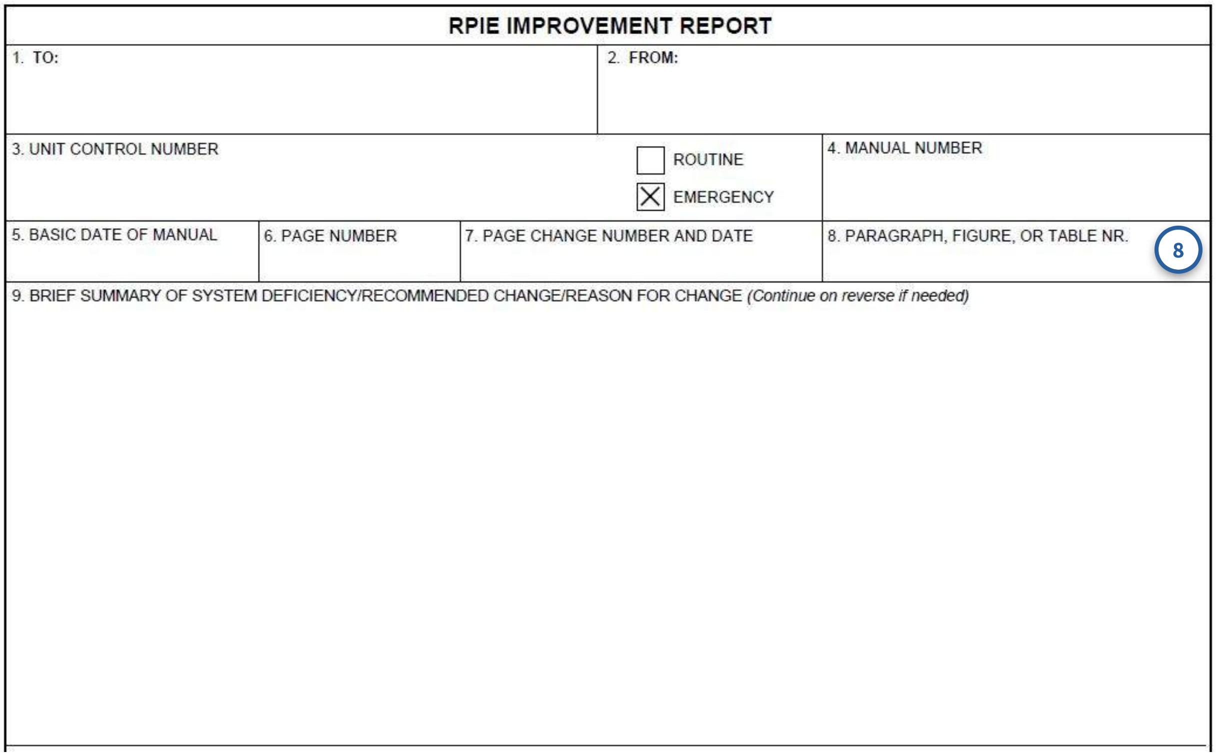
RPIE IMPROVEMENT REPORT

1. TO:			2. FROM:	
3. UNIT CONTROL NUMBER		☐ ROUTINE ☒ EMERGENCY		4. MANUAL NUMBER
5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE 7		8. PARAGRAPH, FIGURE, OR TABLE NR.
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*				

Block 7 – Page Change Number and Date

Block 7 is only used when you are proposing a change to a page or pages that have already been changed in the past. If the word Change appears in the bottom margin of the page or pages, followed by a number, put this information in block 7. Next, you will need to find the date of the change. One of the first few pages in the front of the CEM will be a page that lists all of the change numbers and their dates. Find the date that corresponds to the change number on the bottom of the page, and include it in block 7.

Block 7 (Initiator): If the deficiency involves a page identified with a change date, enter the number and date of the change for the page involved.



RPIE IMPROVEMENT REPORT

1. TO:		2. FROM:	
3. UNIT CONTROL NUMBER		☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER
5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR. 8
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*			

Block 8 – Paragraph, Figure, or Table Number

Block 8 is where you will list the exact number of the paragraph, figure, or table that you are trying to change. The format of paragraph, figure, and table numbers are all the same. Make sure to specify which of the three it is. The paragraphs below explain where to find each.

Block 8 (Initiator): Enter the specific paragraph(s), figure(s), or table(s) number(s) affected.

Paragraph Number

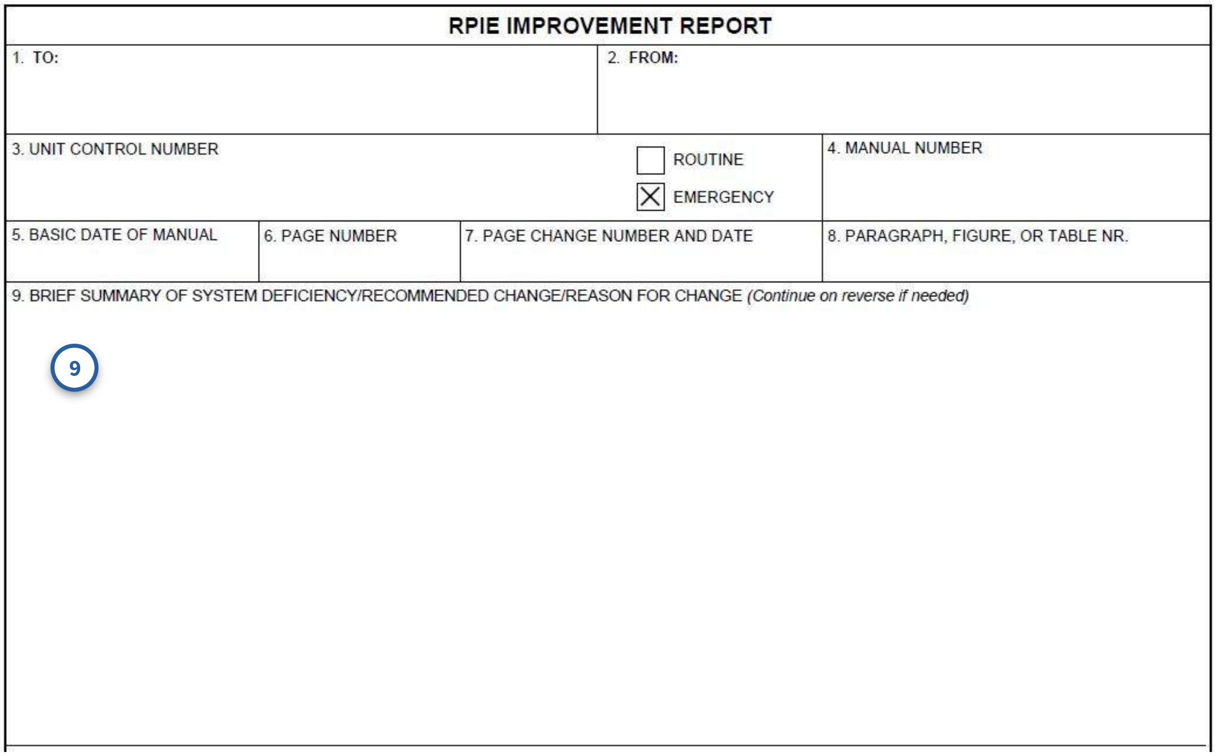
The step you are proposing changes to is likely one of many steps within a paragraph. The paragraph number is closest to the left margin of the page, and is a number followed by the paragraph heading. For example: “2–16. Power System Jack box Installation and Removal.” Some CEMs will have the paragraph heading in bold print, underlined, or in all capital letters, but the meaning is the same. From the example above, you would insert the word “Paragraph” or “Para,” followed by the paragraph number “2–16” into block 8 of the form.

Figure Number

The figure number will always be located under the figure itself. You do not need to list the actual name of the figure, just the figure number. Again, make sure to preface the figure number with the word “Figure” or “Fig”

Table Number

The table number is located at the top-left of the page, followed by the name of the table. Put this number in block 8, prefaced by the word “Table.”



RPIE IMPROVEMENT REPORT

1. TO:		2. FROM:	
3. UNIT CONTROL NUMBER		☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER
5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.
9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*			

9

Block 9 – Summary of Deficiency, Recommended Change, and Reason for Change

Block 9 must contain your proposed change, word for word, as if you were writing the procedure yourself, and this is where the majority of your time authoring the AFGSC 272 will be spent. The block heading suggests that you provide a "brief summary" of what you would like changed, but the instructions on the rear of the form ask for more clarity. Here is where you will enter whether the change is being submitted as a correction or an Airmen Powered by Innovation (API) program submission.

Block 9 is also where you will enter a description of the deficiency, your recommended change, and the reason for the change. To make sure that the individuals at Missile Engineering know exactly what you want changed, you should loosely format this section just like a step in the CEM. Examples will be provided on how to create changes for paragraphs, figures, and tables in a way that will relay the information the most effectively.

Complete the content above before moving on to learn about formatting the change for a paragraph.

Below are examples of changing a paragraph, a figure, and a table that would go into Block 9 of the AFGSC Form 272. Click on each tab before moving forward in the lesson.

CHANGING A PARAGRAPH	CHANGING A FIGURE	CHANGING A TABLE

Format the change for a paragraph exactly like the CEM shows it, but with your change inserted. Don't worry about copying the entire procedure word for word; that is not necessary. You will want to list the steps before and after the step you're trying to change so that other individuals who view the form can easily tell what you're requesting to change. This form does not have all of the functionality of a Microsoft Word document, so you may need to get creative at times. Take a look at the example below.

As you can see, you do not need to list every single step leading up to the step you want to change. You already gave a brief synopsis of what you want changed, as well as an example of how you would like it to look. This is obviously an over simplified example, but any change to a paragraph would take on a similar format. Be as concise as possible when explaining the change you are proposing, as well as the reason for it. This will prevent the submission of your AFGSC 272 from being delayed or returned due to questions from other individuals or agencies.

API submission.

DESCRIPTION OF DEFICIENCY: In step q. of Paragraph 5–74, the technician is directed to torque the battery lead fastening nuts to 60 in–lbs.

RECOMMENDED CHANGE: Change step q. to direct the technician to torque the battery lead fastening nuts to 80 ft–lbs.

REASON FOR CHANGE: Every other procedure in this CEM lists the battery lead fastening nut torque as 80 in–lbs. Please see the suggested change below:

5–74. LF diesel electric unit (DEU) Voltage Regulator Removal and Installation.

p. Rotate...

q. Reconnect DEU battery leads and torque fastening nuts to 80 in–lbs.

r. Apply...

CHANGING A PARAGRAPH	CHANGING A FIGURE	CHANGING A TABLE

Proposing a change to a figure is more difficult due to the fact that a figure is a picture or a drawing. Unlike the AFTO 22, the AFGSC Form 272 does not allow the user to attach documents. Since the form is e-mailed between agencies, you have the option of sending a photo or an image that you have drawn in the e-mail attachment. If the change is as simple as a mislabeled component in a figure, simply state that in block 9. Take a look at the example below.

API submission.

DESCRIPTION OF DEFICIENCY: The component in Figure 5–3 labeled “(22) REAR CONTACT MOUNTING SCREW” is labeled incorrectly.

RECOMMENDED CHANGE: Change the component labeled “(22) REAR CONTACT MOUNTING SCREW” to “(22) MOTOR MOUNT CAPSCREW.”

REASON FOR CHANGE: The incorrect labeling of this component may cause the technician to install and/or order incorrect parts, and could result in equipment damage.

If you are sending attachments with this change, it is a smart idea to list their names here. Example: **Please see the accompanying attachments FIGURE1.JPG and FIGURE2.JPG** (or similar).

CHANGING A PARAGRAPH | CHANGING A FIGURE | CHANGING A TABLE

Changing a table involves a bit more creativity due to the fact that tables are formatted with vertical lines separating the columns. No formatting is allowed in the current version of the AFGSC 272, so you would need to use extra spaces, underscores, and vertical lines to get your point across. However, creating a table in a Microsoft Excel or Microsoft Word document might help to make the process simpler. The point is not the formatting; no change will be rejected because of that. The point is to clearly illustrate what you want changed, and why. Your shop or your local QA evaluators might already have an established process. Check with them if you are unsure. An example of a change to a CEM table built with Microsoft Excel is shown in figure 2–22. As you can see in figure 2–22, only pertinent information is included. On the AFGSC 272, you still need to include the same information as you would for a change to a paragraph or figure. See the example below.

Regardless of the change you are trying to make, including too much information in block 9 is preferred over not including enough. Be as explicit and descriptive as you can. Lastly, if new vendor or manufacturer manuals are required for the change, you will need to send copies of those along with your AFGSC Form 272. These can typically be downloaded from the Internet or requested in digital format directly from the vendor or manufacturer.

CEM 21-SM80A-X-X-X

Table 4-6. LF DEU Troubleshooting (Continued)

PROCEDURE	NORMAL INDICATION	ABNORMAL INDICATION	CORRECTIVE ACTION
g. Connect jumper wire…	…	…	… …
h. Connect jumper wire between relay K10-1 and K10-3 in engine control panel, and check voltage between terminals 2 and 6 on governer controller.	Approximately 12 VDC.	Not approximately 12 VDC.	Proceed to step i. Replace governer controller (table 5-1).
i. Check voltage between…	…	…	… …

Figure 2–22. Sample change to a table using Microsoft Excel.

Submission for CORRECTION.

DESCRIPTION OF DEFICIENCY: In the NORMAL INDICATION and ABNORMAL INDICATION columns of Table 4–6, step h., the technician is directed to check for approximately 8 VDC.

RECOMMENDED CHANGE: Change NORMAL INDICATION and ABNORMAL INDICATION columns of Table 4–6, step h. to direct the technician to check for approximately 12 VDC.

REASON FOR CHANGE: Checking for 8 VDC instead of 12 VDC could cause a technician to erroneously remove/replace a functioning governor controller, or leave a malfunctioning governor controller installed. Please see the suggested change in the attached Microsoft Excel document.

Complete the content above before moving on.

In this section, you will click on each number located on the bottom section of the AFGSC Form 272 to learn what information must be included in the specific blocks.

10. REPORTED BY: 1		
A. INITIATOR	SIGNATURE	DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR	SIGNATURE	DATE *(YYYYMMDD)*

11. COORDINATION: 2		
A. UNIT QUALITY ASSURANCE	SIGNATURE	DATE *(YYYYMMDD)*
☐ APPROVE ☒ DISAPPROVE		
B. UNIT TECHNICAL/SYSTEM ENGINEER	SIGNATURE	DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT	SIGNATURE	DATE *(YYYYMMDD)*
☒ APPROVE ☐ DISAPPROVE		

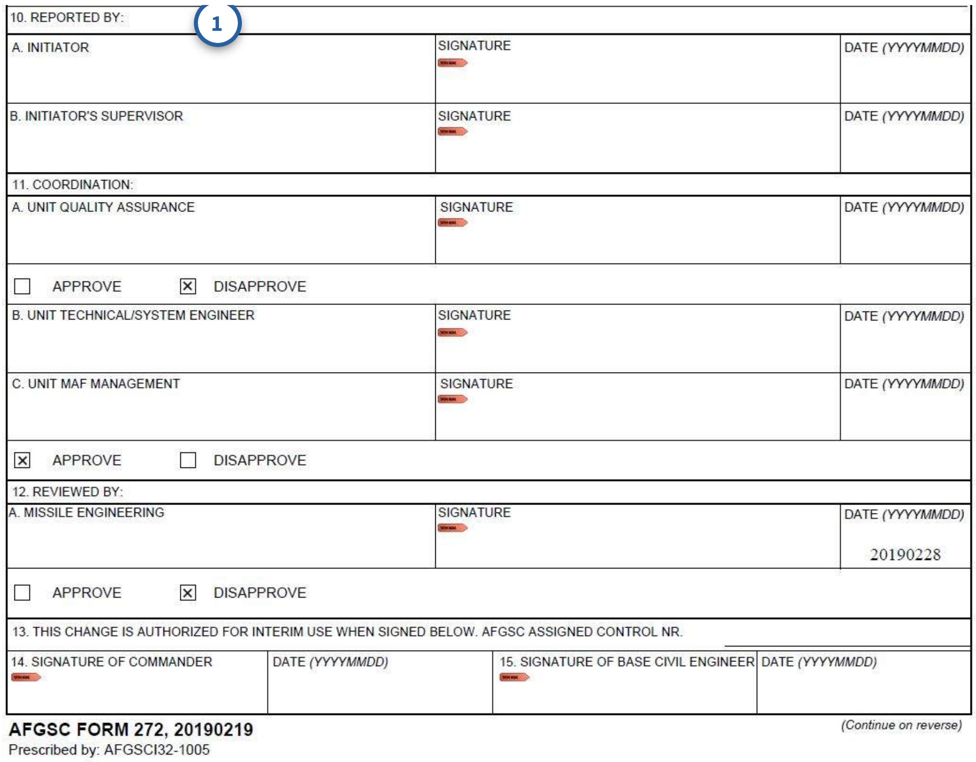
12. REVIEWED BY: 3		
A. MISSILE ENGINEERING	SIGNATURE	DATE *(YYYYMMDD)* 20190228
☐ APPROVE ☒ DISAPPROVE		

13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR. 4

14. SIGNATURE OF COMMANDER 5	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER 6	DATE *(YYYYMMDD)*

AFGSC FORM 272, 20190219 *(Continue on reverse)*

Prescribed by: AFGSCI32-1005



10. REPORTED BY:		
A. INITIATOR	SIGNATURE	DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR	SIGNATURE	DATE *(YYYYMMDD)*
11. COORDINATION:		
A. UNIT QUALITY ASSURANCE	SIGNATURE	DATE *(YYYYMMDD)*
☐ APPROVE ☒ DISAPPROVE		
B. UNIT TECHNICAL/SYSTEM ENGINEER	SIGNATURE	DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT	SIGNATURE	DATE *(YYYYMMDD)*
☒ APPROVE ☐ DISAPPROVE		
12. REVIEWED BY:		
A. MISSILE ENGINEERING	SIGNATURE	DATE *(YYYYMMDD)* 20190228
☐ APPROVE ☒ DISAPPROVE		

13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR.

14. SIGNATURE OF COMMANDER	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER	DATE *(YYYYMMDD)*

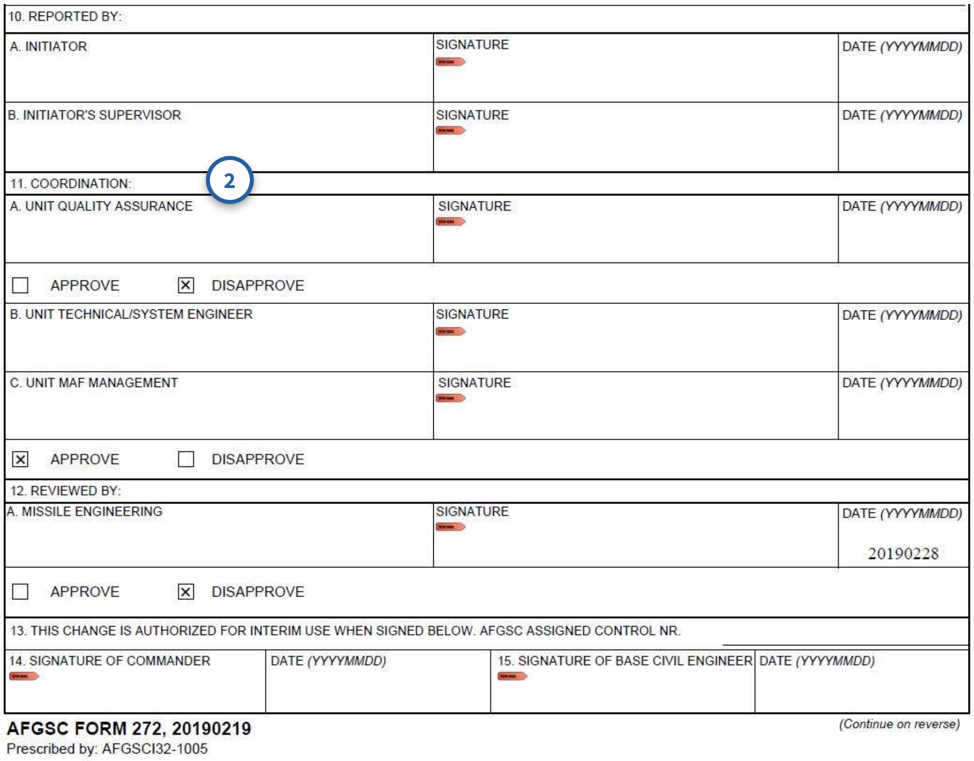
AFGSC FORM 272, 20190219 *(Continue on reverse)*
Prescribed by: AFGSCI32-1005

Block 10 – Reported By

Block 10 - Contains two pieces of information: The initiator and the initiator's supervisor's information.

Block 10A - Initiator: Enter your name, grade, duty phone number and office symbol, and then sign and date the form.

Block 10B – Initiator's Supervisor: Your supervisor will review your work and make remarks, if applicable. They will then add their name, grade, duty phone number, and office symbol, and then sign and date. Your supervisor can add comments in the remarks block if they desire to do so.



10. REPORTED BY:		
A. INITIATOR	SIGNATURE	DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR	SIGNATURE	DATE *(YYYYMMDD)*
11. COORDINATION: 2		
A. UNIT QUALITY ASSURANCE	SIGNATURE	DATE *(YYYYMMDD)*
☐ APPROVE ☒ DISAPPROVE		
B. UNIT TECHNICAL/SYSTEM ENGINEER	SIGNATURE	DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT	SIGNATURE	DATE *(YYYYMMDD)*
☒ APPROVE ☐ DISAPPROVE		
12. REVIEWED BY:		
A. MISSILE ENGINEERING	SIGNATURE	DATE *(YYYYMMDD)* 20190228
☐ APPROVE ☒ DISAPPROVE		
13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR.		

14. SIGNATURE OF COMMANDER	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER	DATE *(YYYYMMDD)*

AFGSC FORM 272, 20190219 *(Continue on reverse)*
Prescribed by: AFGSCI32-1005

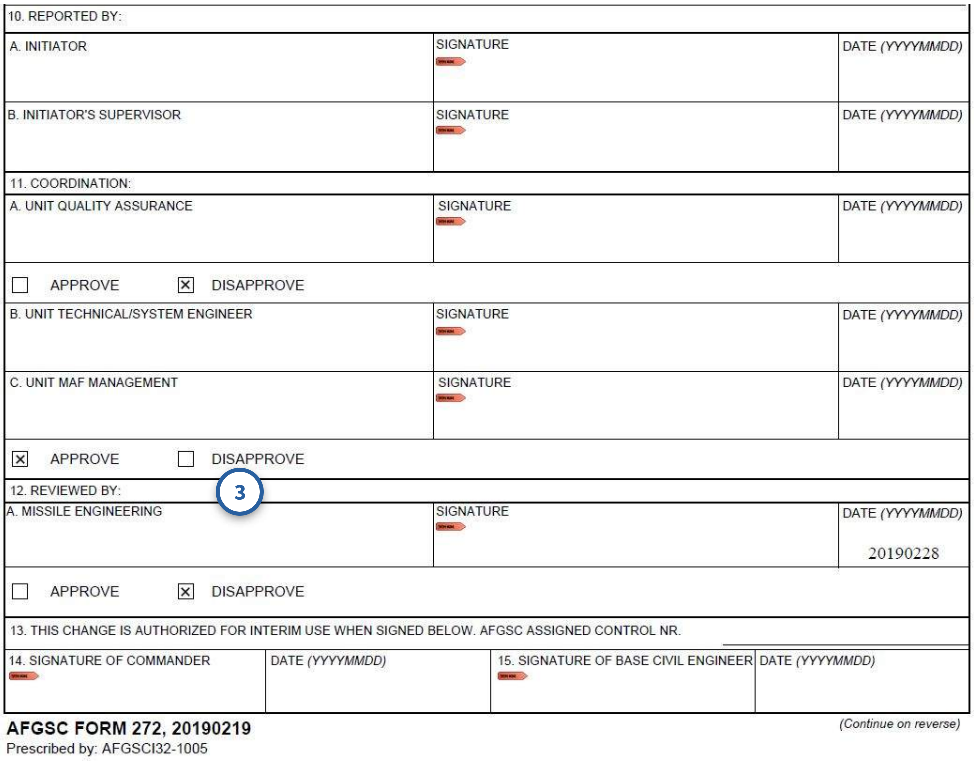
Block 11 – Coordination

Block 11 - Contains coordination information of the offices or personnel who must review/complete the AFGSC Form 272 before submission.

Block 11A – Unit Quality Assurance: Block 11A is completed by the QA evaluator that reviewed your submission. The QA evaluator will either approve or disapprove your request, then the evaluator enters his/her name, grade, and duty phone number, and then signs and adds the date. Note that the AFGSC Form 272 will continue to the next agency regardless of whether or not it is disapproved by your local QA. The evaluator may leave comments in the remarks block as well.

Block 11B – Unit Technical/System Engineer: Block 11B is completed by your unit's technical or system engineer. They will enter their name, grade, and duty phone number, and then sign and add the date. They may also leave comments in their remarks box.

Block 11C – Unit Missile Alert Facility Management: If your proposed change involves any CEM in the 21–SM80–19 series, the wing missile alert facility (MAF) management representative will need to review it. They will enter their name, grade, office symbol, and duty phone number, and then sign and add the date, and approve or disapprove there quest. They may also provide comments in the remarks block. Again, even if the request is disapproved at this point it will still be routed to missile engineering.



10. REPORTED BY:		
A. INITIATOR	SIGNATURE	DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR	SIGNATURE	DATE *(YYYYMMDD)*
11. COORDINATION:		
A. UNIT QUALITY ASSURANCE	SIGNATURE	DATE *(YYYYMMDD)*
☐ APPROVE ☒ DISAPPROVE		
B. UNIT TECHNICAL/SYSTEM ENGINEER	SIGNATURE	DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT	SIGNATURE	DATE *(YYYYMMDD)*
☒ APPROVE ☐ DISAPPROVE		
12. REVIEWED BY:		
A. MISSILE ENGINEERING	SIGNATURE	DATE *(YYYYMMDD)* 20190228
☐ APPROVE ☒ DISAPPROVE		
13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR.		

14. SIGNATURE OF COMMANDER	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER	DATE *(YYYYMMDD)*

AFGSC FORM 272, 20190219 *(Continue on reverse)*
Prescribed by: AFGSCI32-1005

Block 12 – Reviewed By

This block is where the missile engineer will enter their name, grade, and duty phone number, and then sign and date the form. The missile engineer can approve or disapprove the request, and add comments in the remarks section. Note that the change will not continue any further if the AFGSC Form 272 is disapproved by the missile engineer.

10. REPORTED BY:		
A. INITIATOR	SIGNATURE	DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR	SIGNATURE	DATE *(YYYYMMDD)*
11. COORDINATION:		
A. UNIT QUALITY ASSURANCE	SIGNATURE	DATE *(YYYYMMDD)*
☐ APPROVE ☒ DISAPPROVE		
B. UNIT TECHNICAL/SYSTEM ENGINEER	SIGNATURE	DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT	SIGNATURE	DATE *(YYYYMMDD)*
☒ APPROVE ☐ DISAPPROVE		
12. REVIEWED BY:		
A. MISSILE ENGINEERING	SIGNATURE	DATE *(YYYYMMDD)* 20190228
☐ APPROVE ☒ DISAPPROVE		
13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR: 4		

14. SIGNATURE OF COMMANDER	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER	DATE *(YYYYMMDD)*

AFGSC FORM 272, 20190219 *(Continue on reverse)*
Prescribed by: AFGSCI32-1005

Block 13 – Air Force Global Strike Command Missile Engineer Squadron Assigned Control Number

If the change is authorized, missile engineering will annotate a control number in this block.

10. REPORTED BY:		
A. INITIATOR	SIGNATURE	DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR	SIGNATURE	DATE *(YYYYMMDD)*
11. COORDINATION:		
A. UNIT QUALITY ASSURANCE	SIGNATURE	DATE *(YYYYMMDD)*
☐ APPROVE ☒ DISAPPROVE		
B. UNIT TECHNICAL/SYSTEM ENGINEER	SIGNATURE	DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT	SIGNATURE	DATE *(YYYYMMDD)*
☒ APPROVE ☐ DISAPPROVE		
12. REVIEWED BY:		
A. MISSILE ENGINEERING	SIGNATURE	DATE *(YYYYMMDD)* 20190228
☐ APPROVE ☒ DISAPPROVE		

13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR.

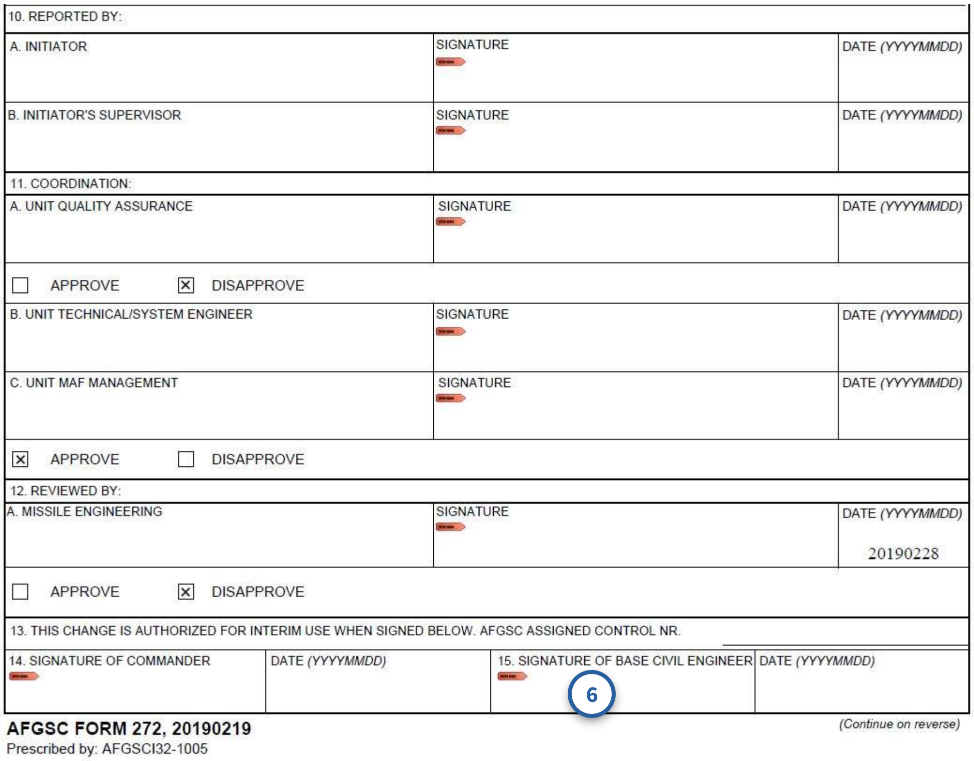
14. SIGNATURE OF COMMANDER	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER	DATE *(YYYYMMDD)*
5			

AFGSC FORM 272, 20190219
Prescribed by: AFGSCI32-1005

(Continue on reverse)

Block 14 – Signature of Commander

Your wing commander or equivalent will sign and date in block 14.


10. REPORTED BY:

A. INITIATOR	SIGNATURE	DATE *(YYYYMMDD)*
B. INITIATOR'S SUPERVISOR	SIGNATURE	DATE *(YYYYMMDD)*

11. COORDINATION:

A. UNIT QUALITY ASSURANCE	SIGNATURE	DATE *(YYYYMMDD)*

☐ APPROVE ☒ DISAPPROVE

B. UNIT TECHNICAL/SYSTEM ENGINEER	SIGNATURE	DATE *(YYYYMMDD)*
C. UNIT MAF MANAGEMENT	SIGNATURE	DATE *(YYYYMMDD)*

☒ APPROVE ☐ DISAPPROVE

12. REVIEWED BY:

A. MISSILE ENGINEERING	SIGNATURE	DATE *(YYYYMMDD)* 20190228

☐ APPROVE ☒ DISAPPROVE

13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR.

14. SIGNATURE OF COMMANDER	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER 6	DATE *(YYYYMMDD)*

AFGSC FORM 272, 20190219
Prescribed by: AFGSCI32-1005

(Continue on reverse)

Block 15 – Signature of Base Civil Engineer

Your wing's civil engineer will sign and date in block 15. This has been a step-by-step breakdown of each of the blocks on an AFGSC Form 272. Remember that instructions can also be found on the rear of the form, under the heading RPIE IMPROVEMENT REPORT GENERAL INSTRUCTIONS. The instructions on the newest version of the AFGSC Form 272 will always supersede the instructions in this CDC.

Complete the content above before moving on.

RPIE IMPROVEMENT REPORT

1. TO: AFGSC/A4C, Bldg 5541, Barksdale AFB, LA 71110	2. FROM: 576 FLTS, 1785 Utah Ave, Vandenberg SFB, CA, 93437

3. UNIT CONTROL NUMBER: CE-21-01	☐ ROUTINE ☒ EMERGENCY	4. MANUAL NUMBER: CEM 21-SM80-19 VOLUME VIII

5. BASIC DATE OF MANUAL	6. PAGE NUMBER	7. PAGE CHANGE NUMBER AND DATE	8. PARAGRAPH, FIGURE, OR TABLE NR.
01 March 2010	3-1	Change 6, 1 January 2016	Paragraph 3-2

9. BRIEF SUMMARY OF SYSTEM DEFICIENCY/RECOMMENDED CHANGE/REASON FOR CHANGE *(Continue on reverse if needed)*

Deficiency - Para. 3-2 LAUNCH CONTROL CENTER ENTRY has a warning that the LCC shall not be entered if ECS has been off for 24
hours or more. CEM has no procedures for performing contaminated atmosphere testing while wearing a self contained breathing apparatus
and no procedures for performing purging if testing deems it necessary.

Recommended change - Add procedures to test atmosphere using an MX6 at the top of elevator shaft and entry into capsule. Add procedures for purging through the elevator shaft or ladder shaft.

Reason for change - Unit has no way to enter LCC if there is an ECS failure. If there were an ECS failure that could not be resolved topside, unit would have no way forward to get a team downstairs to troubleshoot or repair the failure.

10. REPORTED BY:

10. REPORTED BY:

	SIGNATURE	DATE *(YYYYMMDD)*
A. INITIATOR: SSgt Jim Daniels	DANIELS.JIM.JAYMES.1234567890	20210520
B. INITIATOR'S SUPERVISOR: MSgt Robert Roberts	ROBERTS.ROBERT.TIM.1234567890	20210520

11. COORDINATION:

	SIGNATURE	DATE *(YYYYMMDD)*
A. UNIT QUALITY ASSURANCE: TSgt Aaron Brady	BRADY.AARON.TONY.1234567890	20210522
X APPROVE ☒ DISAPPROVE		
B. UNIT TECHNICAL/SYSTEM ENGINEER		
C. UNIT MAF MANAGEMENT		
☒ APPROVE ☐ DISAPPROVE		

12. REVIEWED BY:

	SIGNATURE	DATE *(YYYYMMDD)*
A. MISSILE ENGINEERING: Benjamin R. Martyn, GS-14, Chief, Mission Engineering	MARTYN.BENJAMIN.ROBERTS.1234567890	20210605
X APPROVE ☒ DISAPPROVE		

13. THIS CHANGE IS AUTHORIZED FOR INTERIM USE WHEN SIGNED BELOW. AFGSC ASSIGNED CONTROL NR.

14. SIGNATURE OF COMMANDER	DATE *(YYYYMMDD)*	15. SIGNATURE OF BASE CIVIL ENGINEER	DATE *(YYYYMMDD)*

AFGSC FORM 272, 20190219
Prescribed by: AFGSCI32-1005

(Continue on reverse)

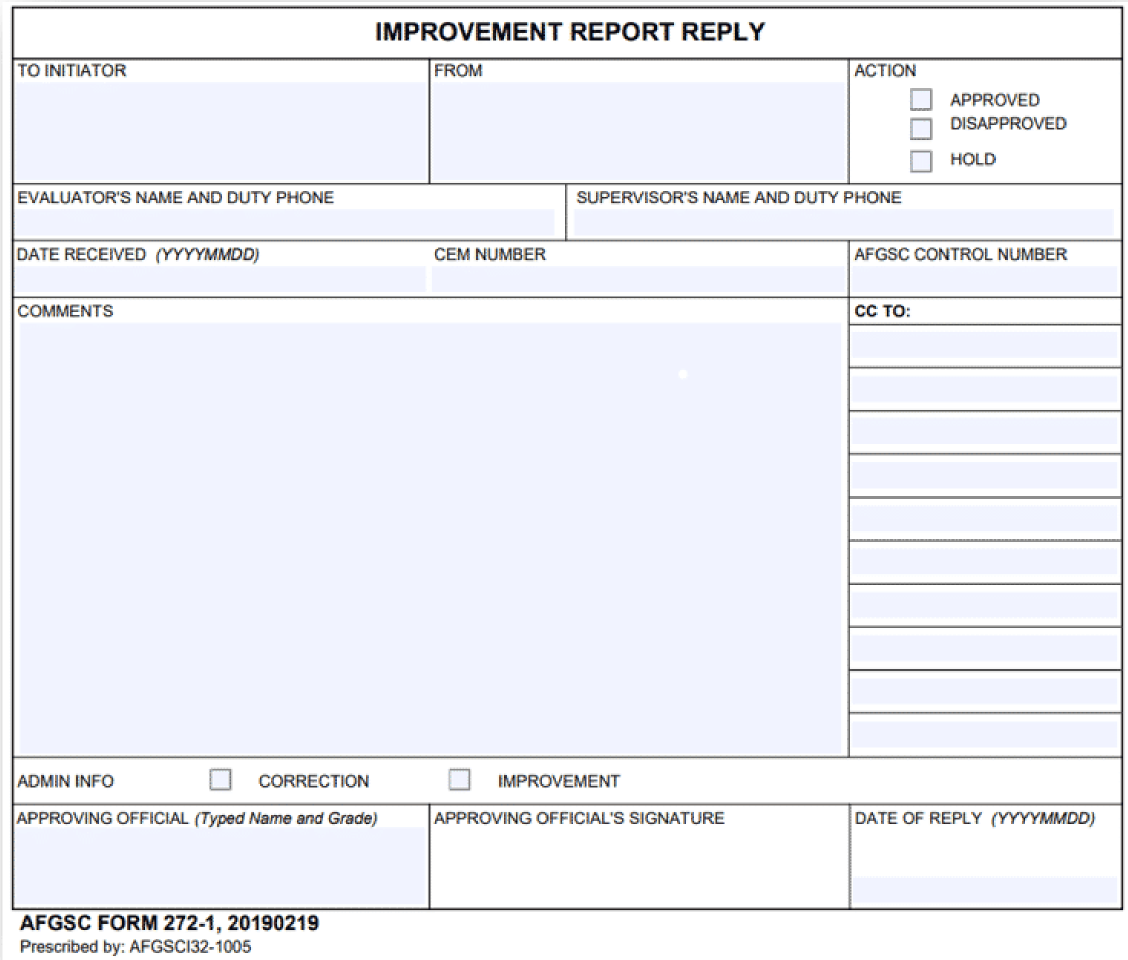
RPIE IMPROVEMENT REPORT *(Continued)*

16. REMARKS

(5 Jun 21, Martyn, 30 CES) Concur with proposal; however, specific steps must be developed including allowable measured values from the MX6 device, etc.

RPIE IMPROVEMENT REPORT GENERAL INSTRUCTIONS

Click through each image to see a sample of a completed AFGSC Form 272.



IMPROVEMENT REPORT REPLY

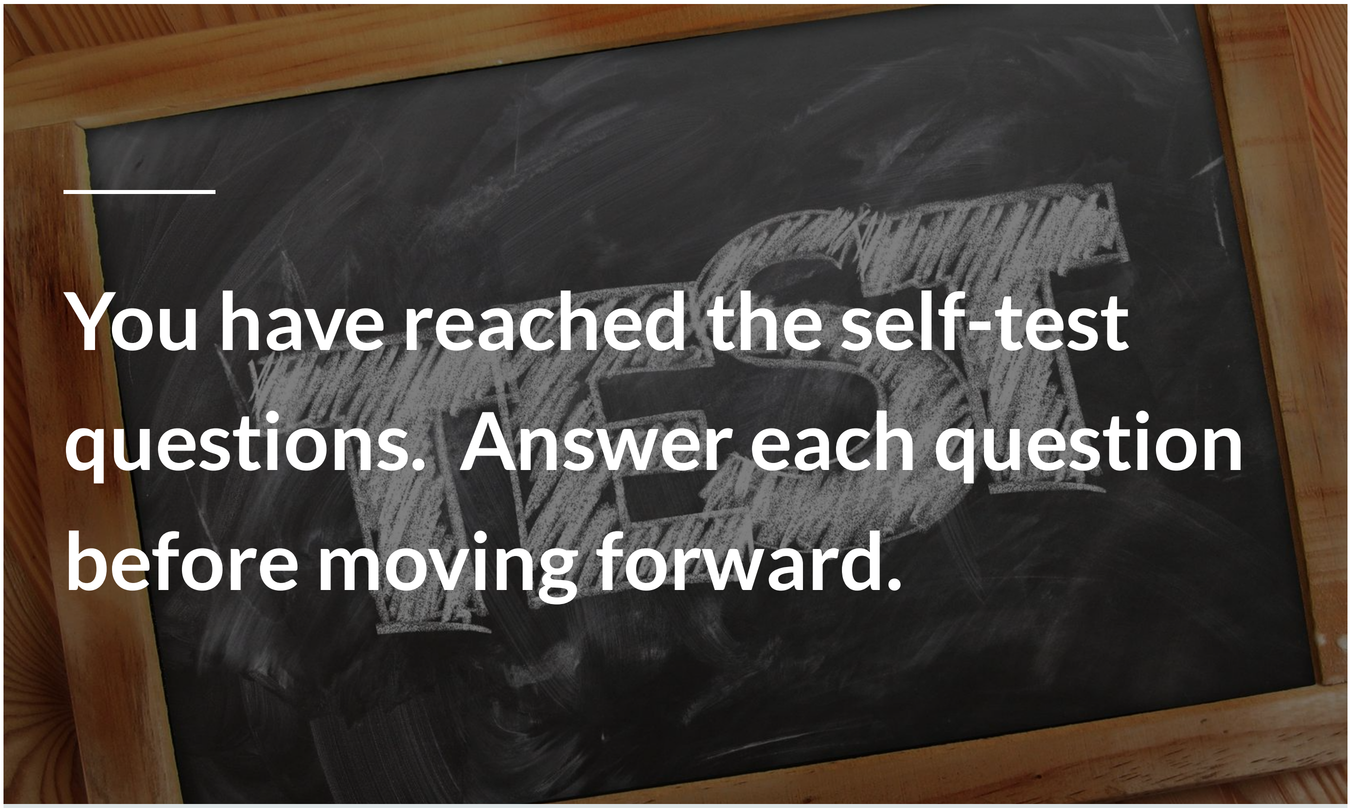
TO INITIATOR	FROM	ACTION ☐ APPROVED ☐ DISAPPROVED ☐ HOLD
EVALUATOR'S NAME AND DUTY PHONE	SUPERVISOR'S NAME AND DUTY PHONE	
DATE RECEIVED *(YYYYMMDD)*	CEM NUMBER	AFGSC CONTROL NUMBER
COMMENTS		CC TO:
ADMIN INFO ☐ CORRECTION ☐ IMPROVEMENT		
APPROVING OFFICIAL *(Typed Name and Grade)*	APPROVING OFFICIAL'S SIGNATURE	DATE OF REPLY *(YYYYMMDD)*

AFGSC FORM 272-1, 20190219
Prescribed by: AFGSCI32-1005

Air Force Global Strike Command Form 272–1, *Improvement Report Reply*

After your change has been reviewed, missile engineering will send you an AFGSC Form 272–1, *Improvement Report Reply*. This form lists the evaluator who reviewed your submission, whether your change was approved, disapproved, or put on hold, and comments regarding your submission, as well as other information. It is highly advisable that you keep copies of the AFGSC Form 272 and 272–1, with any attachments you made in case the originals are misplaced.

This lesson provided specific instructions on how to properly complete the AFGSC Form 272, *RPIE Improvement Report*, and knowing the information here can save you hours of time during the authoring process.



You have reached the self-test questions. Answer each question before moving forward.

You have reached the self-test questions. Answer each question before moving on to Lesson 3. For the fill-in the blank questions, you will need to add (.) period to the end of the sentences.

Click here to answer the self-test questions pertaining to the description of civil engineering manuals.

1. What does a system manual provide?

Type your answer here

SUBMIT

27

2. What is an equipment manual a collection of?

Type your answer here

SUBMIT

28

3. What information does a master change log contain?

Type your answer here

SUBMIT

Answer all of the questions above before moving to the questions on CEM format.

Click here to answer the self-test questions pertaining to the format of civil engineering systems and equipment manuals.

1. What can make researching replacement parts in a civil engineering manual somewhat difficult?

Type your answer here

SUBMIT

2. What do the illustrations in the special tools and test equipment section of a system manual show you?

Type your answer here

SUBMIT

30

3. What should you do if you receive any indication other than a normal indication when performing a checkout in a three-column format?

Type your answer here

SUBMIT

31

4. What should you do if the corrective action of a checkout does not refer you to specific procedures?

Type your answer here

SUBMIT

32

5. If a system manual does not have a maintenance section, where would you find maintenance instructions?

Type your answer here

SUBMIT

33

6. When can you use civil engineering manual schematics for troubleshooting without following written procedures?

Type your answer here

SUBMIT

34

7. Where do you refer to see what master change log an interim change page applies to?

Type your answer here

SUBMIT

35

8. What information is contained in the equipment manual vendor data reference table?

Type your answer here

SUBMIT

36

9. How is the commercial data in an equipment manual arranged?

- ○ Sequentially.
- ○ Numerically.
- ○ Alphabetically.

SUBMIT

Answer all of the questions above before moving to the questions on submitting CEM reports.

Click here to answer the self-test questions pertaining to submitting civil engineering manual improvement reports.

1. What are changes submitted for civil engineering manuals limited to?

Type your answer here

SUBMIT

37

2. What should you do before starting the process of completing an Air Force Global Strike Command Form 272?

Type your answer here

SUBMIT

38

3. What information goes into block 4 of an Air Force Global Strike Command Form 272?

Type your answer here

SUBMIT

39

4. When will block 7 of an Air Force Global Strike Command Form 272 be used?

Type your answer here

SUBMIT

40

5. Where is the number of a figure located in a civil engineering manual?

Type your answer here

SUBMIT

41

6. When submitting a change to a table in a civil engineering manual, what might make the process simpler?

Type your answer here

SUBMIT

7. What information is entered into block 10B of an Air Force Global Strike Command Form 272?

Type your answer here

SUBMIT

8. What information is contained in an Air Force Global Strike Command Form 272–1?

Type your answer here

SUBMIT

This completes Lesson 2. You can find the answers to the self-test questions in the Module 2 table of contents.

Lesson 3. Maintenance Fundamentals

Main Points

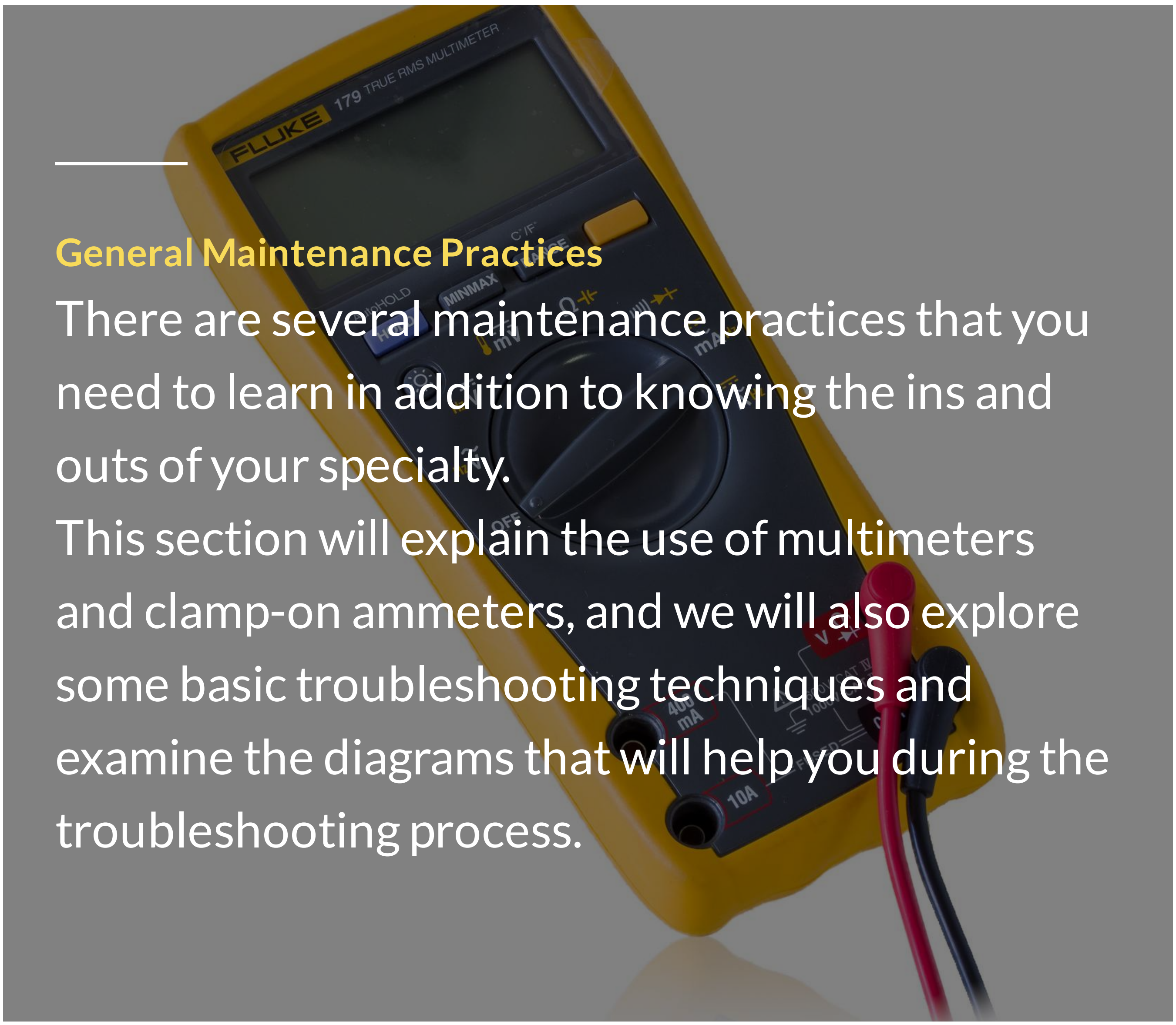
1. General Maintenance Practices
    a. Using digital multimeters and clamp-on ammeters
    b. Troubleshooting techniques
    c. Hardware
    d. Electrostatic discharge control
2. Maintenance Programs
    a. Deficiency reporting
    b. Integrated Maintenance Data System (IMDS)

Maintenance involves much more than simply turning wrenches. To become a successful maintenance technician, you need to learn several other skills that are basic to your specialty because mechanical skills alone will not solve all of the problems you encounter in the missile field.

In this lesson, we will explore a few maintenance practices that will help you succeed in this career field and help to ensure that the weapon system is maintained in optimal condition. We will also explore some of the maintenance support programs that you will use throughout your career.

You will also learn about the process of reporting a deficiency after a defect is discovered in a piece of equipment or system. And lastly, you'll learn about the integrated maintenance data system (IMDS), which is what the AF uses to track a multitude of maintenance related data.

Click here to begin Lesson 3.



General Maintenance Practices

There are several maintenance practices that you need to learn in addition to knowing the ins and outs of your specialty.

This section will explain the use of multimeters and clamp-on ammeters, and we will also explore some basic troubleshooting techniques and examine the diagrams that will help you during the troubleshooting process.

Using Digital Multimeters and Clamp-on Ammeters

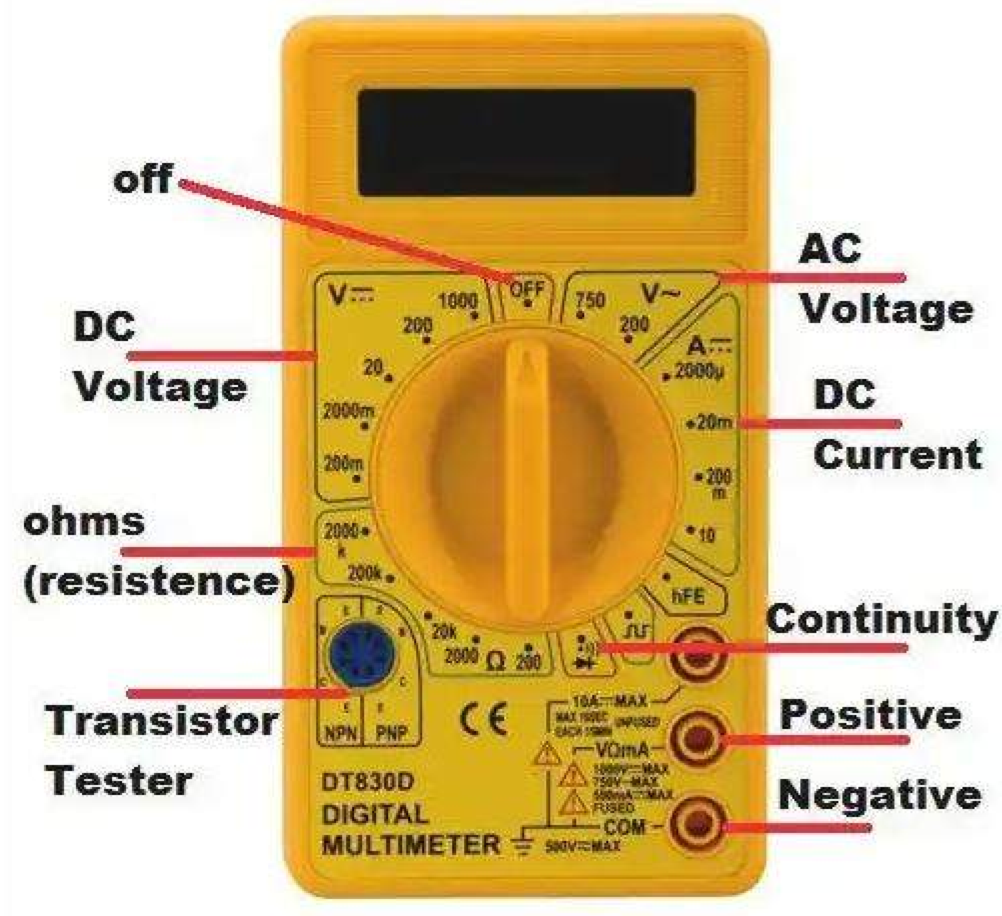
As a 2M0X3, you will be issued a multimeter and a clamp-on ammeter as a part of your equipment load for a facilities maintenance team (FMT) dispatch, and you'll already have several of each of these meters on your van as a periodic maintenance team (PMT) technician.

This lesson will guide you through the uses and features of each of these meters, as they are powerful electrical system troubleshooting tools. Their features, combined with your TO and knowledge of the system, can lead you right to a variety of faults.

Multimeters

You've already had some hands-on time with a variety of meters in your technical training school. A multimeter is used principally to take voltage, amperage, and resistance readings. Multimeters have come a long way over the years. Technicians many decades ago needed to use a separate type of meter for each of the functions mentioned above, and these meters were large and somewhat difficult to handle.

A member of 91st Missile Maintenance Squadron (MMXS) facilities maintenance section verifies diesel hertz on a multi-meter at a launch facility near Minot Air Force Base, North Dakota, July 17, 2018. The annual code change requires maximum effort across the wing.



Symbols on a Multimeter

Before discussing specifics on using a multimeter, let's take some time to refresh our knowledge of the electrical symbols that are displayed on the face of one of your issued multimeters or ammeters. It is important to know what each symbol represents so that you can quickly and accurately identify what type of measurement you're taking. Refer to figure 3–1 for an explanation of common symbols and refer to it as needed when we discuss the multimeters in this section.

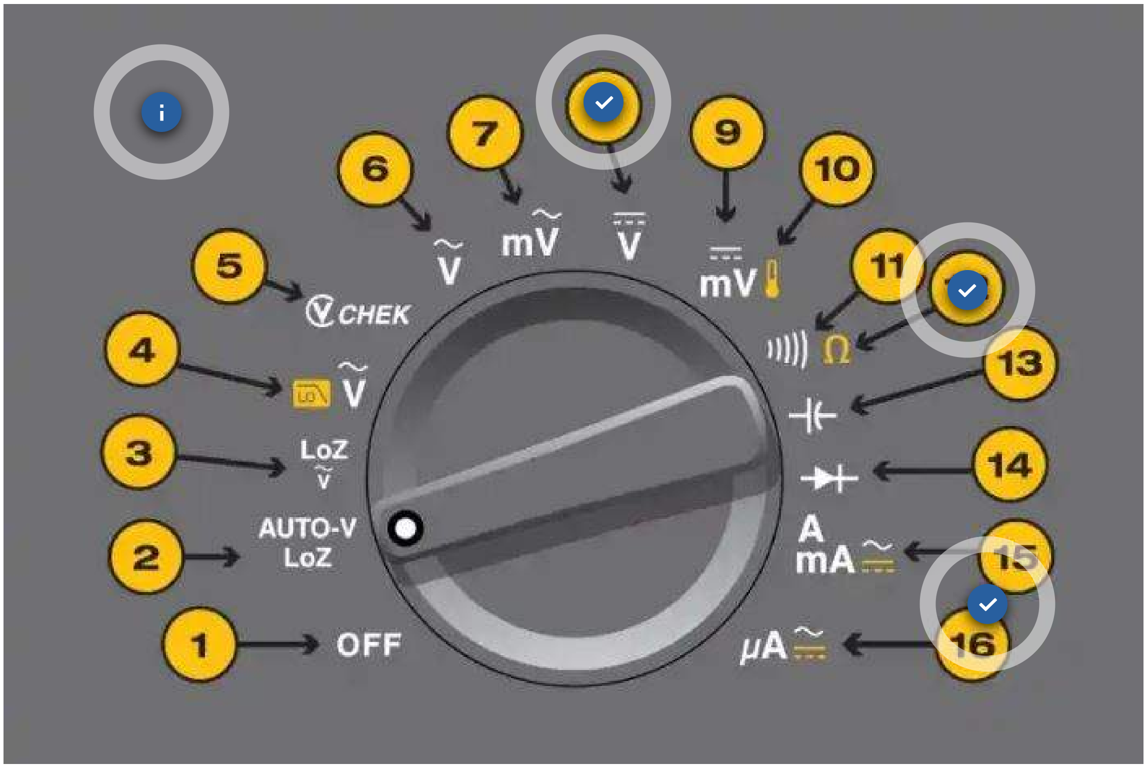
Symbols	Measurements	Descriptions
$\tilde{V}$	AC Voltage	Measures amount of AC electrical pressure
$\overline{V}$	DC Voltage	Measures amount of DC pressure
mV	Milli Volts	.00V or 1/1000V
A	Amperes	Measures amount of electron flow
mA	Milli Amperes	.001 or 1/1000A
Ω	Ohms / resistance	Measurement of resistance to the flow of electron
─▶├─	Diode	Device used to control direction of electron flow
••)))	Audible Continuity	Audible indication of continuity for low resistance
COM	Common (ground jack)	

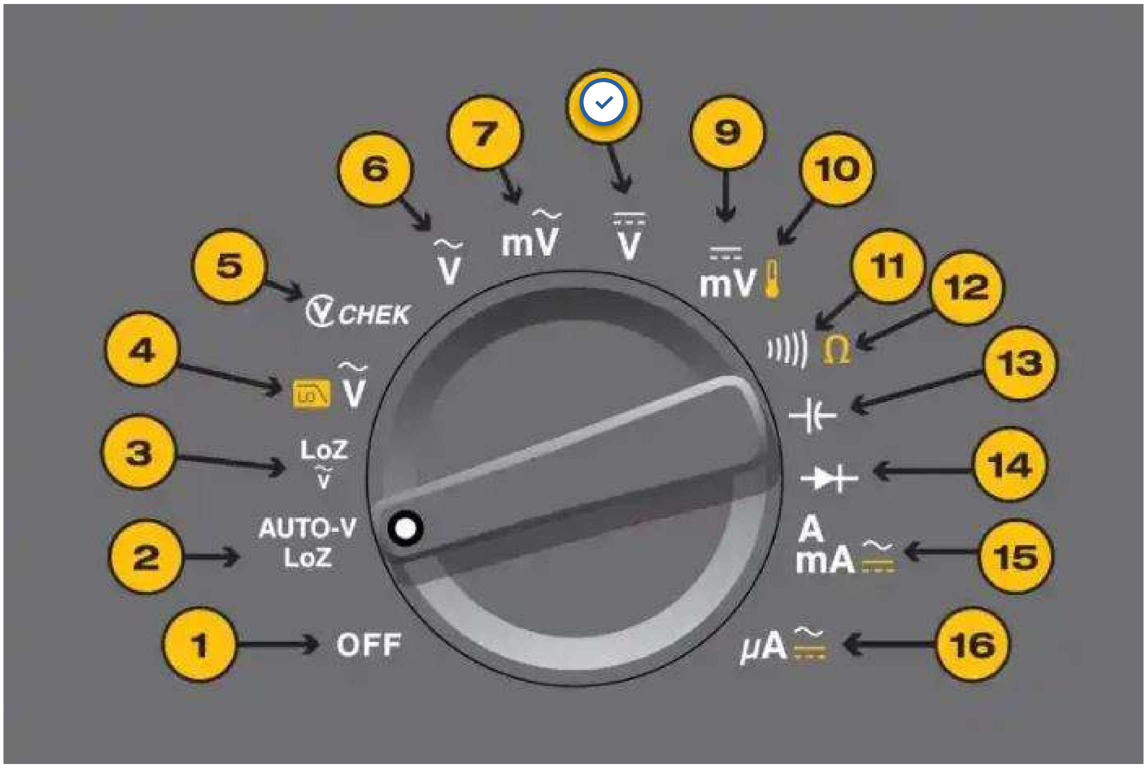
Figure 3–1. Common electrical symbols.

Alternating Current and Frequency

Alternating current (AC) is measured in volts. You will typically see the symbol "VAC" volts, alternating current (VAC) when your TO or CEM directs you to check for volts of AC. On the multimeter itself, the symbol for VAC is the "V" with a wave line above it. You will be measuring for VAC the majority of the time since it is the type of power that comes in on the commercial powerlines as well as the type of power the DEU generates. This voltage is called AC because it reverses direction many times a second. You will typically work with 60 hertz (Hz) systems, meaning that the AC reverses direction 60 times a second.

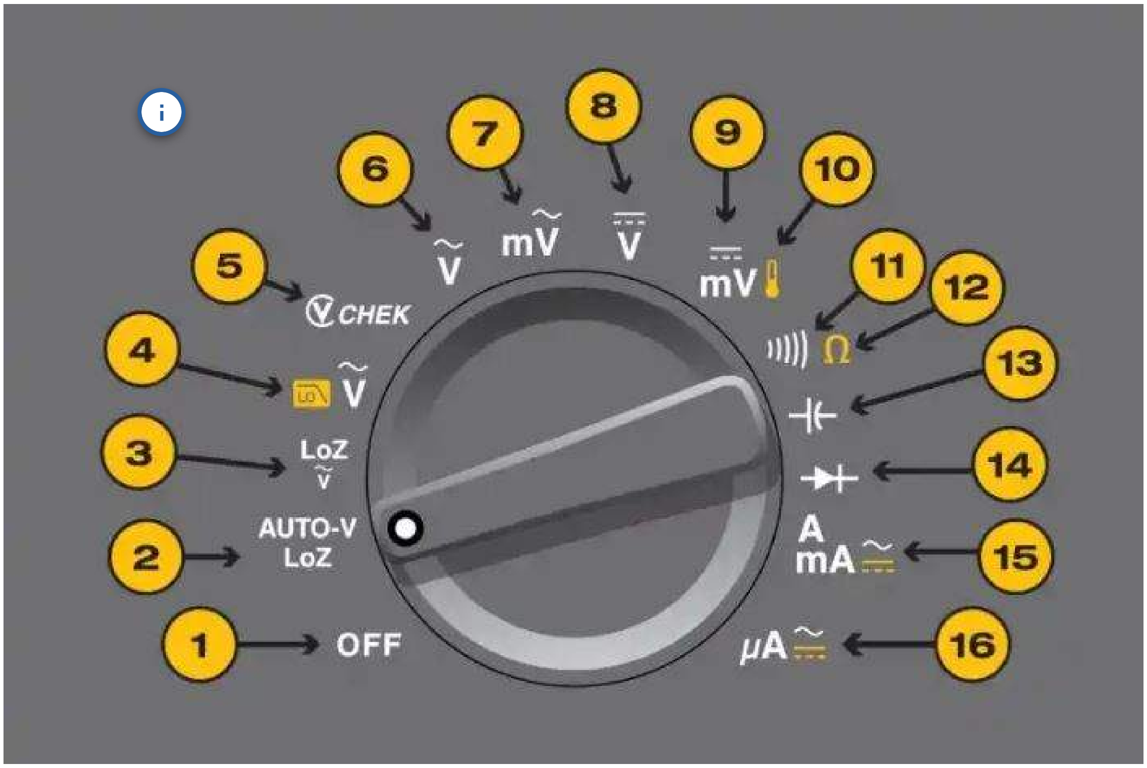
Below is a composite image and not an actual dial. It shows a variety of functions found on multiple Fluke digital multimeter dials. Click on each "blue" button to learn about direct current, amperage, and resistance.


1
OFF
2
AUTO-V
LoZ
3
LoZ
4
5
CHEK
6
7
mV
V
9
mV
10
11
13
14
15
A
mA
16
μA



Direct Current

Direct current (DC) is also measured in volts. When your CEM or TO directs you to measure for volts of DC, you will see the symbol "VDC" (volts, direct current). To measure for VDC with your multimeter, you must set the selector switch to the symbol that is a "V" with a solid line and a dashed line above it. DC does not alternate—it only flows in one direction. Whenever you're testing the DEU starting batteries, the minuteman power processor (MPP) batteries, or the emergency storage batteries, your multimeter will be set to VDC.



The additional symbols represents:

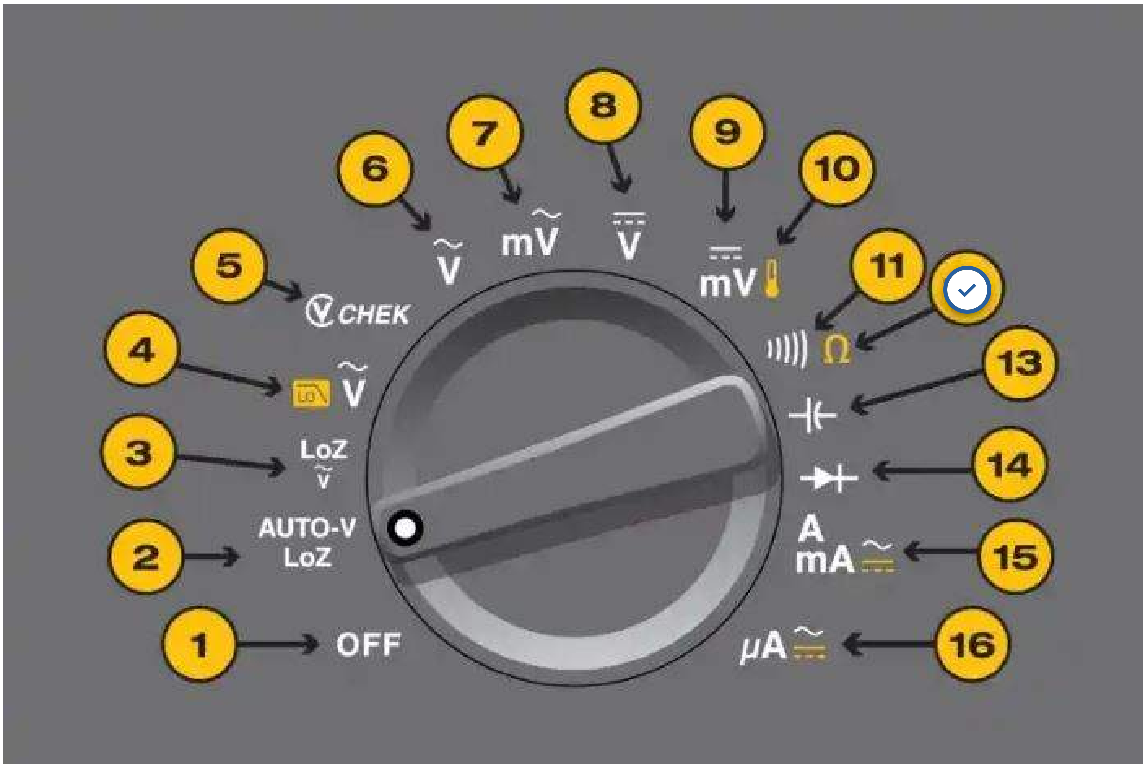
1. ON/OFF switch
2. AUTO-V/LoZ: prevents readings due to ghost voltage; found on the Fluke 114
3. AC voltage/LoZ: uses low-input impedance
4. AC voltage with low-pass filter
5. VCHEKTM: permits simultaneous testing for voltage or continuity; found on the Fluke 113
6. AC voltage
7. AC millivolts
8. **DC voltage (annotated in lesson)**
9. DC millivolts
10. Temperature
11. Continuity: when combined with sound button
12. **Resistance (annotated in lesson)**

13. Capacitance

14. Diode test

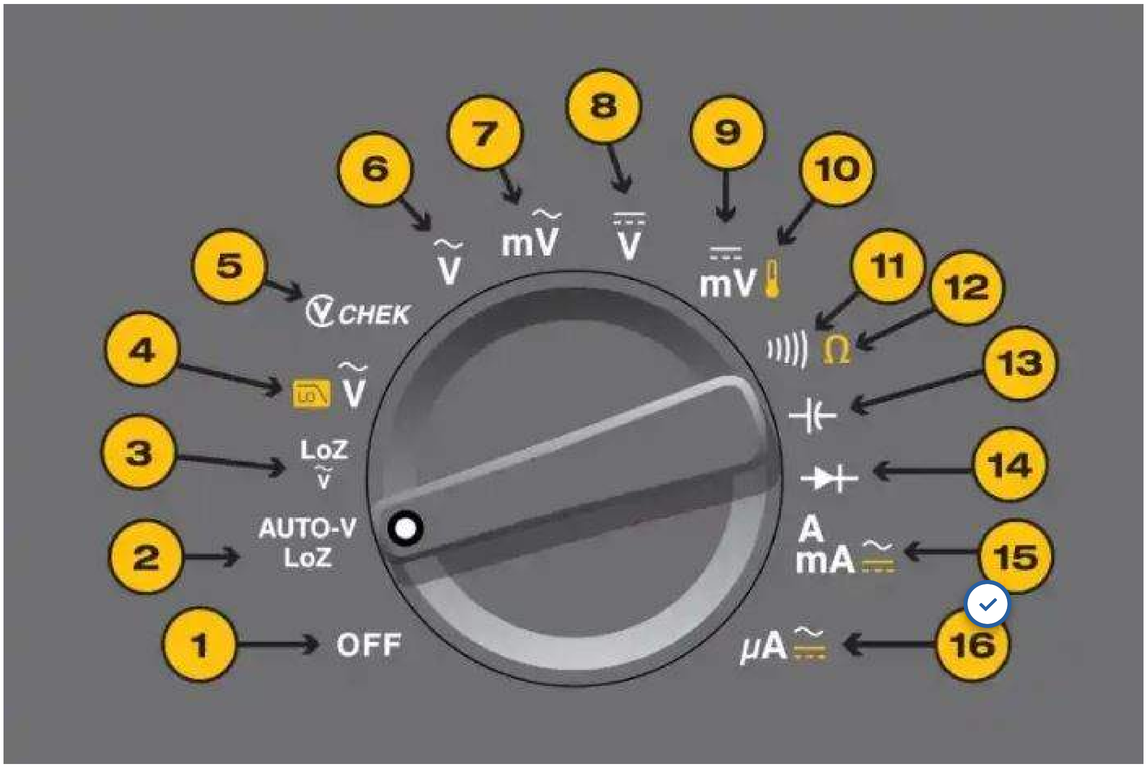
15. AC, DC amps and milliamps **(annotated in lesson)**

16. AC, DC microamps **(annotated in lesson)**



Resistance

Each component in an electrical circuit possesses a different resistance value and using resistance checks can be an extremely helpful troubleshooting aid. Resistance is measured in a unit called an "ohm," which is annotated on your multimeter by the "Ω" symbol. Using a multimeter to test the resistance values of different parts of an electrical circuit is a powerful troubleshooting aid. Although troubleshooting will be covered in another unit, remember that the circuit must be deenergized and isolated prior to taking any resistance reading.



Amperage

Amperage is the measure of the strength of an electric current moving through a conductor, and is measured in amperes, or simply amps. The symbol for amperage is simply an uppercase "A," and amperage checks are typically accomplished with a clamp-on ammeter (to test commercial and standby power as described in detail below), which has a pair of jaws that clamp around the conductor. The amplitude of the current flowing through the conductor will be displayed on the meter's digital readout.

Complete the content above before moving on.

Acceptance of Meters

When you first receive a multimeter from your equipment or support section, always perform a proper checkout to ensure it is serviceable before accepting it. Remember, when dispatching to the missile field, you will likely be hundreds of miles and many hours away from the support base, and taking a few minutes to ensure that your equipment is in serviceable condition can save hours of headache.

Visually inspect the meter to ensure that it is free of physical damage and check the calibration sticker and make sure that the unit is not overdue for calibration. You may need to remove the rubber casing from the meter to see the calibration stickers. If the meter is overdue calibration, or will become due during your dispatch, request another meter.

Turn the power on and confirm a successful power-up self-test; all items on the display should illuminate for 1–2 seconds and then the meter should display whatever the rotary selector switch is set to. If the battery symbol on the digital display is illuminated, make sure that you have extra batteries or request a replacement meter.

Ensure that the insulation on the meter test leads is intact and free of any cracks or dry rot that would expose the inner conductor, and verify that the metal tips are not broken or excessively bent. Connect the multimeter test leads into the input jacks (red test lead to the red jack on the far right, and the black test lead to the black jack). Set the meter to read Ω and then touch the tips of the test leads together. A reading of approximately 0 Ω indicates that your multimeter test leads and the input jacks on the meter are serviceable. If you see a large amount of resistance, or “OL” on the meter’s display, you may have a defective meter test lead or malfunctioning meter. These checks apply to all multimeters, and will help to ensure that you dispatch with a serviceable multimeter.

Figure 3–2. Model 87 multimeter.

Model 87 Multimeter

The meter that will most commonly be issued to you—the Model 87—is sleek, compact, and has a wide range of features (fig 3–2). The Model 87 uses a standard 9-volt battery that can last up to 400 hours. The bottom-left function button is used to illuminate the display so you can see your reading in the dark. The RANGE button is used to switch between the meter's auto-range function and manual range selection, and the meter will automatically switch to auto-range mode if the indication is outside of the manually-selected range. The TOUCH-HOLD function can be used to display the last reading that was taken even after the test leads have been removed from the circuit. The meter will automatically power off to save battery life if the rotary selector switch has been in the same position and the display has not changed for 30 minutes.

Input Jacks

The meter has four input jacks, which can sometimes be confusing to a new technician. There is no need to worry about this though, because each of the input jacks is labeled for what function it accomplishes. The negative (black) test lead is plugged into the "COM" (common) input jack, and for nearly all of the readings you will take on a day-to-day basis, your positive (red) test lead will be inserted into the far-right input jack. You can see from the symbols above the input jack that it will be used for all voltage readings and resistance readings.

The two positive input jacks on the left will be used when you're measuring in-line amperage, which we will cover later in this lesson. Remember that what you choose on the rotary selector switch should correspond to the input jack that your positive meter test lead is plugged into. If you are measuring for VAC or VDC, you'll select one of those with your rotary selector switch, and use the far-right input jack. If you're measuring for resistance, your rotary selector switch will be turned to the 12 o'clock position, and you'll again use the far-right input jack, since the symbols match.

All digital multimeters (DMM) combine the features of an ammeter, a voltmeter, and an ohmmeter. A typical DMM, although different makes and models may have a different number of digits in the display unit and the input/output jacks may be in slightly different positions. Since a DMM is an important tool, you will want to learn how to use one correctly.

Click on each (+) symbol below to learn how to measure alternating current (AC), direct current (DC), resistance, frequency, and in-line amperage.

Measuring Alternating Current –

With the rotary selector switch on the meter set to "OFF," connect the negative test lead to the black input jack on the meter labeled "COM." Next, connect the positive test lead to the red input jack on the meter labeled for voltage readings. Once both test leads are connected to the meter, turn the rotary selector switch to the VAC symbol—you are now ready to take a reading from the circuit. Your meter will display the AC voltage, but read below to ensure that you're using the proper range setting.

Make sure that your meter is using the automatic range selection mode. If you have accidentally pushed the RANGE button on your meter, it might be measuring for very small or very large voltages that are out of the range of the voltage you're looking for. For example, if the meter is set to the millivolts range, it will be measuring for very small voltages. There is always a small, negligible amount of voltage on a circuit. If you're probing on a circuit expecting a reading of "120 VAC," and you see 120 millivolts, but are not paying attention to the range, you may mistakenly think that you have the nominal 120 VAC that you're looking to see. A reading of 120 millivolts is so negligible that it is considered to be zero voltage, and at this point you might continue your checkout or troubleshooting when you should have stopped to find the reason why you had no voltage on the circuit.

In order to avoid this mistake (which is more common than you might think), always ensure that you are using the meter's automatic range selection capability. This will be indicated on the meter's display by the word "AUTO." On the 87 multimeter, this is near the center toward the bottom. It may be displayed in other areas on other meters, but the meaning is the same. If "AUTO" is not displayed on your meter's screen, simply press the RANGE button until "AUTO" appears.

Measuring Direct Current

With the rotary selector switch on the meter set to "OFF," connect the negative test lead to the black input jack on the meter labeled "COM," and connect the positive test lead to the red input jack labeled for voltage. Once both test leads are connected to the meter, turn the rotary selector switch to the VDC symbol and take a reading from the circuit.

Measuring Resistance

Before setting your meter up to take a resistance measurement, you must isolate the component or circuit being tested by disconnecting the wiring from one end of the component. Failing to do so might cause your meter to read the resistance of another component in the circuit instead of the component you intend to test. With the rotary selector switch on the meter set to "OFF," connect the common test lead to the black input jack on the meter labeled "COM," and connect the positive test lead to the red input jack labeled for resistance. Once both test leads are connected to the meter, turn the rotary selector switch to the "Ω" symbol and take a reading.

Extremely large amounts of resistance will be measured in kilohms (1 thousand ohms) "KΩ," or megohms (1 million ohms) "MΩ". If there is infinite resistance, your meter will display "OL" for open loop. This indicates that there is a break or open somewhere in the circuit you're testing. However, if you're testing to see if a set of contacts is open, you will want to see an "OL" reading.

Measuring Frequency

With the rotary selector switch on the meter set to "OFF," connect the common test lead to the black input jack on the meter labeled "COM," and connect the positive test lead to the input jack labeled for voltage. Once both test leads are connected to the meter, turn the rotary selector switch to the VAC symbol, press the frequency function button, and take a reading.

Measuring in-line Amperage

Some TO procedures for the ECS will direct you to take an "in-line" amperage reading in a circuit. In-line means that your multimeter acts as part of the circuit. To do this, set the rotary selector switch to "OFF," and connect the common test lead to the black input jack on the meter labeled "COM." Pay attention here, because amperage readings require that you connect the positive test lead to a different jack that you won't use often. Connect the positive test lead to the red input jack on the meter labeled milliamperes (mA)" Once both test leads are connected to the meter, turn the rotary selector switch to the mA position. Your TO will direct you to disconnect a wire, connect this wire to one multimeter test lead, and then connect the second multimeter test lead to the point where the wire was disconnected from. You are now ready to take a reading from the circuit, and your meter will display the amperage in mA.

You will only be directed to take in-line readings where very miniscule amounts of amperage are involved. In applications where the amperage draw is much higher, you will be using a clamp-on ammeter (described in this lesson) to take the readings.

Complete the content above before moving on to learn about clamp-on ammeters.

Figure 3–3. Clamp-on ammeter.

Clamp-on Ammeters

We already covered taking amperage readings in-line with the circuit being tested with the use of a regular multimeter. Clamp-on ammeters work differently, as you won't be disconnecting any wires to take your readings. The clamp-on ammeter has jaws which are opened and placed around the conductor (fig 3–3). An ammeter works by measuring the intensity of the magnetic field around a conductor, which is directly related to the intensity of the current flowing through the conductor. The clamp-on ammeter is primarily used to obtain amperage draw readings on commercial or standby power. However, observing the amperage draw of motors and other devices can be used as a valuable troubleshooting technique, which we will discuss in a later unit.

Features

In some regards, the digital clamp-on ammeter is much like the Model 87 multimeter. It has a rotary selector switch which lets the user select from a variety of functions, and if a pair of test leads are connected to the bottom jacks, you can check voltage and resistance with this meter as well. The clamp-on ammeter will automatically select the proper range, and also has a hold function which will display the last reading taken even after the ammeter is no longer clamped around the conductor.

Click on each (+) symbol below to learn how to measure alternating current (AC), direct current (DC), resistance, frequency, and in-line amperage.

Measuring Amperage –

To take amperage readings with the digital clamp-on ammeter, first determine if you will be taking readings on an AC system or a DC system. If the system is AC set the rotary selector switch to the VAC symbol, and if the system is DC set the rotary selector switch to the VDC symbol. Place the meter jaws around only a single wire to be tested because the reading will not be accurate if more than one wire is inside the set of jaws. Your meter will now display the amperage draw of the circuit you're testing. Make sure there is no gap between the two jaws—you will not get an accurate reading, or may not get a reading at all, if the jaws are not physically touching. If dirt or debris is keeping the jaws from making contact, clamp the jaws on a piece of sandpaper and then simply pull the sandpaper through.

Measuring Alternating Current

With the rotary selector switch set to "OFF," connect the common test lead to the input jack on the bottom meter labeled "COM," and connect the positive test lead to the positive input jack on the bottom of the meter. Once both test leads are connected to the meter, turn the rotary selector switch to the VAC symbol.

Measuring Direct Current

With the rotary selector switch set to "OFF," connect the common test lead to the input jack labeled "COM," and connect the positive test lead to the positive input jack. Once both test leads are connected to the meter, turn the rotary selector switch to the VDC symbol.

Measuring Resistance

Before connecting the meter, be sure to isolate the circuit you're testing by removing power and disconnecting one side of the circuit. With the rotary selector switch set to "OFF," connect the common test lead to the input jack labeled "COM" and connect the positive test lead to the positive input jack. Once both test leads are connected to the meter, turn the rotary selector switch to the "Ω"symbol and take a reading. This lesson on digital multimeters and ammeters contains a lot of step-by-step information on how to properly operate them. In the next lesson, you will see just how valuable these two tools are for troubleshooting electrical circuits. You might become so adept at troubleshooting with these devices that you'll be able to find a fault in an electrical circuit in the amount of time it takes you to open your TO or CEM to the correct procedure! Let these meters do the work for you.

Complete the content above before moving on to learn about clamp-on ammeters.

Staff Sgt. Jared Hilde, 91st Missile Maintenance Squadron facilities maintenance section team member, reviews maintenance technical orders at a launch facility near Minot Air Force Base, North Dakota. The FMS is comprised of more than 50 technicians responsible for maintaining all of the base's launch facilities.

One could say that finding a fault is the process of working from the most obvious solution to the least obvious one. Your ability to effectively troubleshoot could mean the difference between an easy day in the field and a very long day spent troubleshooting a simple fault. In this lesson, we'll cover the most effective methods for isolating malfunctions in electrical circuits. We will discuss the different types of electrical malfunctions, as well as how to isolate them with a multimeter. Then we'll look at some of the common electrical components in the weapon system and how to identify problems with them. Lastly, we will cover the purpose of schematics and review various characteristics and types of schematics and wiring diagrams you will use in the field to aid in troubleshooting faults. Using these tools, coupled with your experience, will help you tackle any system malfunction.

Troubleshooting Steps

Electrical troubleshooting is the step-by-step process for analyzing, locating, and correcting malfunctions. The purpose of troubleshooting is to isolate a fault or malfunction, and return the system back to its normal operating condition as quickly as possible. Troubleshooting is largely a mental endeavor, and one that can be very taxing and exhausting at times. In order to be effective at it, you have to have the proper mental state and follow a logical order of fault isolation. Here are some actions to keep in mind as you get started.

Click on each arrow and then flip each card to learn about the troubleshooting recommendations and the actions you should take.

Number 1: Troubleshooting Recommendation Actions to Take

Do not jump to conclusions; follow a troubleshooting path until it has been exhausted or leads to the fault. To troubleshoot effectively, you must follow a systematic procedure, not a haphazard "here–and–there" approach. This will help you track down the fault in a minimum amount

1 of 6

Number 2: Troubleshooting Recommendation Actions to Take

Use your experience. Just because you have seen a particular fault in the past does not automatically mean it is the problem this time. Don't get stuck thinking this is the only answer. This will cause you to overlook additional faults or the actual fault entirely.

2 of 6

Number 3: Troubleshooting Recommendation Actions to Take

Be open to suggestions. Sometimes a new set of eyes can help identify a troublesome fault. Use the experience of others in conjunction with your own.

3 of 6

Number 4: Troubleshooting Recommendation Actions to Take

Be wary of fatigue. Troubleshooting can be taxing at times and frustrating for some individuals. Take a break or give someone else a try—most technicians have a hard time following a logical process when they are tired or frustrated.

4 of 6

Most importantly, the TO and CEM have schematics, and you should use them in conjunction

Number 5: Troubleshooting Recommendation Actions to

with your procedures. When following procedures, know

Number 6: Troubleshooting Recommendation Actions to Take

Use the TO and/or CEM and use your head! You have to use both of them and you cannot abandon either one in your troubleshooting efforts. Do not follow the TO or CEM blindly without knowing what you are checking, and use your troubleshooting knowledge when the procedure is leading

Complete the content above before moving on.

Below you will learn about the six fundamental steps to troubleshooting and the order they should be accomplished. Click on the "start" button to begin.

The Six Fundamental Steps to Troubleshooting

There are six fundamental steps to troubleshooting and the order they should be accomplished. Troubleshooting the many intricacies of the Minuteman III weapon system ECS and power generation and distributions systems is not something you will immediately master. Troubleshooting requires a logical plan to identify the fault, a good understanding of basic electrical theory, and an understanding of the specific equipment that you're working with. There are six fundamental steps to troubleshooting. They are listed below in the order they should be accomplished:

1. Perform a preliminary checkout.

2. Perform an operational checkout.

3. Locate a troubleshooting procedure and corresponding schematic.

4. Locate the malfunction.

5. Perform the corrective action (fix the problem).

6. Perform a final operational checkout.

Step 1

Perform a Preliminary Checkout

The first step in troubleshooting is to perform a preliminary checkout. The purpose of a preliminary checkout is mainly to see if there are any obvious indicators or “low hanging fruit” that might point you in the right direction. This can involve several things—but remember that you cannot start probing or making corrections without first referring to your TO or CEM. Here are some things to look for in your preliminary checkout: Use your senses.

- Listen to the system. Determine what components are operating or not operating. Listen for chattering relays, louder than usual motors, or out of balance fans. Listen for anything that does not sound like it is supposed to. After spending enough time on various MAFs and launch facilities (LF), you will become very aware of how the various systems sound when everything is running as it should be. This will give you a good starting point for your troubleshooting.
- Look at the system. Check electrical components for signs of damage from overheating. Look for charred wires. If your system has clear glass fuses, check them with a flashlight to see if they are blown. Visually inspect the wiring to ensure it is all tightly connected and the insulation is intact. Check for corrosion on components. Check for fluid leaks. Check circuit breakers and switches to ensure they are in the proper position. Check alarm indicators, such as the lights on the input/output modules or the light-emitting diodes on the MPP. A good visual inspection starts you on the right road and might even reveal the fault itself. Be cautious though—sometimes what you see is the result of a fault and not the fault itself.
- Smell for abnormal odors. This probably sounds strange, but you will likely be able to smell when an electrical malfunction has occurred when you enter the room or area. Burnt wires or motor windings have a very pungent and particular odor.

- Lastly, touch the different components if necessary. If you are unsure a fan or motor is operating, touch it. If a component that normally operates very smoothly is suddenly vibrating badly, you may have located a problem.

Step 2

Perform an Operational Checkout

Regardless of whether your preliminary checkout turned up any obvious clues or not, the next step is to perform an operational checkout. The purpose of an operational checkout is to discover the first part of the system that does not operate normally. For example, if you begin an operational checkout of the payload transporter (PT) auxiliary power unit (APU), you may find that it won't even start. Or, you may find that it does start, but doesn't run for very long before it shuts down. From this you can immediately assume that you shouldn't waste your time troubleshooting the battery and the starter because the APU already runs. If this is not possible because the system or piece of equipment cannot run, you'll have to skip the operational checkout. Here are some things to consider when performing an operational checkout during troubleshooting:

- If you find a problem, do not overlook it because you don't think it could be the problem.
- If you receive an odd reading or a different reading each time you probe, you may want to take a reading with another meter. This is not very common, but a faulty meter can send you down the wrong path.
- Continue to use your senses during the operational checkout. For example, look for visual problems, listen for abnormal noises, and smell for unusual odors when you run the PT APU.

If you encounter an abnormal indication, perform the corrective action listed in the TO or CEM. If you cannot perform an operational checkout, you'll need to locate a troubleshooting procedure.

Step 3

Locate a Troubleshooting Procedure and Corresponding Schematic

Sometimes locating a troubleshooting procedure and an accompanying schematic is easy. When troubleshooting the ECS, a table in the TO will ask what mode of operation the system is in and what alarm conditions exist in order to help direct you to a procedure. When troubleshooting the power system, the CEM has a list that you can use to match indications on the MPP to specific troubleshooting procedures. Other procedures are in table format with a simple list of problems and possible causes. In a lot of cases, when performing an operational checkout, the corrective action listed in the TO or CEM for an abnormal indication will refer you straight to a troubleshooting procedure.

Step 4

Locate the Malfunction

The fourth step in troubleshooting is where you'll actually locate the malfunction, and this will usually be the most difficult and time-consuming step. This is where you combine your experience and system knowledge with the procedures and schematics you are using. Here are some useful hints on locating the malfunction:

- Sketch the circuit you're working with on a separate piece of paper so you don't get muddled with looking at the entire schematic. Once you're familiar with your schematics and diagrams you probably won't need to do this anymore.
- Using the schematic, understand what the procedure is directing you to check and why. This will eliminate components once they pass their checkout and will also help you recognize when the procedure is not leading you in the right direction. Remember, with a TO, you must use the procedures in all situations, but with a CEM, you can troubleshoot using schematics alone if your procedures do not lead you to the problem.
- Refer to the TO or CEM descriptions for how a circuit should operate. The description of how a system operates is usually in section or chapter 1 of a CEM or TO.
- When troubleshooting a large system using only a schematic, break the system down into smaller parts. Instead of checking directly at the source of power, check power at the component that should be receiving power. If that component is receiving power, you know the rest of the circuit has power and you won't need to check every single test point along the way.
- If the component is receiving power, but not repositioning or operating as it should, isolate that component and take resistance measurements. This will tell you if the coil on a motor starter or other electrical component is defective or not.

Once you locate the malfunction, the next step is to perform the corrective action to repair it.

Step 5

Perform the Corrective Action

Once you locate the malfunction, you must complete the corrective action. When you're doing this, make sure that you always perform a neat and permanent-type repair using TO or CEM approved parts and methods. Do not use a "Band-Aid" or temporary-type fix; otherwise you or another team may have to return and re-accomplish the repair when the problem returns.

Step 6

Perform Another Operational Checkout

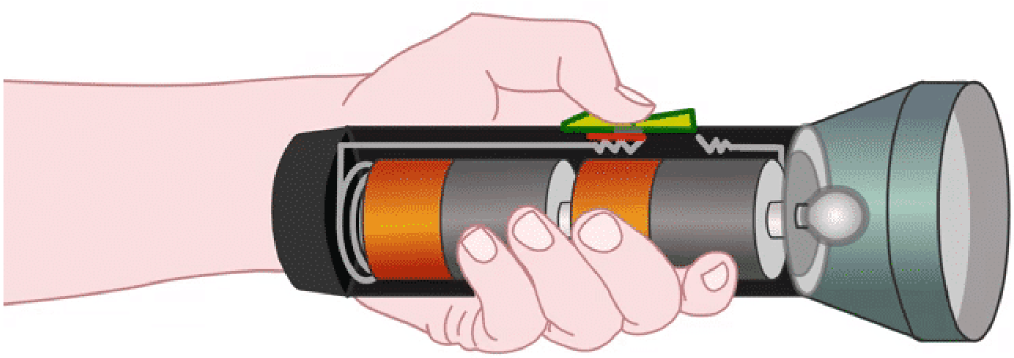
Once you have successfully troubleshot the system, located the malfunction, and have repaired it, you need to verify your work. Always perform a final operational checkout on the system you just repaired using procedures in the TO or CEM. If you fail to perform this step, there is no way of verifying that you have fixed the actual problem, and other problems could exist that were overlooked. Your mission is complete when you have restored the system to operational status and performed a successful operational checkout!

Complete the content above before moving on.

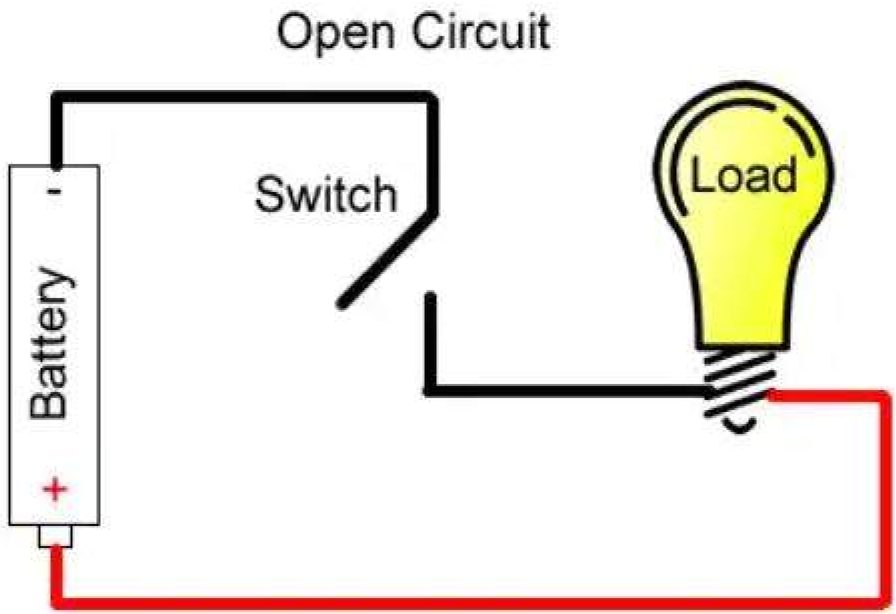
Electrical Malfunctions

To aid in your troubleshooting effort, you must be able to recognize some common electrical malfunctions and how to find them. The two most common electrical problems you will encounter are open circuits and short circuits.

Click the play button below to to watch a simple flow of current when a circuit is opened and then closed.



Complete the content above before moving on.



A open circuit can be intentional or unintentional. An intentional open circuit is one that has a switch light in the picture. An open circuit can also be caused by a break in the wire.

Open Circuit

An open circuit, or 'open', is an incomplete path within a circuit that interrupts the flow of current. These can be caused by a broken wire, a blown fuse, a relay or switch that doesn't close, or when any other device in the circuit fails to provide a complete electrical path.

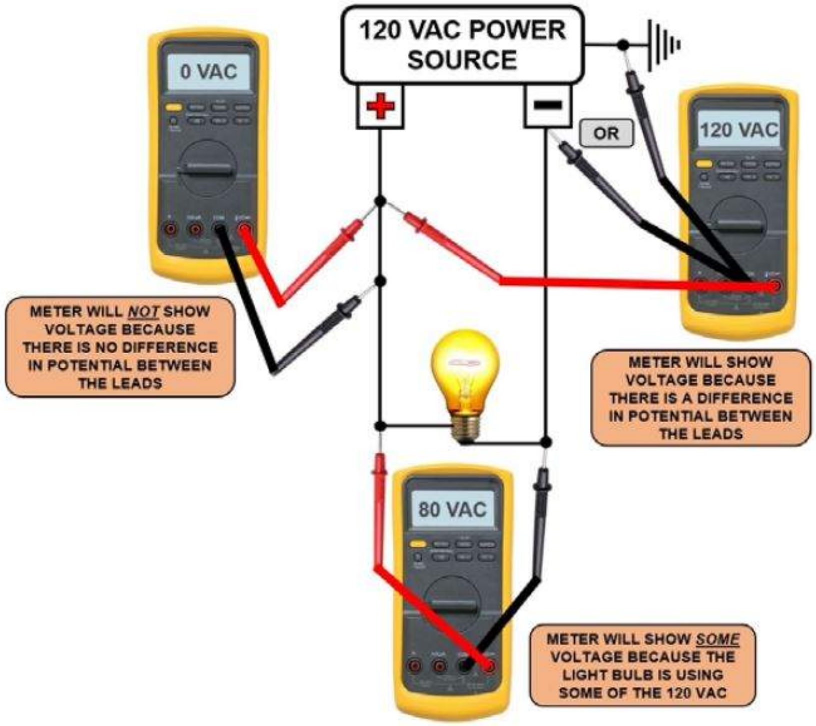
A multimeter is the best way to locate an open, and there are two methods that are typically used.

Below are two ways to check for an open circuit. Click on each (+) to learn about voltage and resistance checks.

Voltage Checks

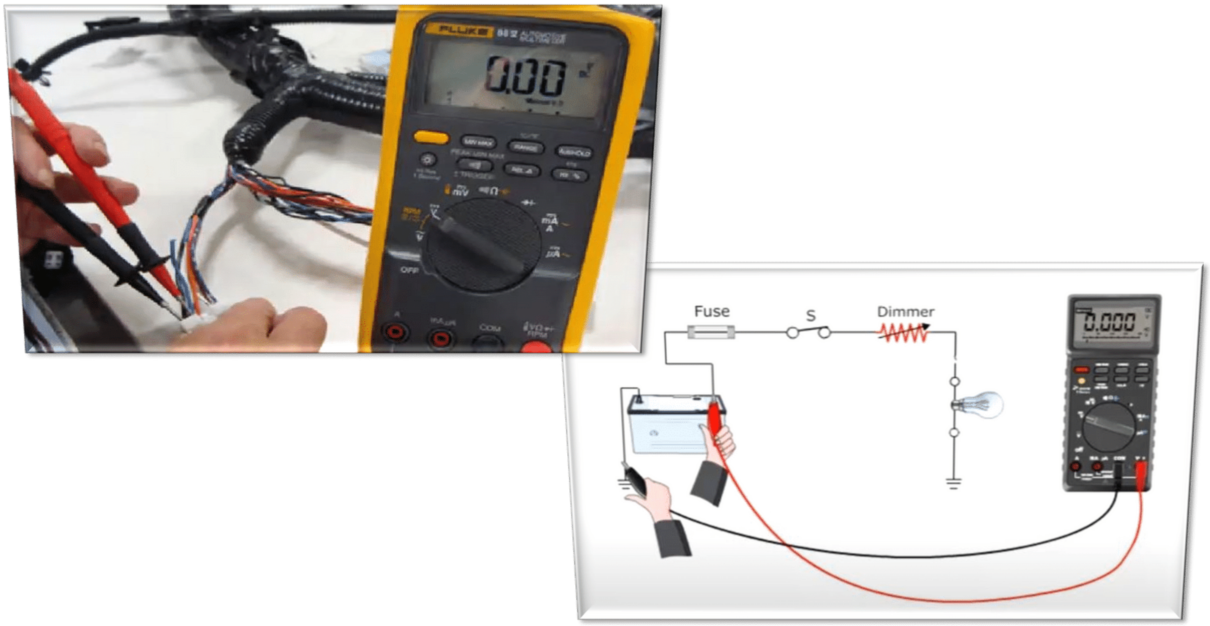
To find an open circuit using the voltage setting on your multimeter, power must be applied to the system. Check the voltage with your positive test lead by touching the power side and the negative test lead to a ground point. Using a schematic, locate test points on the suspected open circuit. Initially you will see a voltage reading, 120 VAC for instance, when testing between powered parts of the circuit and the ground. You will eventually test a point where you see no voltage, and the open circuit is between the last voltage reading and this no voltage reading. Pretty simple, right?

The reason that you're able to troubleshoot an energized circuit with a multimeter is because the meter measures the difference in potential between the two test leads. If you use a multimeter to test between two different points on the same wire that has 120 VAC on it, your meter will not show 120 VAC or even 240 VAC. Why is this? Since you're testing in two places on the same wire, there is no difference in potential or voltage. The same 120 VAC is on the wire at both spots you're testing. Now, take this same concept and apply it to a wire that has 120 VAC on it, and a ground point that has zero VAC on it. What is the difference in voltage? You would be correct if you said 120 VAC, because that is the difference between 0 VAC and 120 VAC. That is how your multimeter works. The difference that is displayed on your multimeter is the difference in the voltage between your positive test lead and your negative test lead. It is easiest to check from a positive terminal to a ground terminal. If your ground system is intact, you should have no voltage on it. Figure 3–4 better illustrates this.



Resistance Checks

To find an open circuit using the resistance setting on your multimeter, remember that power must not be applied to the circuit. Isolate the circuit or component being tested by removing the wiring from either the positive side or the negative side. Check the first test point in your circuit to any other test point in the circuit. A reading of 0 **Ω** indicates that there is continuity between the two points you have your multimeter connected to. Continue checking from the start of the circuit, all the way through the end of the circuit until you finally receive a reading of "OL," which indicates that you've found the open in the circuit. The open circuit exists between the two points your test leads are connected to when you receive an OL indication.



Complete the content above before moving on.

Short Circuit

A short circuit, or "short", is a little harder to find. There are protective devices that open, or break a circuit, in order to prevent a short from damaging the system. For example, if you discover an open fuse, in almost every case, there was a short somewhere else in the circuit that caused excessive current, which in turn caused the fuse to open (blow). Do not replace a fuse until you first find a short or verify the absence of one. There are three types of shorts you might encounter:

- Direct short
- Cross short
- Shorted control

Current flowing through a wire heats the wire. The length of a wire affects its resistance, which determines how much current flows in the wire and how hot the wire gets.

Below are three types of shorts. Click on each (+) to learn about direct, cross, and shorted control shorts.

Direct Short

A direct short occurs when positive and negative conductors make direct contact. Current flows from positive to negative during normal circuit operation, and there is some sort of resistive device, or load in the circuit that consumes that current. A direct short completely bypasses the resistive device and usually causes an excessive amount of current draw in the process. If the excessive current continues long enough, fuses will blow or wires will melt until the circuit opens, interrupting the current flow.

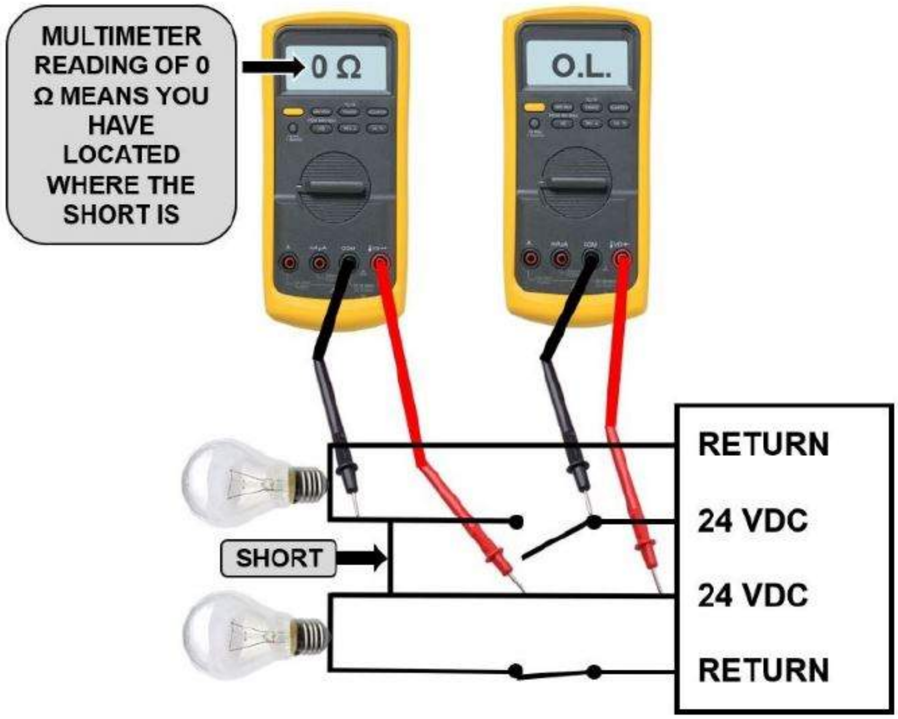
Direct shorts can be located using the resistance function on a multimeter. Remove power to the circuit, verify the absence of voltage, and isolate the part or circuit. All of the ground terminals in the system you're working on are generally interconnected through direct metal contact or other wiring. For instance, if you were to set your multimeter for resistance, and checked between one ground point in the brine chiller control panel, and another point all the way over in the air handler control panel, your meter would show 0 Ω. Check resistance between the ground terminal and the positive conductor.

If OL is indicated, there is not a short between the point you are checking and ground. Continue isolating and reconnecting each part of the circuit and performing resistance checks with your multimeter. Once you get a 0 Ω indication, you have found the location of your short (or continuity where there should be none) in your circuit.

Cross Short

A cross short occurs when the positive conductors of two or more independent circuits make contact. This usually does not result in excessive current, blown fuses, or melted wires; it simply applies power to a circuit that was not supposed to have power. A cross short is illustrated in figure 3–5—do you see how both 24 VDC circuits have continuity even though the switch on the top circuit is open?

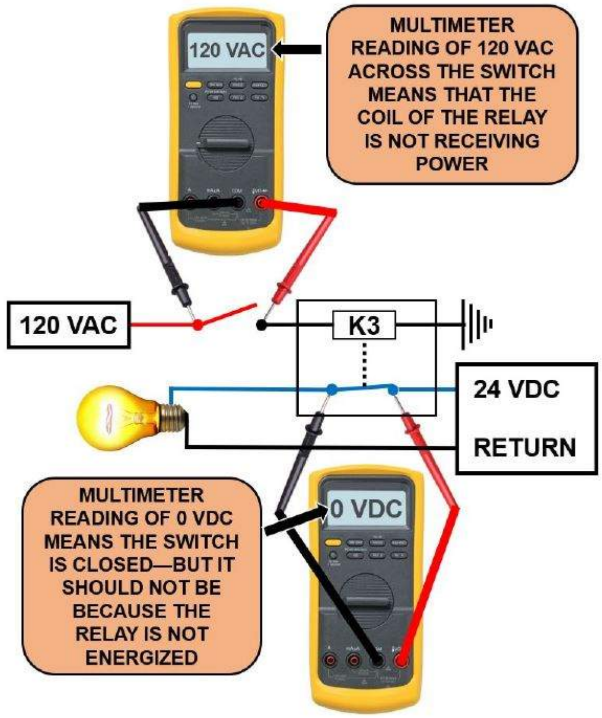
The same procedure for locating a direct short is also used to locate a cross short. The only difference is that you check resistance between the two circuits instead of resistance between the positive conductor and ground.



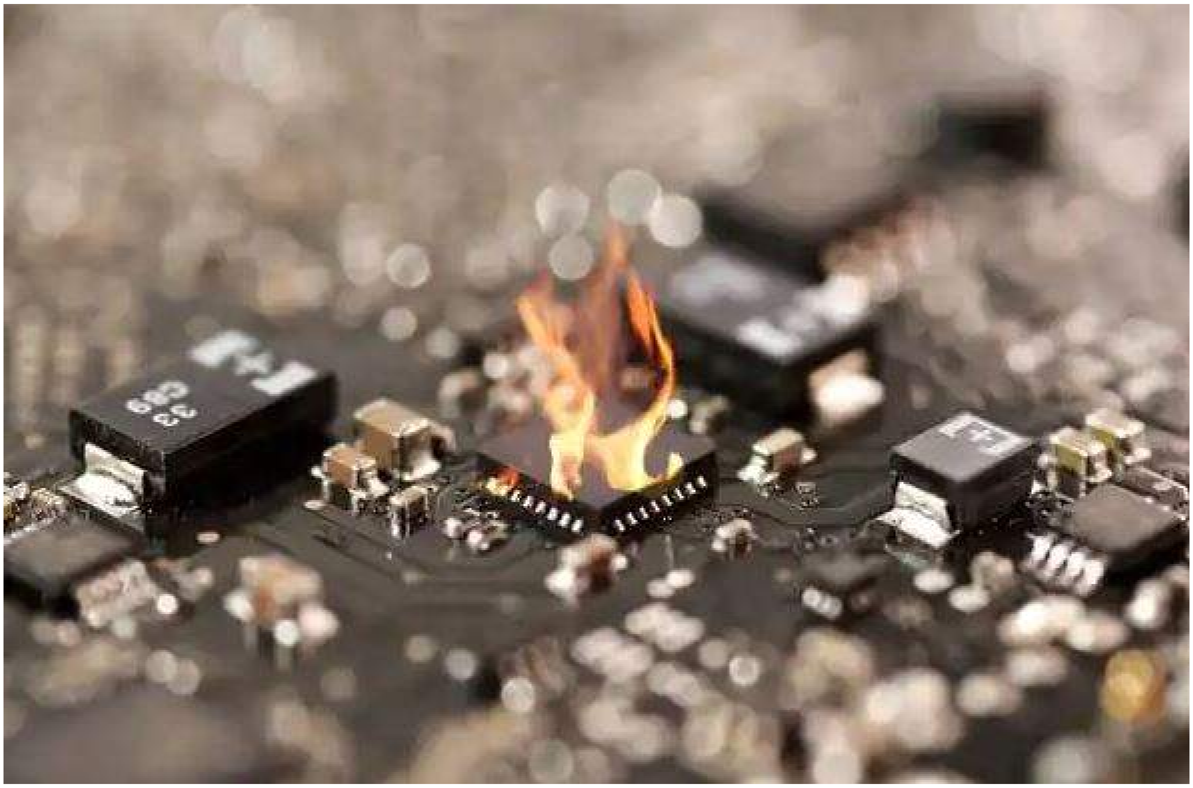
Shorted Control

A shorted control occurs when the contacts of a switch or relay are stuck together. A good example is the contacts of a relay remaining closed even after power is removed from the relay's coil. This would cause power to continue to flow through the relay contacts to the device it controls.

These problems are easy to locate. Remove power from the actuating device and check for voltage on the output side of the device's contacts. If there is voltage, the control is shorted and needs to be replaced or cleaned. A shorted control is illustrated in figure 3–6, do you see how 24 VDC power is still flowing through the contacts of relay K3 even though the coil is not energized?



Complete the content above before moving on.



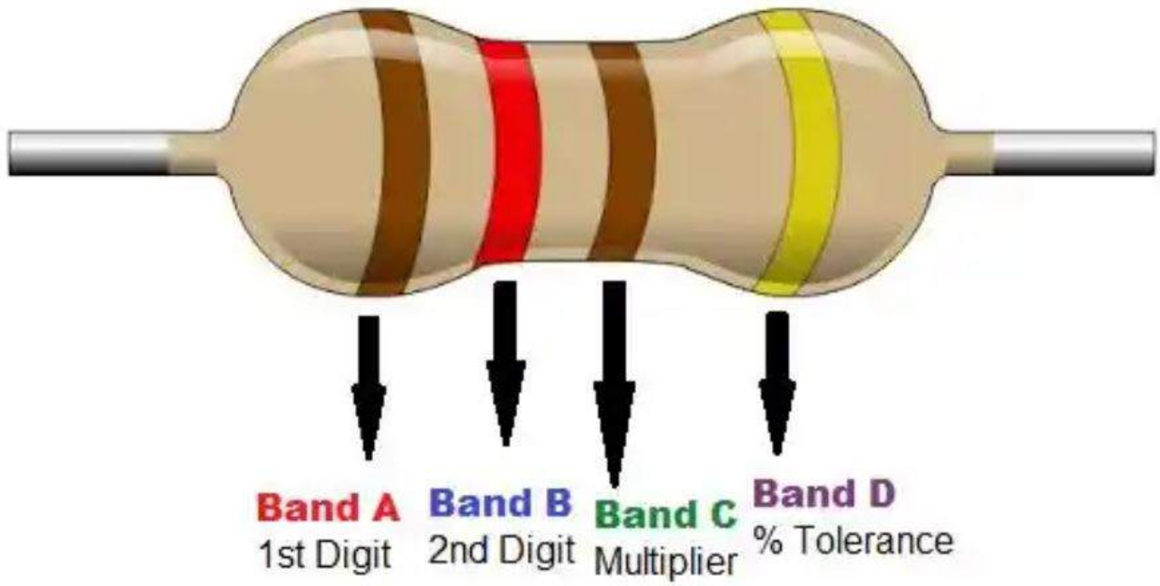
Faulty Components

Faulty components are often the cause of electrical malfunctions and require the troubleshooter to have a basic understanding of how to check their operation using a multimeter. Here is how to check some common components.

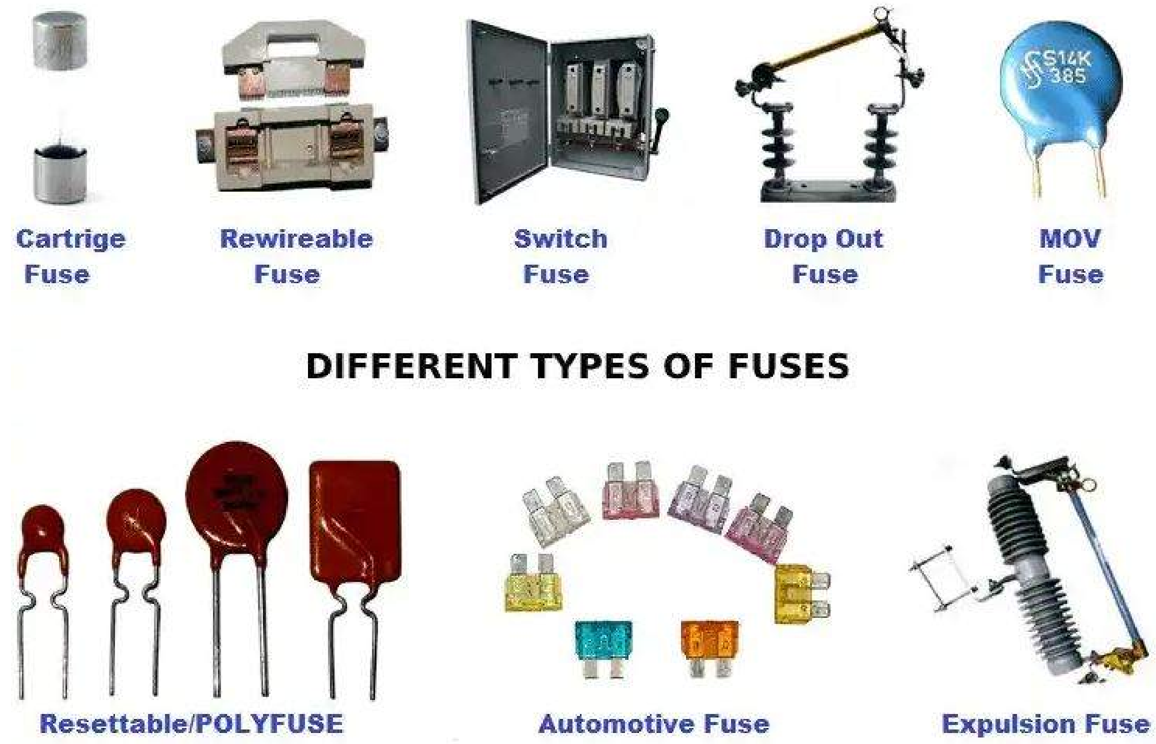
Listed below are some common ways to check components. Click on each tab before moving forward in the lesson.

RESISTORS	FUSES	DIODES	COILS AND WINDINGS	SWI BRE

Resistors are easy to check. Each resistor should have a resistance value indicated in the TO. Isolate the resistor from the circuit and measure the resistance across its terminals. If the measurement you get does not match TO or schematic specifications, then your resistor is defective. There are large resistors in the ECS system that you will sometimes find have malfunctioned.



To check to see if a fuse has opened, remove it from the fuse holder and measure the resistance across it. A serviceable fuse will have no resistance (0 Ω); a blown fuse will read OL. Some fuses used in the power generation and distribution system will show 20 Ω of resistance when you check them with your multimeter—this is normal and will be indicated in your TO or CEM. As long as a fuse does not have excessive resistance or read OL, it is serviceable.



RESISTORS	FUSES	DIODES	COILS AND WINDINGS	SWI… BRE…

Diodes are designed to allow voltage or signals to travel in only one direction, which is why your CEM or TO will direct you to check resistance in both directions after isolating the component. For example, a DC transzorb (zener diode) should read 0.6 Ω in one direction but read OL when you reverse your meter test leads. If the indications you receive do not match TO or CEM specifications the diode is defective.

RESISTORS | FUSES | DIODES | COILS AND WINDINGS | SWI BRE

Coils and windings can be found in motors, transformers, and relays. With power removed from the circuit, isolate the component by disconnecting the incoming wiring. Measure the resistance between the power supply terminal and the ground terminal on the component. If the resistance value of a coil or winding is not specifically stated in a CEM or TO, you may be able to find it on the data plate that is attached to the motor. A serviceable coil or winding should have some amount of resistance, but it should not be extremely low or extremely high. If you're troubleshooting a motor winding, it is invaluable to test the resistance of the winding in one phase against the others. Use the brine pump as an example. If the A and B phase windings have 40 ohms of resistance, and the C phase winding has one megohm of resistance, you can plainly tell that the C phase winding is open. Remember that the coil is the resistive load in the circuit, and it performs work by using the voltage and current provided by the power source.

You also cannot forget to test each phase to see if it is shorted to ground. If A and B phase motor windings show one megohm to ground, but C phase shows 15 ohms to ground, you can plainly tell that the C phase winding is shorted to ground or to the case of the motor. Always investigate when one coil or winding does not have the same resistance readings that other identical coils or windings have.

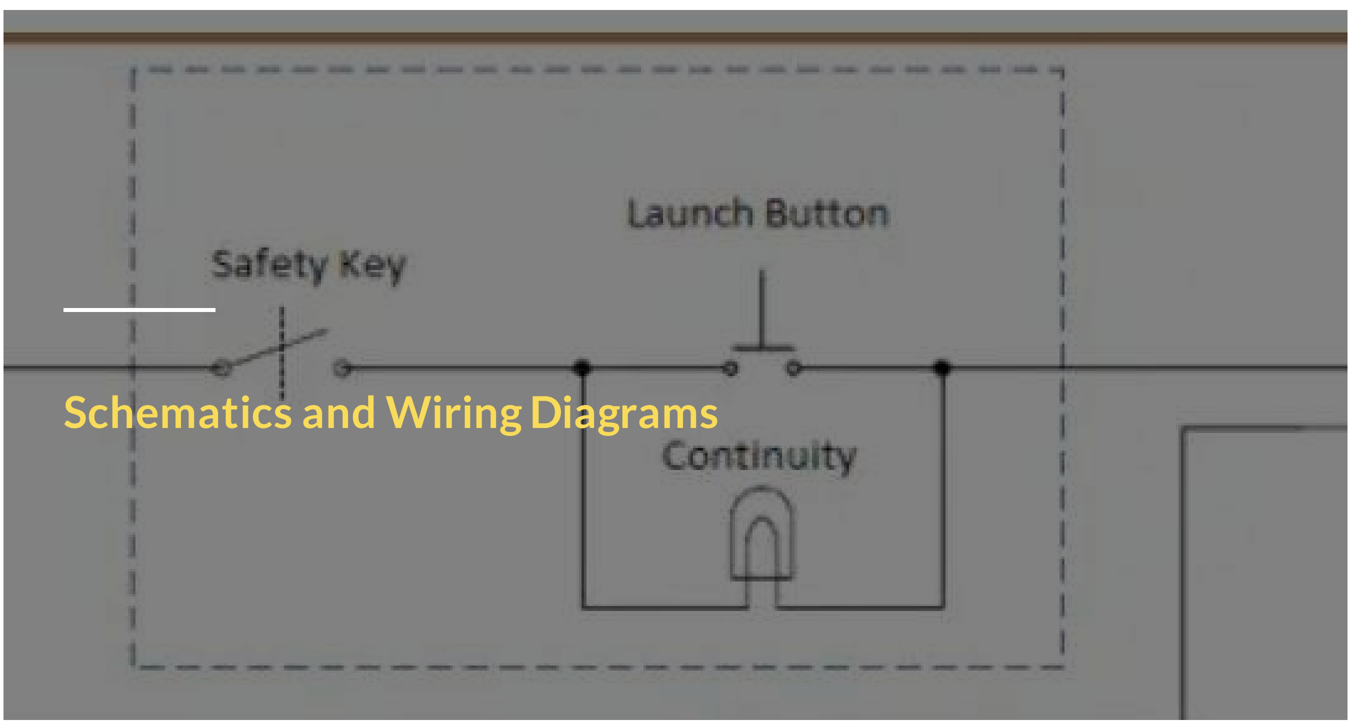
If you are troubleshooting a coil or motor winding using an ammeter, keep in mind that when a motor or component is first starting up, it draws high amperage for an instant and then drops back to normal operating amperage. This condition is generally referred to as the startup current. Unless your TO specifically tells you to measure startup current draw, do not mistake this high amperage on startup as an abnormal indication. Whenever possible, you should perform amperage checks when the system is running normally, and not in the middle of starting up.

RESISTORS	FUSES	DIODES	COILS AND WINDINGS	SWI... BRE...

You can check these components with power either on or off. To check with power applied, set your multimeter up for voltage and measure the difference of potential between the input and output wires of the component. 0 volts indicates the switch or contact is closed because there is no difference of potential between the incoming and outgoing terminals. If your multimeter measures a large difference in potential when the switch or breaker is closed, this is a telltale sign that the component isn't working correctly.

To troubleshoot these components using resistance checks, isolate the wiring and check resistance between the terminals while the switch or contact is closed. A 0 Ω indication means that the switch, circuit breaker, or contact is closed, while an OL indication means the opposite.

Complete the content above before moving on.



Schematics and Wiring Diagrams

There’s no doubt about it, when it comes to troubleshooting, being able to interpret wiring diagrams and schematics can save you hours of headache. These are visual representations of how a system operates, which is beneficial for learning, and is the only way that some people learn effectively. Before we discuss the specific diagrams that you will work with in later modules, it is important that you first understand their characteristics.

Purpose

Most of the systems you work on are complex and require some sort of diagram. These diagrams are very useful and serve three purposes; these purposes are in the following table. As we mentioned earlier, diagrams can be your best friend when it comes to troubleshooting.

Three Purposes of Diagrams	
Element	**Description**
To show system components	Diagrams show system components using a variety of symbols and abbreviations. The diagram does not typically represent the component’s exact location on the site, but rather the most logical location to allow you to understand it.
To allow comprehension of system operation	A diagram provides a visual picture of how components interact with each other. When a diagram is combined with the system descriptions from the TO or CEM, you have the ability to read the description while you move through the diagram which will help you to gain a better understanding of how a system operates.

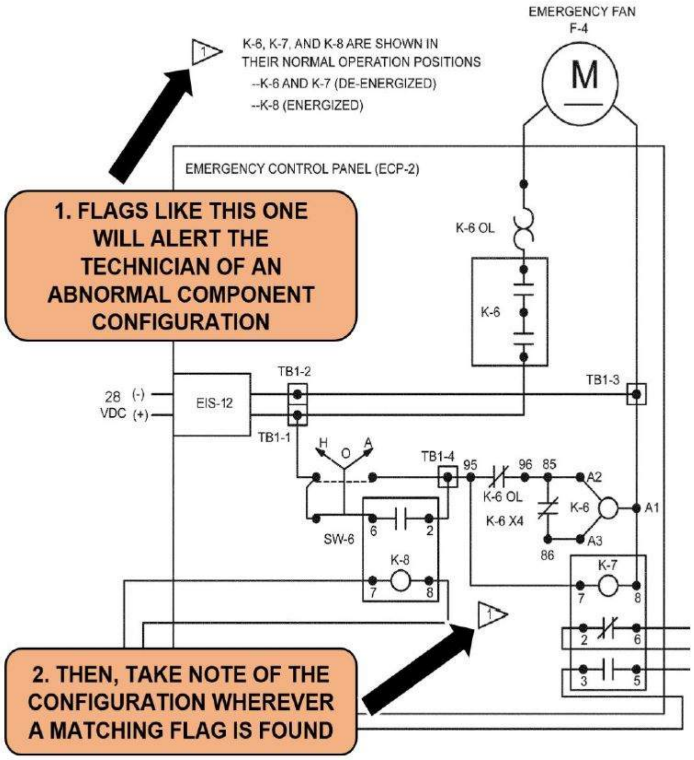
To aid in troubleshooting electrical systems	A diagram can provide a quick representation of a suspected circuit. It is a road map of sorts, allowing you to quickly trace the circuit to the cause as you follow the TO or CEM procedure and take meter measurements.

Characteristics

Diagrams have several characteristics in common. Understanding these characteristics is pivotal to understanding and interpreting a diagram. Click on each (+) below to learn about the different characteristics.

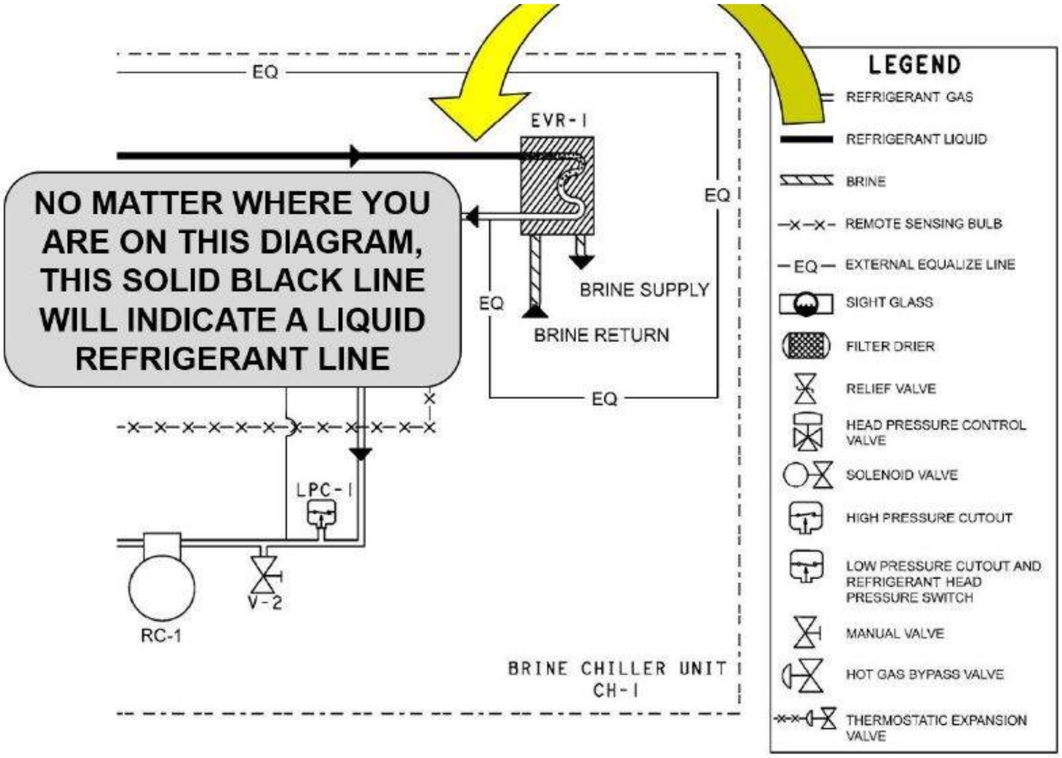
De-energized State

Most diagrams you will use are drawn in the system's de-energized state, which is intended to make understanding system operation easier. This means no power is applied, and all switches and contacts are in their de-energized positions. It helps if you envision a brand-new site that has just been built but has not been powered up yet. The switches, components, and contacts will remain in that state until the system is energized, and this makes it easier to understand system operation. It is much easier to imagine that a component is energized when tracing a circuit than imagining it de-energized. There are some instances where a schematic or diagram may be drawn in the energized state. If this is the case, the diagram will indicate this for you. The flag note "1," shown at the top-left of figure 3–7, indicates that several relays in the emergency fan control panel are drawn in the energized position.



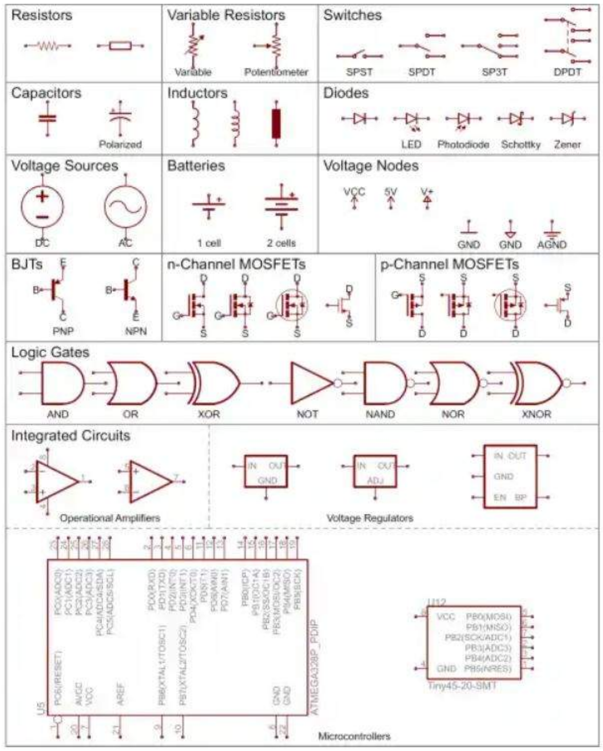
Legends

Many diagrams contain legends, and similar to the legend on a road map, these diagram legends identify what the pieces and components of a schematic represent. There's generally not enough room on a diagram to provide a description next to each and every component, and as a result the legend simplifies the diagram and makes it easier to read. Look at the legend illustrated in figure 3–8, it indicates that the solid black line entering the evaporator coil (EVR–1) on the brine chiller unit contains liquid refrigerant. You now know that every other occurrence of this solid black line indicates liquid refrigerant.



Symbols

Graphic symbols are used to represent system components and parts, and they do not necessarily represent a component's physical appearance, but rather its function. We will explore symbols thoroughly when we look at the power and ECS schematics. Symbols further simplify diagrams and, coupled with the component designators, can help you to quickly understand what every symbol on a diagram represents. It may look a bit overwhelming at first, sort of like learning another language. With a bit of time and practice, these symbols will become second nature to you, and read like words on a page.



Abbreviations

Space is usually an issue when developing diagrams, and for this reason many abbreviations are used in the place of spelling out the name of every item. Component designators are used to show components in short form, and these designators can usually be found in a table in your TO or CEM that lists each component on a diagram along with its designator and actual nomenclature. As an example, the following table shows you some abbreviations and designators from the MAF and LF power system schematic.

Abbreviation Example	Meaning
TB40–15	Pin 15 of terminal board 40
FU3	Fuse Number 3
C2TS	Contactor 2, transfer switch
K1-4	Pin 4 of relay 1

SW2	Switch number 2
BC6	Pin 6 of the battery charger
R7	Resistor number 7

Complete the content above before moving on.

Types

Just as there are different types of road maps, such as topographical and political, there are also different types of diagrams. Now that you have an understanding of how a diagram is drawn with the legends, abbreviations, and symbols, let's look at the three types of diagrams you will likely encounter:

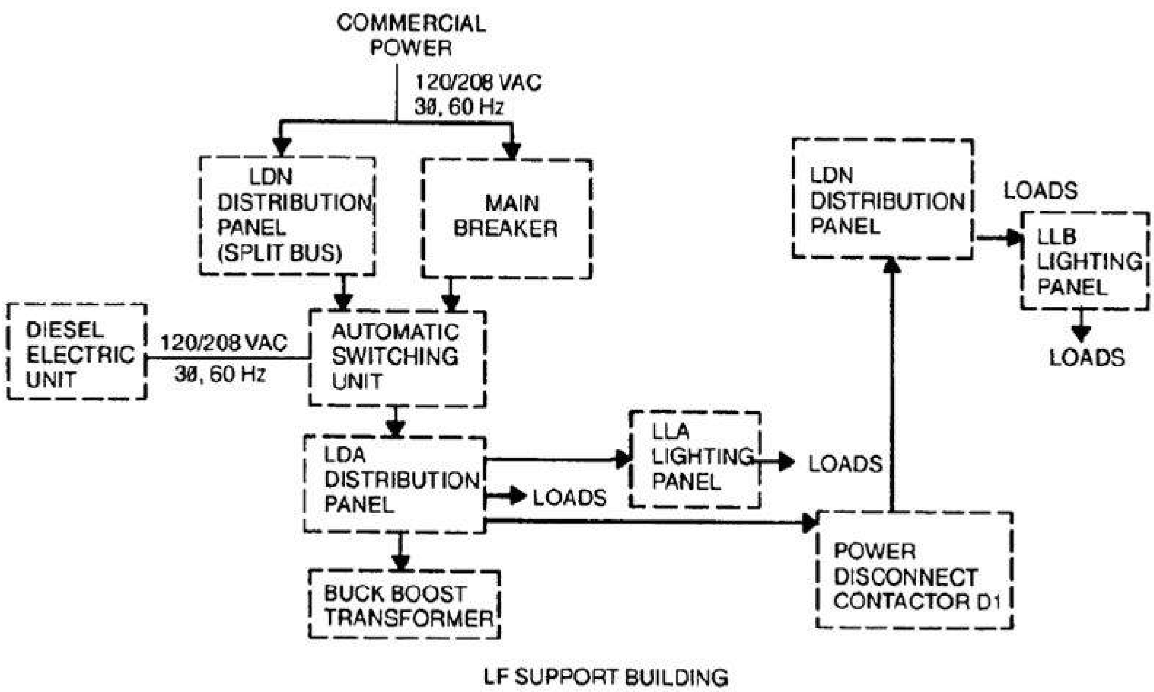
- **Functional or block diagram**
- **Wiring diagram**
- **Schematic diagram**

Click on each (+) below to learn about the different types of road maps.

Functional Diagrams

Functional diagrams are often called block diagrams, and they're designed to provide a "big picture" view of the system (fig 3–9). As the name implies, they are drawn in the form of blocks that represent major end items or components, and they won't show you the inner workings of each end item or component.

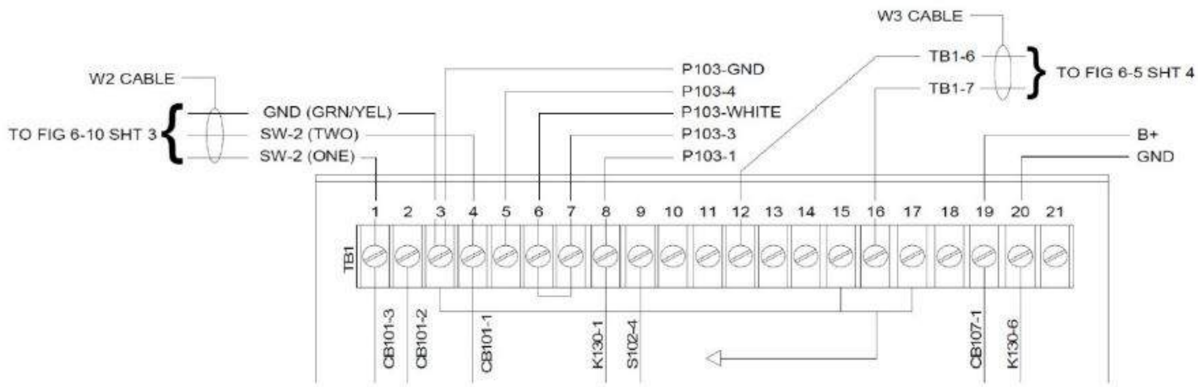
Connecting lines are used to show relationship between the different blocks, and these are usually electrical connections with arrows that show the direction the path is traveling. Functional or block diagrams are very useful because they give you a quick and general view of a system. When provided, they can be used to identify individual circuits because the block is named after the circuit being represented. Figure 3-9 shows a typical block diagram.



Wiring Diagrams (1)

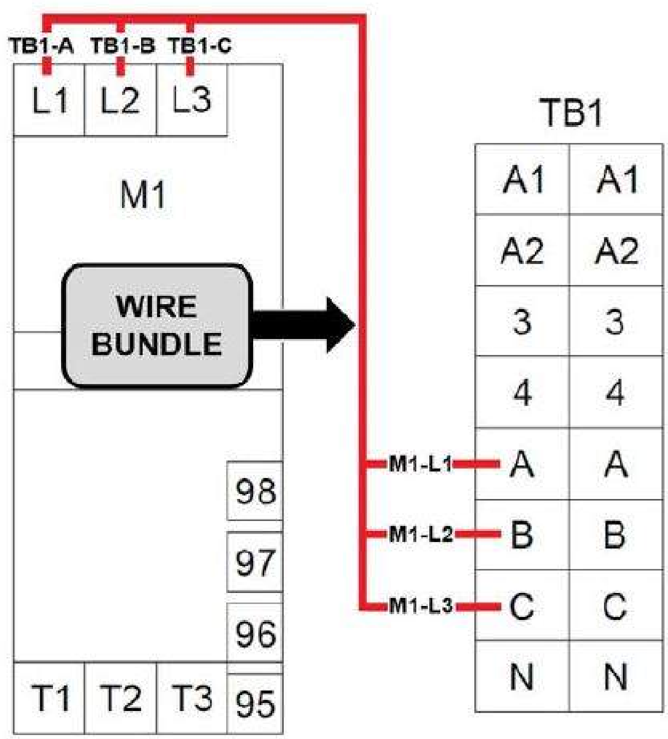
Wiring diagrams are designed to show point-to-point connections between components (fig 3–10). They are commonly separate from schematics and have very few electrical symbols, if any. Wiring diagrams are useful when troubleshooting opens and shorts and when replacing components.

When they're used for troubleshooting they provide quick wire number references for suspected circuits, allowing you to physically trace the circuit and verify a component is wired properly. This information is especially useful to identify where particular wires attach when replacing a component.



Wiring Diagrams (2)

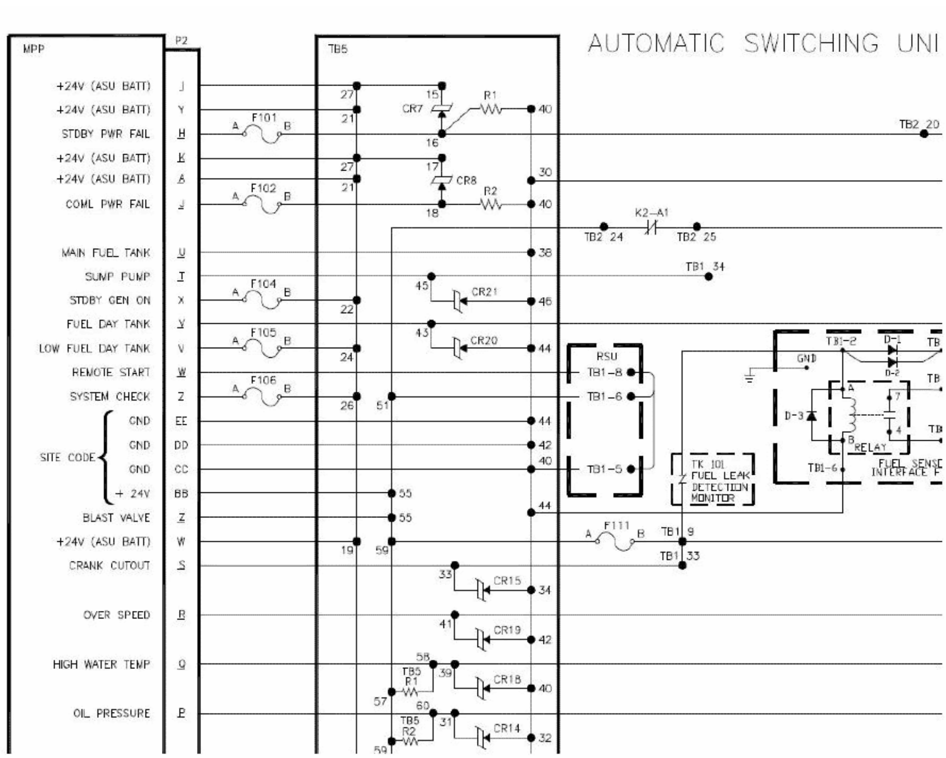
Wiring diagrams can have either or both forms of representation—wire bundles or individual wire runs between terminals. Wire bundles have alphanumeric designators and contain more than one wire (fig 3–11). Notice that the destinations of specific wires are listed at the beginning of the wire bundle, and the end of the bundle shows you where the wires originated from. Individual wire runs contain the same information at the termination point of the wire.



Schematic Diagrams

Schematic diagrams illustrate the interconnection of components within a circuit, and most also include component values, tolerances, and standard symbols (fig 3–12). A schematic diagram does not indicate the physical arrangement of the components, but rather shows how the components are interconnected.

Schematic diagrams are formulated through a combination of connectors, wires, cable runs, and components of a system. Even though schematic diagrams look complicated, they are designed to be easy to read since they represent all of the operational elements included in a system or unit. The schematic is the most important and useful diagram for troubleshooting and understanding system operation.



Complete the content above before moving on.

Environmental Control System Schematics

ECS schematics are different from other schematics because they include visual representation of refrigerant lines, brine lines, airflow ducts, damper actuators, and a variety of other components that have different pressure ranges and positions. As with troubleshooting the system, you will get better at putting it all together in your mind the more you do it.

Power System Schematics

Using a power system schematic can make it quite easy to interpret and troubleshoot a system. Very few power system components have variable inputs or outputs that respond differently to different voltages. Generally, when troubleshooting the power system, voltage either exists or it doesn't. It's not a hard and fast rule, but this is usually the case.

This lesson focused on the process for troubleshooting electrical components and then covered schematics and diagrams, which are extremely useful tools that tell you what should be occurring in a specific system. As long as you know how to properly test components and where to find the information you need, you will be able to successfully understand and troubleshoot any of the systems you work with.

Hardware

There are several lug nuts that hold the wheels onto your car that are made from very strong materials designed to keep your wheels attached to your car in a variety of environments. Now imagine the tiny screws that hold your cellphone, laptop, or other electronic device together. They don't need to bear a load like the lug nut holding your car's wheel does and are therefore made of much softer and lighter metal. What if your lug nuts were replaced with hardware that looked like normal lug nuts, but was not made of the correct type of metal? It wouldn't be long before the threads stripped out and you lost a wheel. The weapon system is no different because it requires different types, strengths, and configurations of hardware depending on different factors. If the correct hardware is not used, or it is procured from an unauthorized source, problems with hardness can occur.

As you have already seen through your technical training as a 2M0X3, you will use a lot of hardware. Your job requires that you take many components apart and reassemble them, and the majority of the time, you'll be using bolts, washers, and nuts. All of these items can be grouped under the heading hardware. In this lesson, we will cover the characteristics of the hardware you'll commonly be using, followed by information on some other ways we secure fasteners. When replacing hardware, make sure to always verify the proper configuration in a TO, CEM, or Illustrated Parts Breakdown (IPB). This will aid in maintaining the site's built-in hardness and survivability. We will cover bolts, nuts, washers, and conclude by discussing quick release pins.

Aerospace Hardware

The missile is the only part of the weapon system that will leave the ground and take flight, and for that reason the hardware used on the missile (or any aircraft) is called aerospace hardware. Aerospace hardware is just like regular hardware, but it must meet more strict standards, and be made of lighter and stronger materials. For example, it doesn't matter how much the nuts weigh that fasten the Electrical Surge Arrestor (ESA) doors to the walls of the lower Launcher Equipment Room (LER)—but every single gram of weight matters on a missile or aircraft. As a 2M0X3, you will rarely be concerned with actual aerospace hardware, but it is still important that you understand the terminology.

Hardware used in the Minuteman III weapon system is distinct and serves specific purposes, and all hardware must be ordered through authorized sources using codes and stock numbers listed in your technical data. Even if you have seen the same nut, bolt, or washer in a bin at your local hardware store doesn't mean that it is fit for use in the weapon system. In the hardness lesson from volume 1, you learned that some pieces of hardware must be of a specific strength or be a specific dimension to properly serve their purpose during a nuclear event. A piece of hardware from the local hardware store may seem to be an exact replacement, but would almost certainly fail if it was exposed to thee extremes of a nuclear environment. Remember that all of our replacement hardware must come from authorized sources.

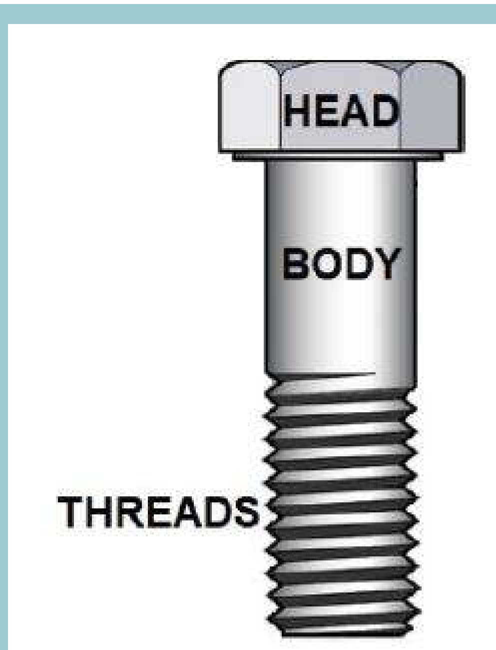


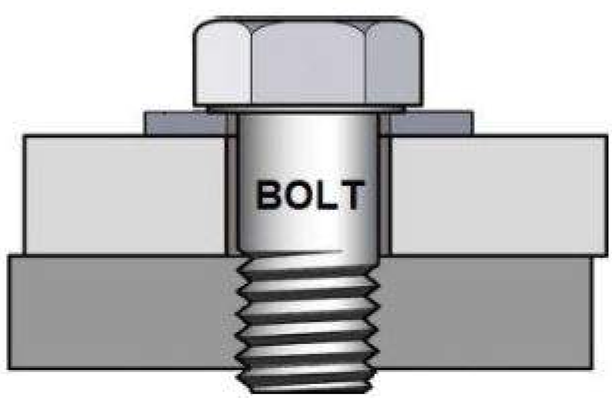
Figure 3–13. Bolt.

Bolt

A bolt is a fastener built from a cylindrical body with a thread spiraling around its external circumference (fig 3–13). One side of the cylindrical body has a head on it that is shaped so that it can be tightened with a wrench or a socket. The purpose of a bolt is to fasten one or more objects together. Since the threads spiral around the body of the bolt, twisting it into a set of matching threads on another object will cause it to engage, and "thread" in. There must be another object on the opposite side of the head for the threads on the bolt to engage, and this is accomplished in one of two ways.

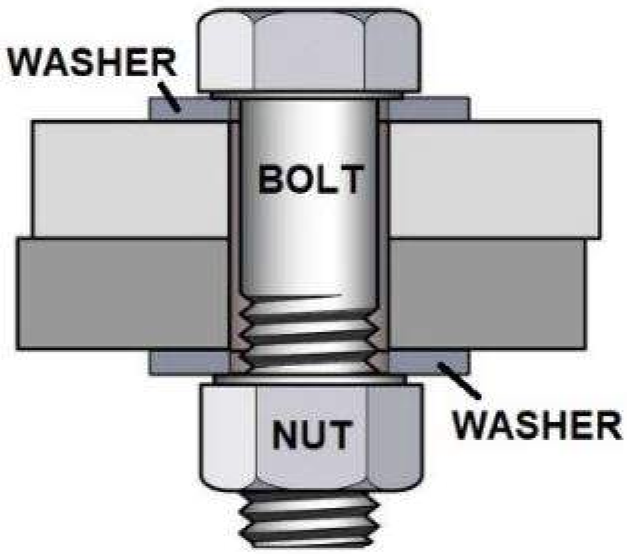
Threading the Bolt Into Hard-Mounted Threads

Hard-mounted threads are physically attached to the structure. Sometimes, you will see this is done as simply as welding a nut to the panel, and other times threads will be physically cut into the panel. You put the object that you want to secure in place, and then place the bolt through the object and into the threads. The object being fastened typically does not have any threads—the bolt simply slides straight through it. You can see an example of a nut threaded into hard-mounted threads in figure 3–14. An advantage of this method is that there is no nut to lose. A disadvantage is that if the threads on the structure become too worn or strip out, a larger hole must be drilled and have threads cut into it. The original bolt will no longer fit, and a larger one will need to be used.



Threading the Bolt Into a Nut

A nut is used when two or more objects need to be "sandwiched" together (fig 3–15). You place the bolt through the front of the objects, and then thread the nut onto the threads of the bolt protruding out of the other side. You may find that the head of the bolt begins to spin when you're tightening the nut, or vice versa. This can be remedied with the use of a backing wrench, which is simply the use of another tool to hold the head of the bolt stationary while you tighten the nut. Naturally, this problem would not occur with hard-mounted threads.



Complete the content above before moving on.

Nut

A nut is an object that a bolt or other threaded object threads into with the main intent of securing or compressing one or more objects together. Since the threads on a bolt are on the outside of its body; that means that the threads on a nut must be on the inside of its body. Just like the head of a bolt, the outside of a nut’s body is shaped so that a wrench or socket can fit onto it so that it can be tightened. Now that you have an understanding of what a nut is for, let’s discuss the common types of nuts.

Wing Nut

A wing nut isn’t shaped so that a wrench or socket can fit onto it. Instead, it has two “wings” that can be grasped between your thumb and forefinger, which is how it is tightened. Wing nuts are quick and convenient since they can be removed and installed by hand without the use of any tools. You will occasionally encounter a wing nut on a panel, and so forth, but not very often.

Castellated Nut

A castellated nut, castle nut, or slotted nut, has slots cut into the top so that once it's tightened, it can be secured into place using safety wire or a cotter pin. The safety wire or cotter pin goes first through one side of the slotted nut, then through a hole drilled through the bolt, and then through a slot on the opposite side of the nut. The castellation on the nut is designed to prevent the nut from turning or vibrating loose.

Locking Nut

A locking nut is just like a regular nut, but it has a plastic or nylon insert on its threads. As the bolt is tightened into the nut, the bolt's threads cut into the insert, creating friction, and "locking" the nut in place. The threads are only cut into the plastic insert once—if the locking nut is removed it must be replaced with a new one.

Complete the content above before moving on.

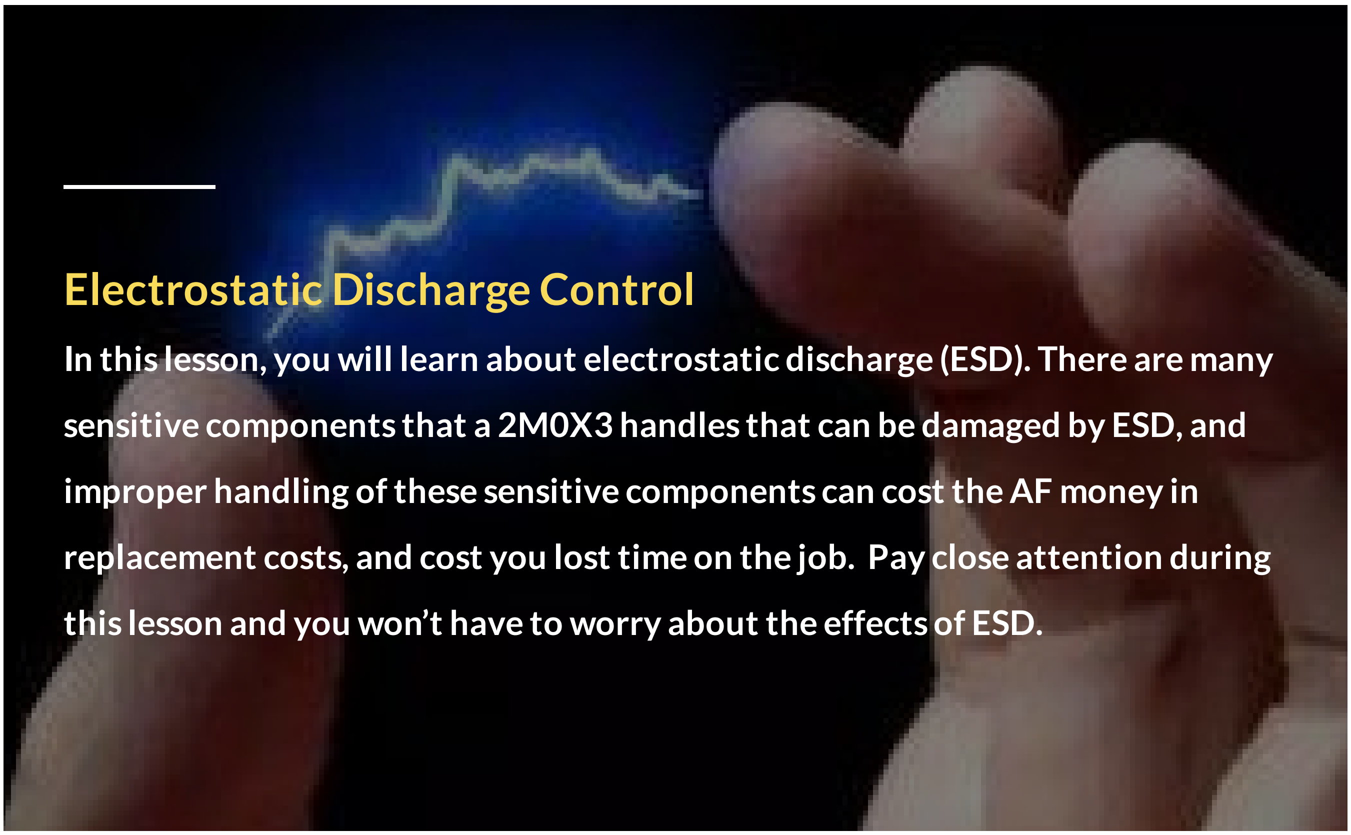
WASHER	QUICK RELEASE PIN

A washer is a thin, disc-shaped piece of metal with a hole in the middle that the body of a bolt goes through. The washer is placed between the head of the bolt and the item being fastened, or between the nut and the item being fastened, or both, depending on the configuration. A washer's job is two-fold; it distributes the load of the bolt or nut, and since it doesn't spin when the fastener is being tightened, it also helps to keep surfaces from getting scratched or gouged due to the twisting motion of the fastener. Washers can be made of many different materials and be many different sizes and thicknesses. As with all other hardware in the system, you must make sure that you replace washers with authorized duplicates and use the proper configuration. For instance, if your IPB shows that there are two washers underneath the head of the bolt, you must ensure that you install two new washers when you replace the hardware.

WASHER	QUICK RELEASE PIN

Another piece of hardware that you will encounter is the quick release pin (QRP) (fig 3–16). QRPs are most commonly used where equipment needs to be assembled or disassembled rapidly. The equipment being held together by the QRP is "sandwiched" between the head of the QRP at one end, and metal retainers at the other end. The release button on the head of the QRP must be pressed to remove or install it. Doing this allows the retainers to fall into the body of the QRP. The release button is spring loaded so that it returns to its original position when it is released, and the retainers lock in the outward position. It is important to inspect all QRPs to ensure that there is smooth motion and no binding when depressing or releasing the retainer release button. Many QRPs are used to assemble the guided missile maintenance platform (GMMP). This lesson provided a basic explanation of hardware as well as the most common types of hardware you'll encounter when performing maintenance.

Complete the content above before moving on.



Electrostatic Discharge Control

In this lesson, you will learn about electrostatic discharge (ESD). There are many sensitive components that a 2M0X3 handles that can be damaged by ESD, and improper handling of these sensitive components can cost the AF money in replacement costs, and cost you lost time on the job. Pay close attention during this lesson and you won't have to worry about the effects of ESD.

Description

ESD is defined as a sudden flow of electricity between two electrically charged objects. All objects can carry an electrical charge, and on a day-to-day basis most objects contain a neutral charge and exist in a state of equilibrium. It is important to remember that nature wants to retain this neutral equilibrium. Imagine that you are wearing a pair of heavy-wool socks, and you've been scooting your feet across the living room carpet. You don't know it, but by doing this your entire body is building up static electricity. Static electricity is simply that; a static or stored charge. You reach for a doorknob… and ZAP!—the positive charge that had built up in your body was suddenly equalized into the metallic door knob. Another great example of ESD is a lightning strike, which is a much larger scale example, but the idea is the same. The charge of the surface of the earth and the charge in the atmosphere are not in equilibrium. Once the difference becomes too great, lightning strikes the earth to equalize the charge between the two objects.

Effects of Electrostatic Discharge on Sensitive Electronics

The door knob mentioned above isn't going to be harmed by the ESD because it's just a hunk of metal. However, if you were to discharge that same voltage into an ESD sensitive circuit card, it would overload and possibly damage some of its electrical components. The circuits on that card were meant to operate at a certain steady voltage. Large surges from an ESD are unexpected, and could cause damage to the card.

It is also important to know that you won't always know when you've transferred your static charge into a component. When you reached for your door knob in the example above, there was a very evident "zap," and you probably felt it too. A very small discharge, too small for you to even notice, can damage a sensitive component, which is why you must always discharge any static charge that you may be carrying prior to handling any ESD sensitive device.

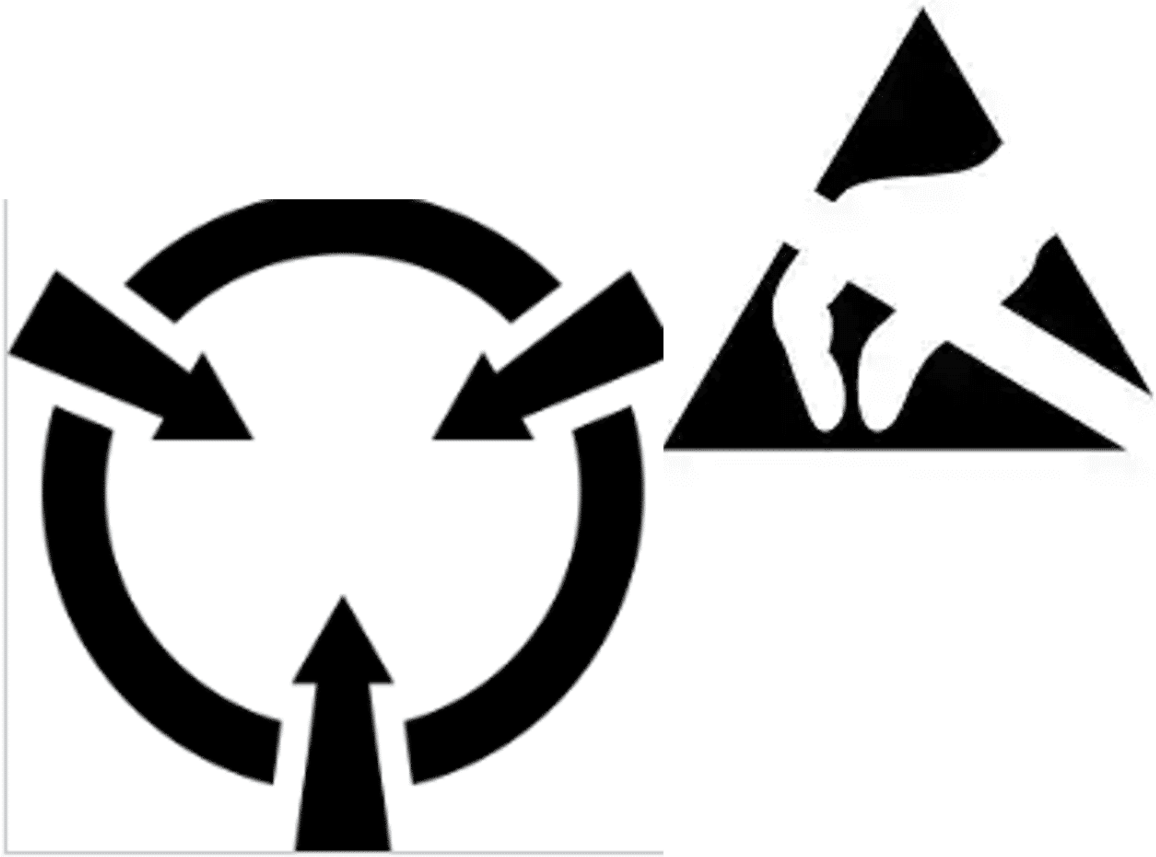
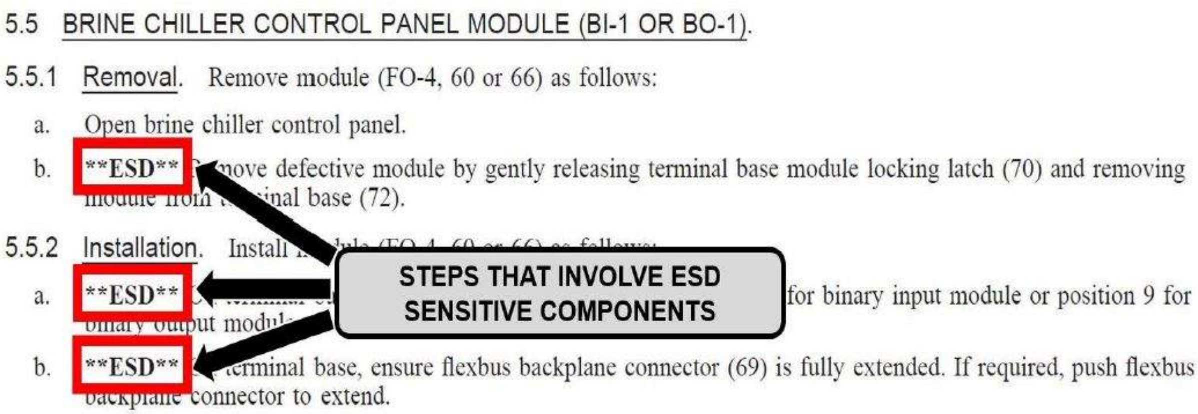


Figure 3–17. Symbols Indicating Electrostatic Discharge Sensitive Devices

Identifying Electrostatic Sensitive Components and Procedures

ESD sensitive components are stored in special protective packaging, typically in the form of antistatic bags. An antistatic bag will look different from a normal bag because it will have either a metallic or pink hue. In addition to the packaging, all ESD sensitive components will also have the ESD sensitive logo printed directly on the bag or on a sticker attached to the bag. There are two different commonly used symbols for ESD sensitive components, but both have the same meaning (fig 3–17).



5.5 BRINE CHILLER CONTROL PANEL MODULE (BI-1 OR BO-1).

5.5.1 Removal. Remove module (FO-4, 60 or 66) as follows:

a. Open brine chiller control panel.

b. **ESD** Remove defective module by gently releasing terminal base module locking latch (70) and removing module from terminal base (72).

5.5.2 Installation. Install module (FO-4, 60 or 66) as follows:

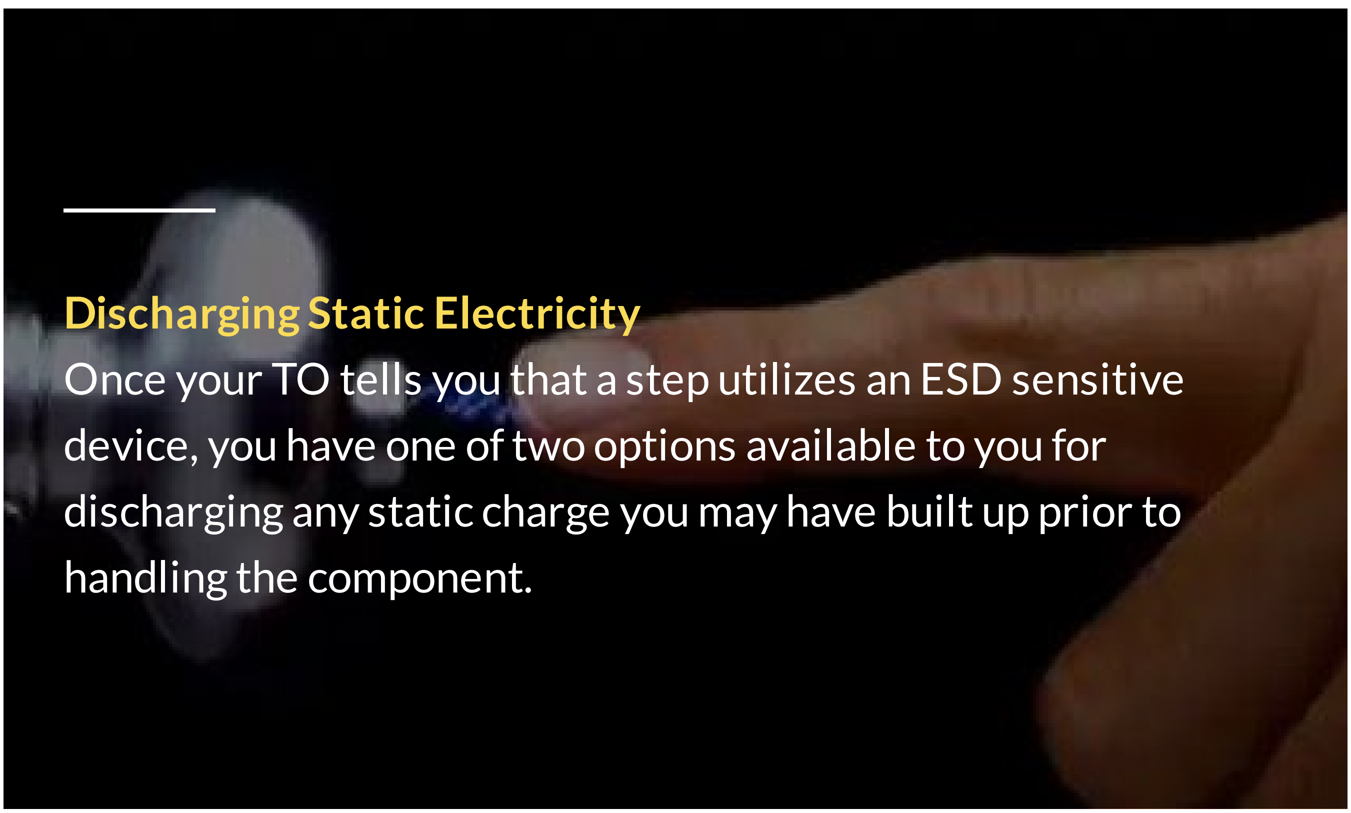
a. **ESD** ... for binary input module or position 9 for binary output module.

b. **ESD** ... terminal base, ensure flexbus backplane connector (69) is fully extended. If required, push flexbus backplane connector to extend.

Figure 3–18. Technical Order Procedure with an Electrostatic Discharge Sensitive Component

Identifying Electrostatic Sensitive Components and Procedures

To make it even easier, your technical order will indicate if a procedure includes an ESD sensitive device with the designator **ESD** (fig 3–18).



Discharging Static Electricity

Once your TO tells you that a step utilizes an ESD sensitive device, you have one of two options available to you for discharging any static charge you may have built up prior to handling the component.

Option 1

Option 1, as outlined in TO 00–25–234, *General Shop Practice Requirements for the Repair, Maintenance, and Test of Electrical Equipment*, is to simply ground yourself to any metal portion of the cabinet or panel that you'll be installing the component into, and all you have to do is touch a metal (preferably unpainted) surface with your bare skin.

For example, if you're installing a module into the brine chiller control panel, a great place to ground yourself is the unpainted portion of the panel where the radio frequency interference (RFI) gasket rests. Also remember that you must maintain bare skin contact with that surface the entire time that you're handling the module.

Option 2

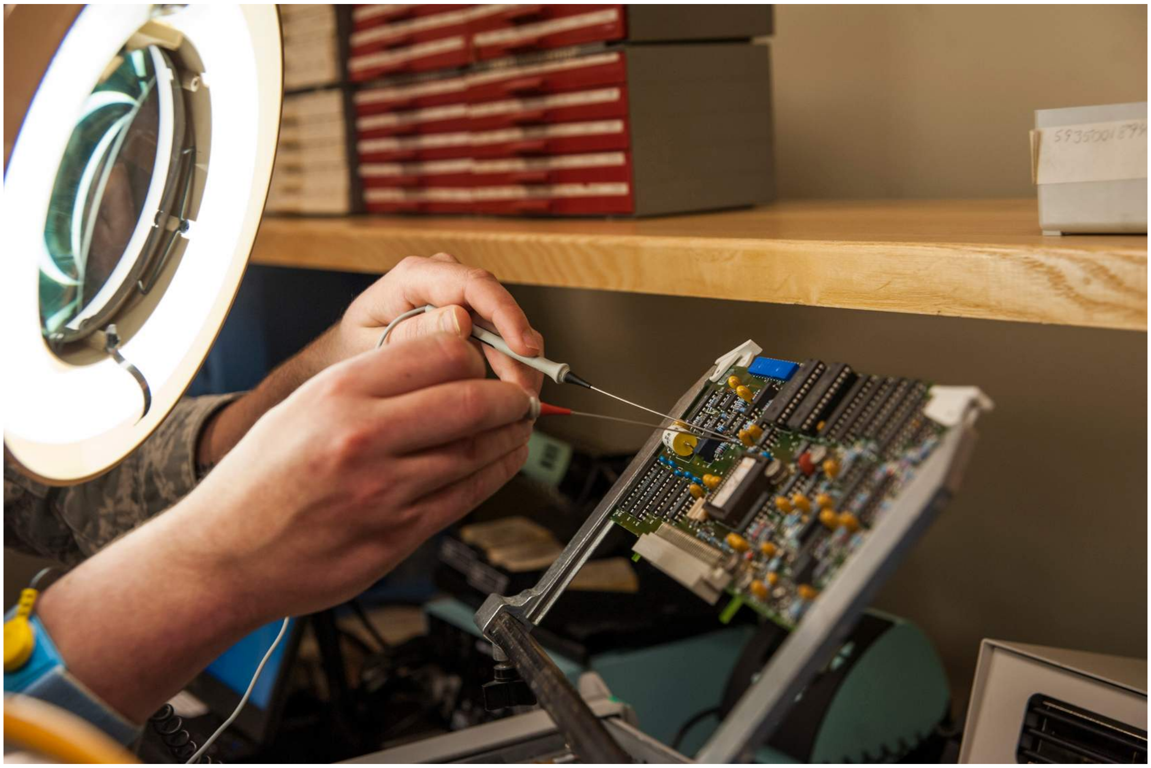
Option 2 is to use an ESD wrist strap. Before we proceed any further, it is extremely important to know that you cannot use an ESD wrist strap in a panel with electricity applied to it (you will typically have power removed from any cabinet or panel where you are removing or replacing an electrical component though). The ESD wrist strap has a metallic pad that touches the skin on your wrist, and the strap is connected to a length of wire with a clip on the other end.

The clip is placed somewhere on a bare metal surface in or on the cabinet or panel you'll be working in. The ESD wrist strap serves the same purpose as grounding yourself to the cabinet or panel with your bare skin, with the added convenience of being able to use both of your hands. Both methods are authorized—use whichever one works best for you.

Avoiding Contact with Electrostatic Discharge-Sensitive Parts

There is another option outlined in the safety summary of all ECS TOs. That option is to simply avoid contact with any exposed connector pins. This option works very well with some of the modules in the ECS because they're made up of a plastic shell with small electrical pins on the rear. It is very easy to handle the module without touching the pins. However, options 1 or 2 will still need to be used for ESD sensitive components that are not encased to the point where they can be handled without touching any of the electronics.

In this lesson you learned about ESD and how it can damage devices that are sensitive to it. The lesson then concluded with explanations of methods that you can use to discharge ESD from your body before handling sensitive components.



Complete the content above before moving on.

KNOWLEDGE CHECK TIME!

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to using digital multimeters and clamp-on ammeters.

1. Why is it important to be familiar with the symbols on a multimeter or ammeter?

Type your answer here

SUBMIT

1

2. What is the symbol that represents alternating current?

Type your answer here

SUBMIT

2

3. What is the symbol that represents direct current?

Type your answer here

SUBMIT

3

4. What piece of equipment is typically used to accomplish amperage checks?

Type your answer here

SUBMIT

4

5. What should you do if you receive a multimeter and the battery symbol is illuminated during your acceptance checkout?

Type your answer here

SUBMIT

5

6. What does it mean if a multimeter shows a large amount of resistance, or shows "OL" when you're checking continuity between the meter test leads?

Type your answer here

SUBMIT

6

7. If your multimeter is set to auto-range mode, and you take a reading that is above or below that range, what will your multimeter do?

Type your answer here

SUBMIT

8. When using a Model 87 multimeter, what type of readings are the two input jacks to the far left used for?

Type your answer here

SUBMIT

9. What two input jacks are used on the Model 87 multimeter to take an alternating current voltage reading?

Type your answer here

SUBMIT

9

10. How many ohms are in one megohm?

Type your answer here

SUBMIT

10

11. Procedures for what system might direct you to take an in-line amperage reading with the Model 87 multimeter?

Type your answer here

SUBMIT

12. How does an ammeter work?

Type your answer here

SUBMIT

13. What might happen if the jaws of your clamp-on ammeter are not making direct contact?

Type your answer here

SUBMIT

13

14. How do you configure your clamp-on ammeter to measure resistance?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to troubleshooting techniques.

1. What does it mean to not jump to conclusions while troubleshooting?

Type your answer here

SUBMIT

2. What is the most important troubleshooting recommendation?

Type your answer here

SUBMIT

3. How would you likely be able to tell if there were burned wires before ever seeing them?

Type your answer here

SUBMIT

16

4. What do the fault matrixes and fault lists in your technical data help you to accomplish?

Type your answer here

SUBMIT

17

5. When locating the malfunction of a system, what provides a technician with an outline of how the system should operate?

Type your answer here

SUBMIT

6. What type of repairs should technicians always make?

Type your answer here

SUBMIT

7. When checking for an open using voltage checks, what will your multimeter indicate when you have discovered an open circuit?

Type your answer here

SUBMIT

8. When checking for an open using the resistance function of a meter, how would the location of an open be indicated?

Type your answer here

SUBMIT

9. What is a cross short?

Type your answer here

SUBMIT

22

10. What is a shorted control?

Type your answer here

SUBMIT

23

11. Why should you always take amperage readings on a system when it is running normally, and not in the process of starting up?

Type your answer here

SUBMIT

24

12. What does it mean when you measure a large difference in voltage potential across a closed circuit breaker or switch?

Type your answer here

SUBMIT

25

13. What is the purpose of a legend?

Type your answer here

SUBMIT

26

14. What do functional or block diagrams provide?

Type your answer here

SUBMIT

27

15. How can a wiring diagram be helpful for troubleshooting?

Type your answer here

SUBMIT

28

16. What will the beginning and end of a wire be labeled with on a wiring diagram?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to hardware.

1. What is the difference between regular hardware and aerospace hardware?

Type your answer here

SUBMIT

2. Where must all replacement hardware come from?

Type your answer here

SUBMIT

30

3. What is the purpose of a bolt?

Type your answer here

SUBMIT

31

4. What is a disadvantage of hard-mounted threads?

Type your answer here

SUBMIT

32

5. Why is the use of a wing nut quick and convenient?

Type your answer here

SUBMIT

33

6. What purpose(s) is a washer used for?

Type your answer here

SUBMIT

34

7. What action allows the retainers to fall into the body of a quick release pin?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to electrostatic discharge control (ESD).

1. What is a large-scale example of electrostatic discharge?

Type your answer here

SUBMIT

35

2. What is important to know about the effects of electrostatic discharge?

Type your answer here

SUBMIT

36

3. What two icons warn of electrostatic discharge sensitive components?

Type your answer here

SUBMIT

37

4. What is Option 2 for the control of electrostatic discharge?

Type your answer here

SUBMIT

38

5. What is a third method of controlling electrostatic discharge that is mentioned in your technical data?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click on the video below to watch a video about a periodic maintenance team (PMT) team chief (TC).

Complete the content above before moving on.

Maintenance Programs

How frustrated would you be if you dispatched to the missile field to replace a component and then found out that the part was defective before you installed it? What if the part was in working condition but it wasn't the right part for the job? There are AF programs in place to handle both of these situations. A deficiency report will need to be initiated for the broken part, and you would have received the correct part for the second scenario if the IMDS had been used properly. The following lessons will outline the deficiency reporting process and familiarize you with IMDS.

Click here to learn about deficiency reporting.

Deficiency Reporting

Consider the following scenario: Your first job of the dispatch is to replace a launch tube heater motor. You remove the old motor and install the new one without error. You double check all of your TO steps and button everything back up. You begin your operational checkout, and when you press the switch to start up the launch tube heater motor, it fails to operate! After troubleshooting, you determine that the replacement motor was defective before it was ever installed. You have just discovered a deficiency and identified a need to let product managers and other missile units know that your squadron received a defective part. This lesson will introduce you to a program that was tailor made for this type of situation—the deficiency reporting process.

Purpose

The purpose of the deficiency reporting process is to provide the AF with a means of identifying deficiencies and resolving them with the resources available to the unit, and also tells leadership at high-levels whether deficiencies are being resolved within their organizations. Program managers can also assess the operational risk posed by the deficiency to the system's overall safety, suitability, and effectiveness. For instance, if you repeatedly received faulty launch tube heater motors, your leadership would take steps to find out why this continues to happen, and the AF may even decide to start purchasing the motors from a different manufacturer altogether if the problem persists long enough. The hope is that our efforts will save money and time by fixing a broken process early rather than continuing to throw money away on unsuitable or unsafe products.

Definitions

The following paragraphs introduce you to some terms that you need to know in order to understand and make use of the deficiency reporting process. Click on each (+) below to learn about the different terms.

Deficiency Report

A deficiency report is a generic product used for recording, submitting, and transmitting deficiency data. A deficiency report is submitted in order to alert managers or an inferior of unsafe product. This will ensure your unit is reimbursed the costs of the component or item, and also ensures that the right products are being used for the job.

Defect

A defect is any problem or issue with a product that causes it to not perform as required, but this does not automatically mean that any defective component is classified as a "defect" under the deficiency reporting process. When you replace a launch tube heater motor and your new one fails to operate properly, you have a defect—the part you received did not work as the manufacturer and your TO states that it is supposed to. Some parts also include fasteners or other hardware needed for proper operation of the part, and it is also considered a defect if some or all of this extra hardware is missing. The AF also expects to receive what it pays for.

Acceptance Inspection

An acceptance inspection is performed by your unit on new equipment to validate whether acceptable levels of quality have been met, and this inspection will be of sufficient depth to determine the ability of the item to perform its designed function. This is required for all items received from the air logistics center (ALC). For example, if your unit received a PT that had just undergone programmed maintenance at the AFB depot, an acceptance inspection would be performed on it before it was placed back into service. A deficiency report would automatically be generated if any discrepancies were discovered during the acceptance inspection.

Exhibit

The exhibit is the component or equipment with the defect. This represents the deficient condition and the item must be set aside by itself so it can be properly investigated by product managers.

End item

An end item is a system, equipment, or component that by itself performs a military function that contributes to the mission. An end item is usually made up of several smaller parts that are procured separately and removed and/or replaced in order to return the end item to service. A good example is the LF brine chiller. You sometimes have to replace the entire brine chiller due to an issue with a component that only the power, refrigeration, and electrical (PREL) shop is authorized to repair. However, if the problem with the brine chiller is repairable by replacing a part of it, such as the brine pump, that will be done on site.

Complete the content above before moving on to learn about the different types of defects.

Defects

There are three types of defects, and they're classified based on the danger they present to personnel and the negative impact they'll have on the weapon system.

Types of Defects	
Type	**Description**
Critical Defect	This is a defect that judgment and experience indicate is likely to result in hazardous or unsafe conditions for technicians using, maintaining, operating, or depending on the product. It may also be a defect that judgment and experience indicate is likely to prevent performance of the tactical function of a major end item, such as a missile or space vehicle.
Major Defect	This is a condition, other than critical, that is likely to result in failure, or reduces the usability of the item for its intended purpose.
Minor Defect	A minor defect is a defect that is not likely to reduce the usability of the unit or product for the intended purpose, or is a departure from established standards, and has little bearing on the effective operation of the unit. A good example is a screw that is discovered missing during an acceptance inspection on a GMMP received from Depot at Hill AFB—the missing screw will not affect the usability of the GMMP, but it is still classified a defect and a deficiency report is submitted so the unit gets reimbursed for the cost of the part.

Types of Defects Table.

Click to continue in the lesson.

Types of Deficiencies

The criticality of the defect as well as the type of deficiency are what determine the method of response. A sample of the many types of deficiencies are listed in the table below:

Types of Deficiencies	
Type	**Criteria**

Product Quality Deficiency	• Deficiency on hardware or software
	• New, newly repaired, revised, installed, or overhauled product that has typically already been placed in service
	• Can be from
	  • Initial failure
	  • A defect (may be latent)
	  • A non-conforming condition (workmanship)
	• Includes failures on an item that is still within its warranty
	• period

Engineering Investigation Deficiency	• Report unacceptable condition or request failure analysis
	• Can be for
	  • Compatibility issues
	  • Component and/or item failures
	  • Anomalous behavior
	  • Providing improvement recommendations
	  • Software/application failures

Acceptance Inspection Deficiency	• Identified during an acceptance inspection on newly received, assigned, or acquired aircraft, engines or equipment • Includes trainers, simulators, ground support equipment

Types of Deficiencies Table.

Click to continue in the lesson.

Deficiency Report Categories

Deficiency reports are prescribed as either Category I or Category II and the following table will help you to determine which category to use. A defect that is a minor nuisance does not require the same amount of attention or expedience as a report for a critical defect that could hurt technicians or damage equipment. If any doubt exists about where to categorize a deficiency, your unit QA section or wing safety office can assist you.

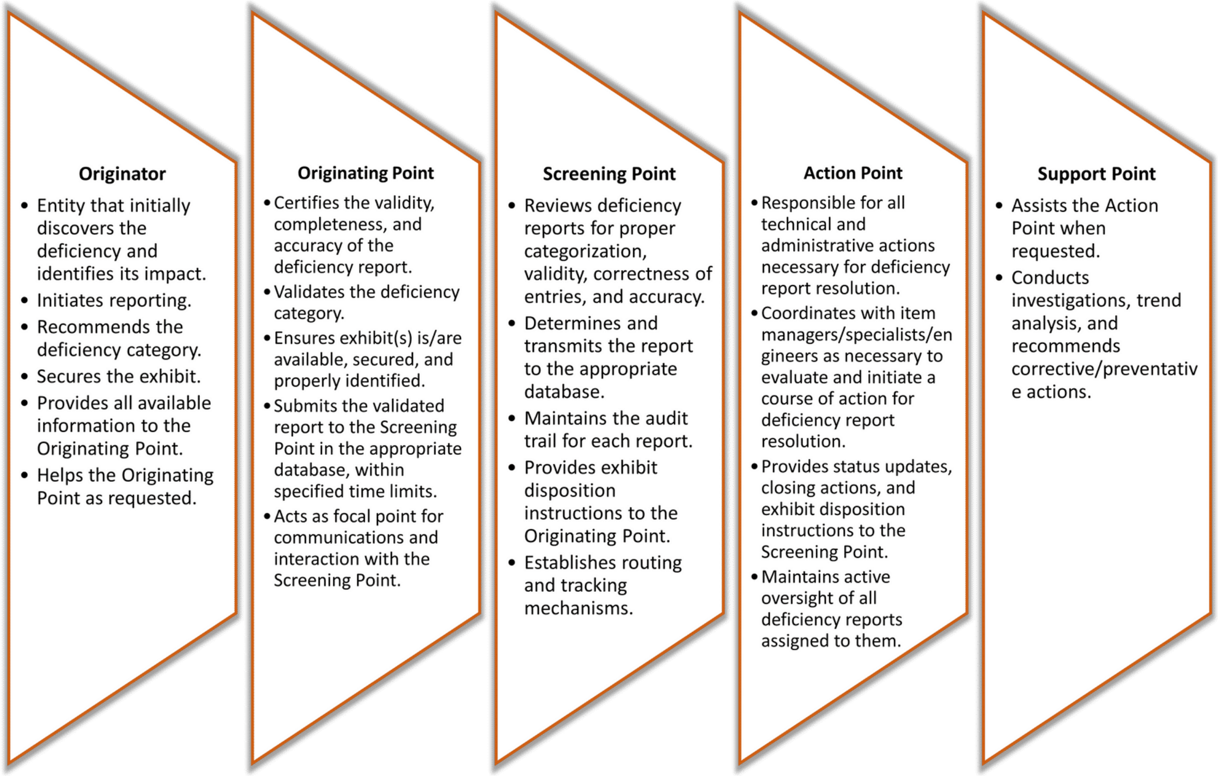
Deficiency Report Categories	
Category	**Description**
I	Category I deficiencies are those which: • If uncorrected, would cause death, severe injury, or severe illness. • In uncorrected, would cause major loss or damage to equipment or a system. • Directly restrict combat or operational readiness.
II	Use this category when reporting a deficiency that *does not meet* the criteria for a Category I deficiency, or is: • Attributable to errors in workmanship, nonconformance to specifications, drawing standards, or other technical requirements. • Found during an initial acceptance inspection. • A potential enhancement (applies to enhancements noted during the acquisition phase of a product). • A failure or condition that occurs during initial inspection, initial bench check, initial installation operational checkout, or initial operational use.

Deficiency Report Categories Table.

Click to continue in the lesson.

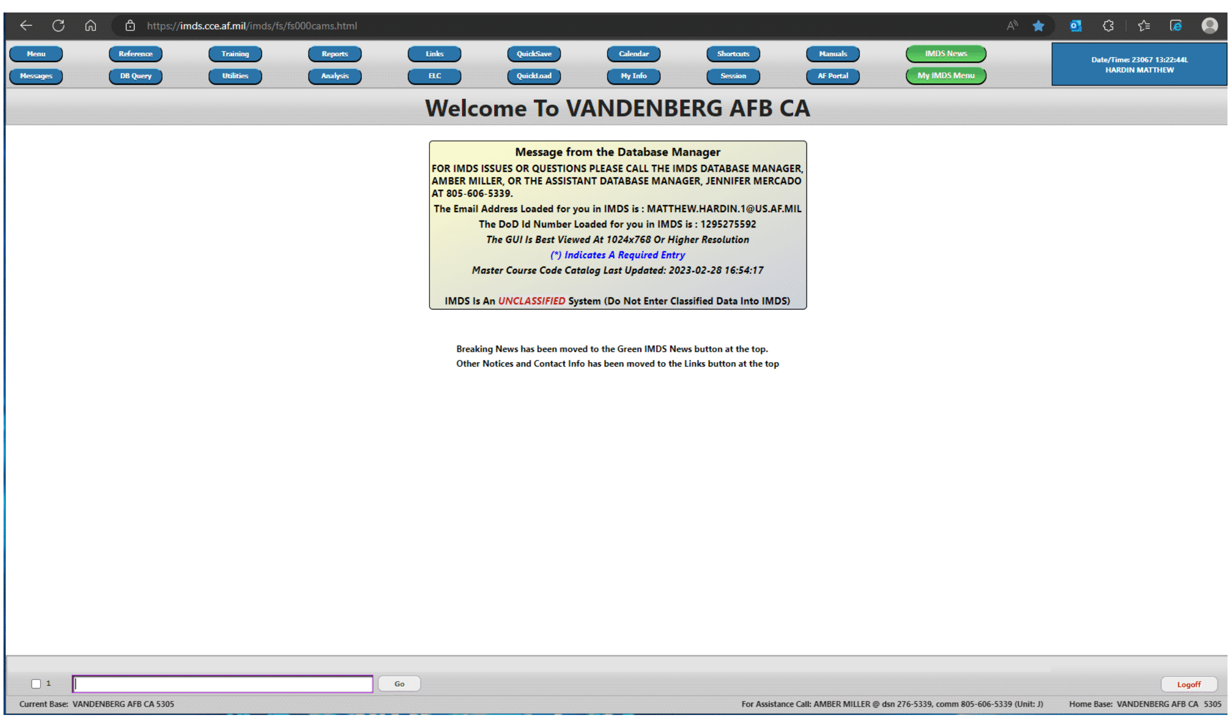
Responsibilities

The following table describes all of the steps in the deficiency reporting process and who is responsible to initiate it and resolve it. In this lesson you learned about terms and definitions associated with the deficiency reporting process, as well as what roles different organizations play.



Deficiency Reporting Roles and Responsibilities Chart.

Click to continue in the lesson.



IMDS Home Screen.

Integrated Maintenance Data System

IMDS is an automated data collection and information system that supports all maintenance efforts; it was designed to enhance readiness by improving the flow and availability of maintenance information. IMDS supports the commander and managers at all levels of the maintenance community and also provides much of the maintenance data used by MAJCOMs and other agencies to manage and track maintenance resources worldwide. As a technician, you need to understand how IMDS is used in the maintenance complex because you are a major contributor to the integrity of the data collected.

You may be currently using IMDS to order parts in the tool room or to issue equipment to teams, but your role in entering data into IMDS will change as you progress through your career. You will be provided with new training whenever your role in entering data into IMDS changes.

Objectives

When maintenance is performed, whether on-site or on base, extensive data must be collected to account for the time you spent, the parts you used, the systems you worked on, and the steps you took to checkout or repair the system. This data tells a story of what you did, what it took to complete that job, and how long you spent doing it. IMDS data translates information to commanders and managers regarding how many technicians are needed to perform a task, what high-failure parts should be kept on hand, and/or what systems are aging and may need to be upgraded. It is very important that you record your actions as accurately as possible since this will benefit you and future technicians that follow you. Some objectives of IMDS are to:

- Eliminate and/or reduce nonproductive administrative tasks.
- Ensure that AF material is serviceable, operable, and properly configured.
- Provide better capability for maintenance information programs and organizations to support AF peacetime and wartime missions.
- Provide more accurate maintenance data, which is needed to develop technical requirements, concepts, and plans that will support weapon system development.

- Identify changing needs for the maintenance community in the areas of personnel, equipment, and subsystem upgrades and modifications.
- Provide more responsive maintenance systems and methods to support changing operational needs.
- Support senior managers in their need to better organize and train the force to support the operational mission in the most effective and productive manner possible.

As you can see, IMDS provides a wealth of information to managers and helps make your maintenance organization more productive, and provides the right personnel, equipment, and resources to do the job. The accuracy of the data in IMDS ultimately makes your job easier.

Functions

IMDS allows you to perform three basic functions—update the database, retrieve information from the database, and report the data required to agencies that manage and track maintenance resources.

Integrated Maintenance Data System Functions

Database Updates

- Allows the entry of new data, modification of existing data, and the removal of erroneous and obsolete data.

Types of Information Retrieval

- Real–time retrievals are processed at the time of input and returned to the requesting terminal, and this function allows you to view current data.
- Background retrievals are processed and sent to your remote line printer or the high–speed printer located at the data processing center, and this function allows you to view historical data.

Reporting

- Reports required by higher HQ are produced as a byproduct of the normal base-level operation of IMDS. They are then automatically extracted and transmitted to other maintenance information systems.

Integrated Maintenance Data System Functions Table.

Subsystems

IMDS has several subsystems that aid the program in meeting the objectives and requirements of the maintenance community, and a sample of some commonly used subsystems are listed below:

Integrated Maintenance Data System Subsystems	
Subsystem	**Description**
Maintenance Events	Allows the user to track maintenance actions and has both maintenance and supply data. The user can create, schedule, defer, reschedule, and cancel events. The user can also inquire into supply data related to recorded discrepancies.
Location	Allows the user to automate the location of missiles and aerospace ground equipment (AGE), as well as any other equipment deemed critical to the organization's operation.
Job Data Documentation (JDD)	Allows the user to document, inquire, and retrieve information on maintenance actions. Work activity and job completion can be viewed for all maintenance performed both on and off base.
Operational Events	This subsystem can be described in three phases: • Phase one (Mission Recording) is the phase where teams and work orders can be scheduled. • Phase two (Mission Accomplishment) is the period of time from start to stop of an operational event. • Phase three (Analysis Phase) provides the capabilities for periodic reports of mission accomplishment.
Maintenance Personnel	Allows the user to monitor manpower and resources.
Training Management	Allows the user to schedule and forecast personnel training requirements. This is commonly used to schedule your recurring training, such as shotgun qualification or gas mask training.
Base Supply System Interface	Allows the user to order parts for unscheduled discrepancies as well as make inquiries on numerous types of supply systems.
Automated Debriefing	Provides debriefing functions including deviation data, discrepancies discovered, and tracking and reporting of recurring discrepancies.

Integrated Maintenance Data System Subsystems Table.

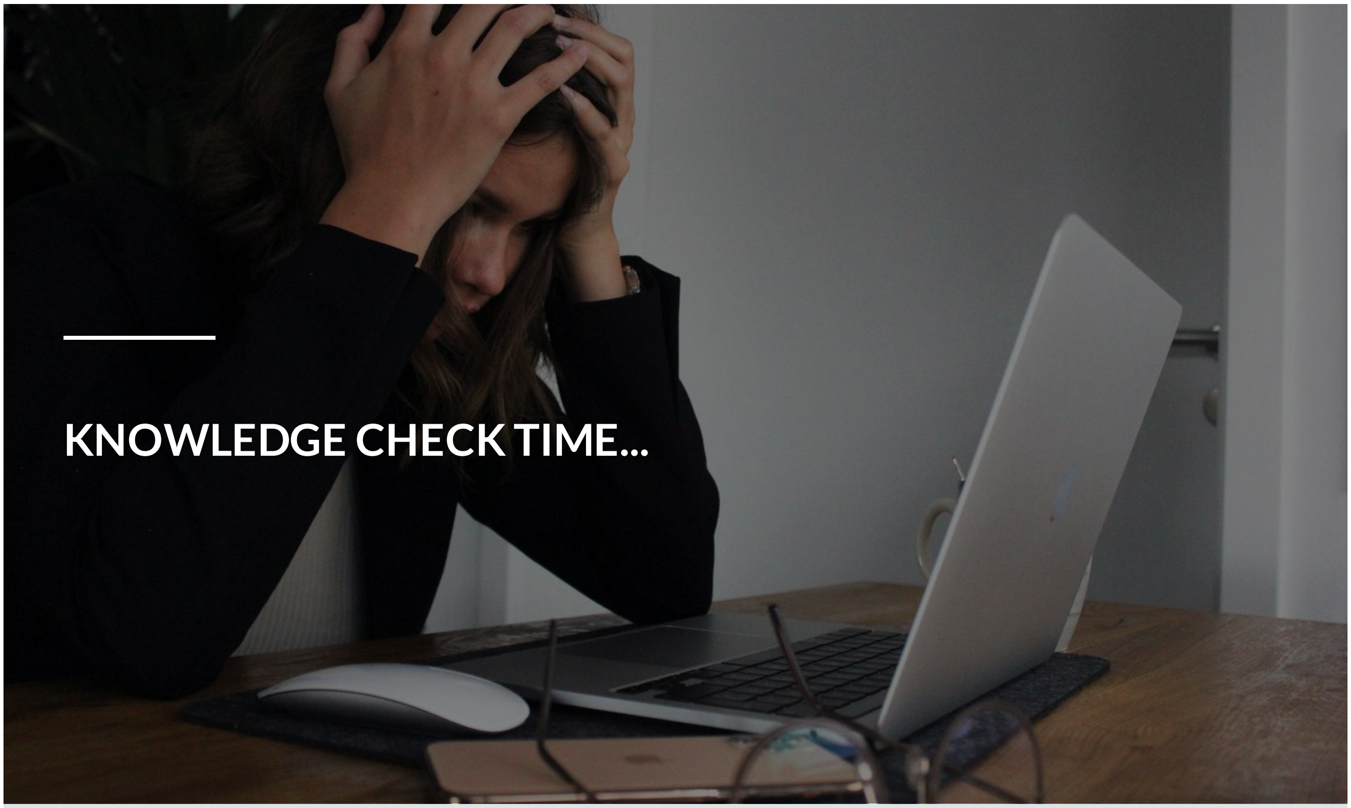
Data Accuracy

Any database is only as robust as the data that is entered into it, so it is critical that you provide the most accurate data that you possibly can. For example, if you forget to record the diesel hours or fuel level from an LF, it is better for you to enter no number at all rather than making a guess. When you discover a discrepancy that requires you to order parts, it is your role as a technician and a team chief to research the correct parts and ensure the part information is attached to the work order when you create it.

Work unit codes (WUC) are used to track the maintenance history on a certain component or end item, so it is critical that you use the correct WUC for the piece of equipment you performed maintenance on. This data in IMDS projects future maintenance actions and helps to obtain the resources needed to do the job.

To protect data accuracy, your work center supervisors are responsible for reviewing the data entered on a daily basis, which further ensures the accuracy and completeness of data entered into IMDS.

As you can see, IMDS is a wealth of information since it tracks nearly every facet of the maintenance process. This affects you because it ensures that you have the correct parts, adequate manpower, and enough time to perform the job to the best of your ability.



KNOWLEDGE CHECK TIME...

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the deficiency reporting.

1. What is a deficiency report?

Type your answer here

SUBMIT

39

2. What is a defect?

Type your answer here

SUBMIT

40

3. What is required to be performed on all items received from the air logistics center?

- [ ] A preventative maintenance inspection.

- [ ] An annual inspection.
- [ ] An acceptance inspection.
- [ ] A scheduled inspection.

SUBMIT

41

4. What type of defect is a condition that is likely to result in failure?

- ○ Minor defect.
- ○ Major defect.
- ○ Critical defect.

SUBMIT

5. What deficiency report category is used when a defect, if uncorrected, would cause death, severe injury, or severe illness?

- Category I.
- Category II.
- Category III.
- Category IV.

SUBMIT

6. What type of deficiency report category is used for deficiencies found during an acceptance inspection?

Acceptance Inspection Deficiency.

Product Quality Deficiency.

Engineering Investigation Deficiency.

SUBMIT

7. The deficiency reporting process is in the first column (left) and the responsibility is in the second column (right). Drag the step from the left side to the corresponding responsibility on the right side. Each item in the second column (right) may be used once or more than once.

1. Secures the exhibit.	Originator
2. Submits the validated deficiency report within time limits.	Originating point

3. Provides exhibit disposition instructions.	Screening point
4. Responsible for technical and administrative actions to resolve deficiency reports.	Action point
5. Provides status updates and closing actions.	Action point
6. Conducts investigations, trend analysis, and recommends corrective actions.	Support point

SUBMIT

Complete the self-test questions below.

Click here to answer the self-test questions pertaining to the integrated maintenance data system.

1. What does IMDS data translate into for commanders and managers?

Type your answer here

SUBMIT

2. What IMDS function allows you enter new data or change existing data?

- Database updates.
- Types of information retrieval.
- Reporting.

SUBMIT

3. What IMDS subsystem allows users to document, inquire, and retrieve information on maintenance actions?

- Location.
- Operational Events.
- Job Data Documentation (JDD).
- Training Management.

SUBMIT

4. What IMDS subsystem is commonly used to schedule shotgun qualification training?

- Maintenance Personnel.

Base Supply System Interface.

Operational Events.

Training management.

SUBMIT

5. Who must review data entered into IMDS on a daily basis?

Type your answer here

SUBMIT

This completes Lesson 3. You can find the answers to the self-test questions in the Module 2 table of contents.

Lesson 4. Hardened Intersite Cable System Fundamentals

Main Points

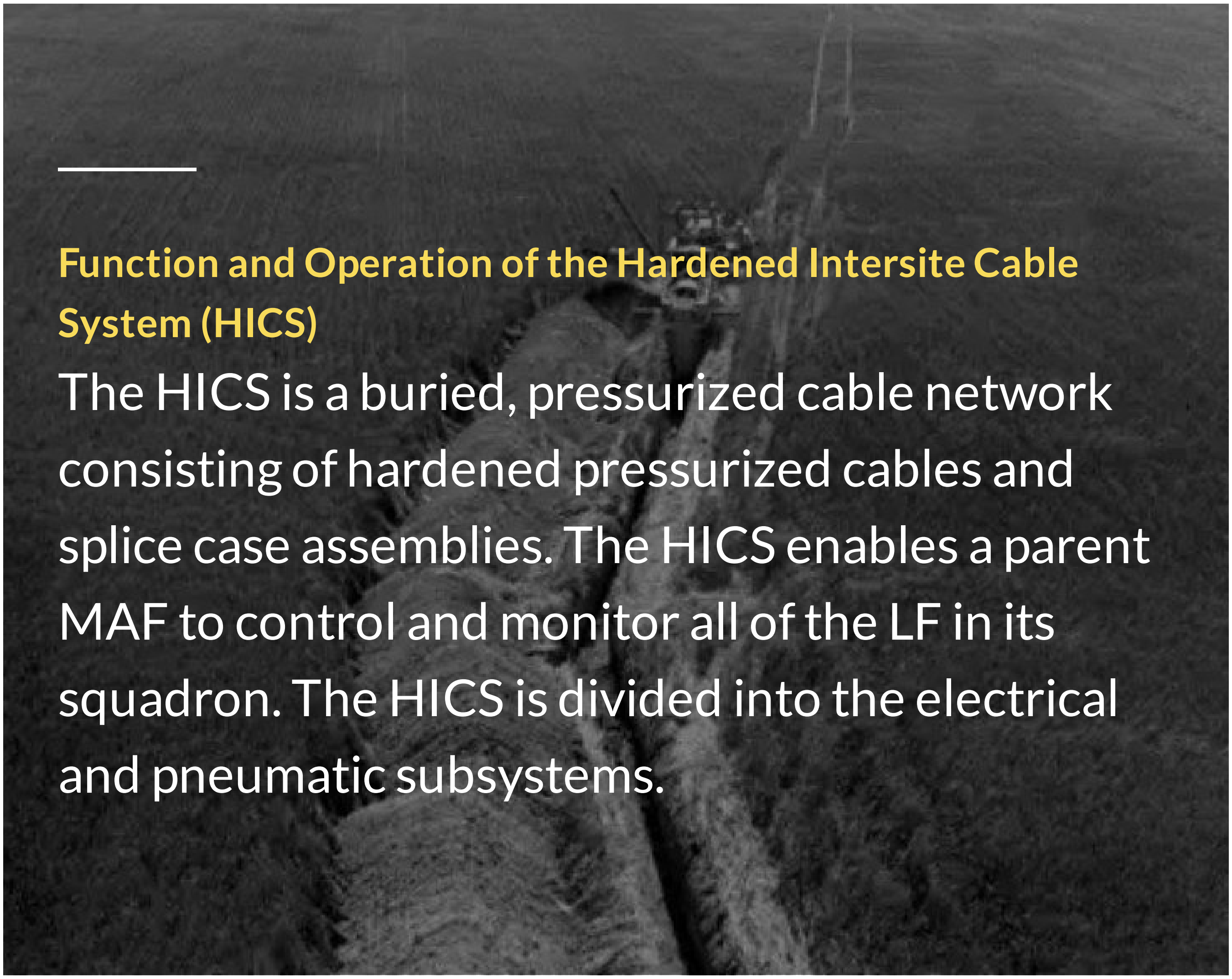
1. Function and operation of the hardened intersite cable system
2. Cable identification and color-coding standards
3. Using hardened intersite cable system test equipment

Airmen John McConnico and Wilfredo Hernandez Mendez, hardened intersite cable system technicians, train to splice together a wire within a larger cable. The 90th MMXS HICS team maintains the upkeep and repair of the cables throughout the missile field. The cables run throughout the F.E. Warren Missile Complex and are part of the communication system between launch control centers and an ICBM at a launch facility.

A lengthy network of buried cables that were laid more than 50 years ago connects all of the MAFs and LFs at each missile wing. Throughout the years, these cables have been repaired, spliced, pressurized, dug-up, and eroded out. The responsibility to ensure that these cables have the capability to carry the critical commands necessary to control and monitor the missiles at the LFs resides with the facilities maintenance journeyman. Maintaining these aging cables becomes more difficult as they continue to need repairs and ground erosion continues to expose them.

If technicians are needed in the hardened intersite cable system (HICS) shop, you may be assigned there instead of attending team training. This unit will familiarize you with how the HICS system is laid out and how it works. We will look at how to identify the types of cables as well as the twisted wire pairs inside each cable. Lastly, we will examine how to use the test equipment items that help a HICS technician locate faults in a cable line.

Click here to begin Lesson 4.

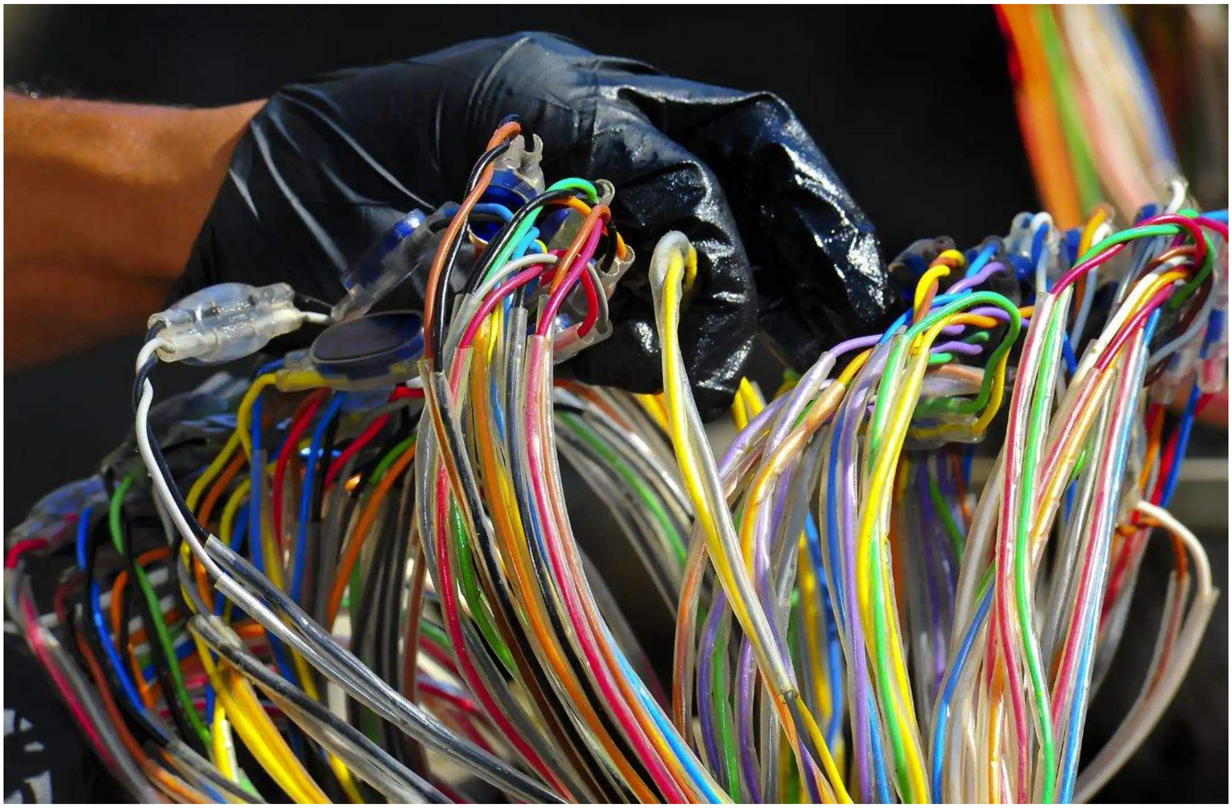


Function and Operation of the Hardened Intersite Cable System (HICS)

The HICS is a buried, pressurized cable network consisting of hardened pressurized cables and splice case assemblies. The HICS enables a parent MAF to control and monitor all of the LF in its squadron. The HICS is divided into the electrical and pneumatic subsystems.

Electrical System

The HICS electrical system consists of the individual cables and cable pairs that provide the command and control link and allow voice communication between the LFs and MAF. Pressure transmitters installed in the electrical system will indicate where a pressure problem exists and will enable a technician to locate pneumatic faults. Some of the major components of the electrical system include the cable network, cable splices, electrical surge arresters (ESA), and high-energy spark gaps. We'll look more closely at these components in the following paragraphs.



Detailed View of HICS Wires.

Close up View of the HICS Cable.

Cable Network

A typical cable network is shown in figure 4–1. A ring of cables encircles the MAF, and four radial cables extend from the MAF to the encircling ring. Each LF is attached to this encircling ring by what are known as feeder cables. Special cables called inter-trunk cables connect different missile flights together and also enable a MAF to control and monitor all of the LFs in its squadron.

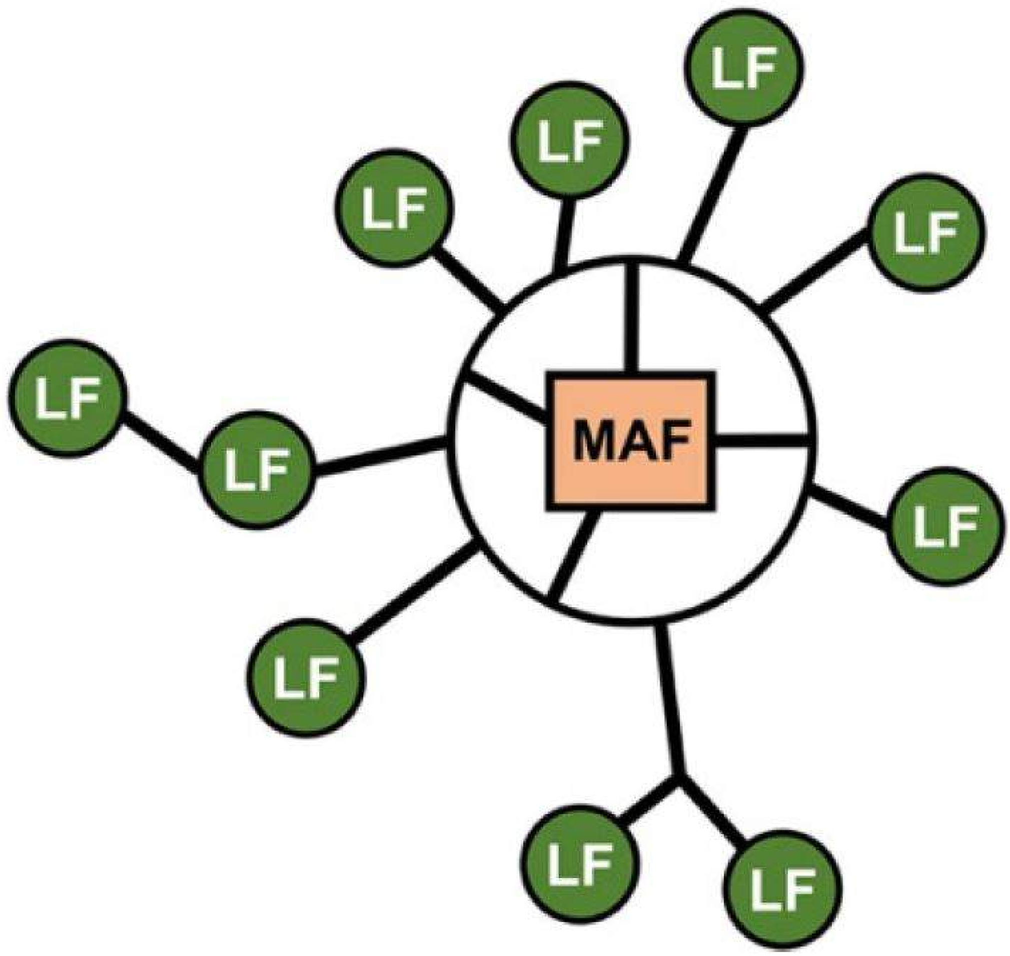


Figure 4–1. Typical Hardened Intersite Cable Network.

Figure 4–2. Splice Case.

Cable Splices

HICS cables are laid out in lengths of 3,000 to 6,000 feet and are connected together inside of a splice case (fig 4–2). Splice cases come in a variety of configurations and their purpose is to enclose and protect the cable splices and provide continuity for the pneumatic system. They are manufactured in either standard length or long length and will have either two or four inlet/outlet ports.

Cable Splices (continued)

The demi-valve is essentially an air tube that runs from the buried splice case up to ground level that allows a HICS technician to test the air pressure at that particular length of cable (fig 4–3). This helps greatly in the effort to accurately locate a pneumatic system fault without physically digging up a splice case.

A marker pole extending five feet above-ground usually identifies splice cases. An aluminum nameplate attached to the marker pole identifies the flight, segment, and number of the splice, and all marker posts are marked at the top with reflective orange tape or paint to help visually locate the pole. If a demi-valve assembly is installed it will be attached at the base of the marker pole (fig 4–3).Instead of a marker pole, some splice cases have a locator peg buried at the splice location indicating that a splice was used to repair a broken cable. A wooden board is also buried roughly one to two feet above the splice case to let the backhoe operator know to stop digging. The rest of the dirt is removed manually so the backhoe's bucket does not damage the splice case.

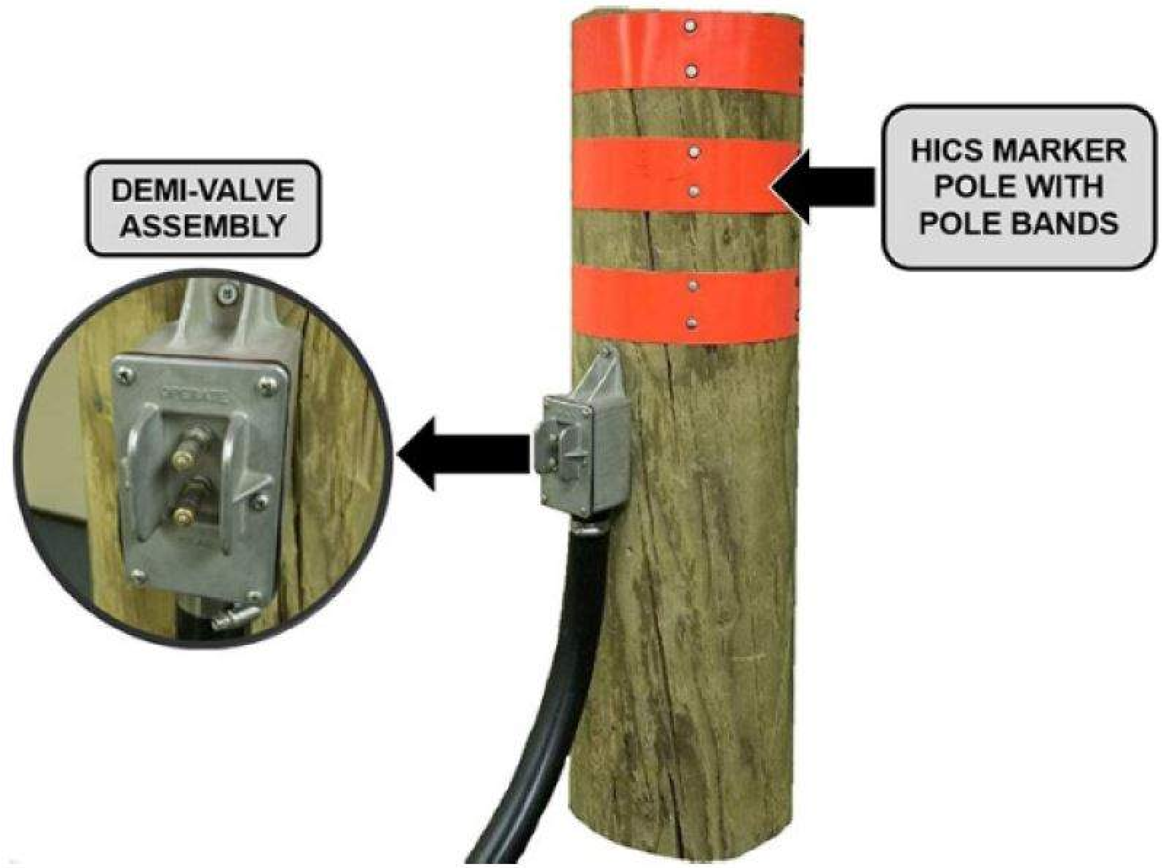


Figure 4–3. Marker Pole with Demi-Valve Assembly.

Figure 4–4. Electrical surge arresters.

Electrical Surge Arresters

HICS cables that enter the LF interface directly with an ESA (fig 4–4). An ESA is used to protect site equipment against damage from electrical surges caused by lightning or electromagnetic pulse (EMP). The ESA is installed between the terminal splice case and interconnecting box and consists of three carbon blocks. These carbon blocks are separated by an air gap and two 20 Ω (ohm) current limiting resistors. The air gap breaks down during voltage and current surges, and the resistors limit the current entering site equipment. Each cable entering the LF is protected by its own ESA and each conductor of the cable is connected to its own carbon block. The third carbon block in an ESA is grounded.

High-energy Spark Gaps

Hardened intersite cable entering the MAF are typically attached to high-energy spark gaps (HESG) and then connected to an ESA (fig 4–5). The HESG provide separation between the input and output wiring of the cable and are used to keep EMP from damaging sensitive equipment. Together, the HESG and ESA provide the launch control center (LCC) equipment with protection from lightning and EMP disturbances. MAF ESAs are installed and function identical to LF ESAs.

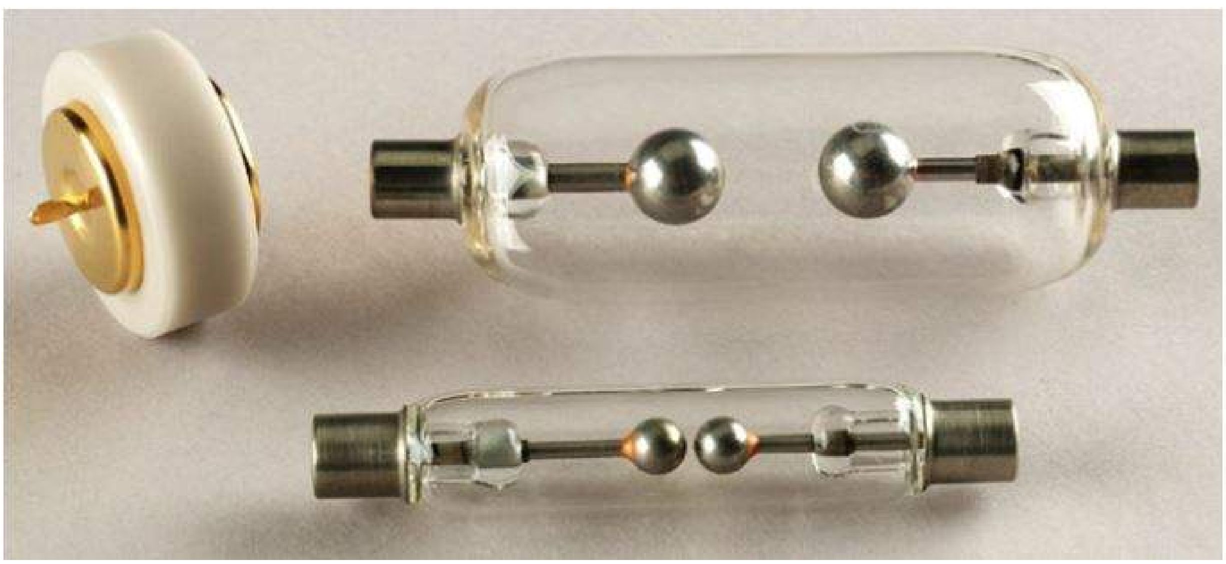


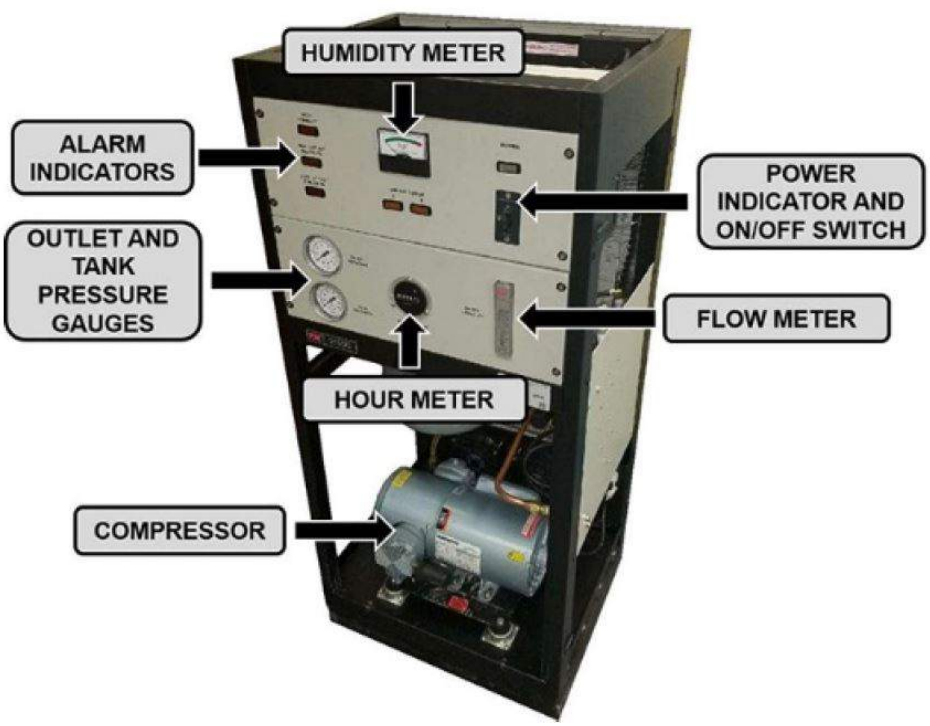
Figure 4–5. High-Energy Spark Gaps (generic).

Pneumatic System

Pressurized air is used to prevent water and condensation from entering through a break in the cable system and two pounds per square inch (psi) is the minimum amount of pressure that will accomplish this. The pneumatic system pressurizes the cable and has several components to check the pressure as well as an electrical method to check and transmit the cable system pressure. This system consists of the cable air dryer (CAD), flowmeter panel, pressure monitoring receiver-transmitter (PMRT), and communications squadron computer (CSC). Each of these are covered in the following paragraphs.

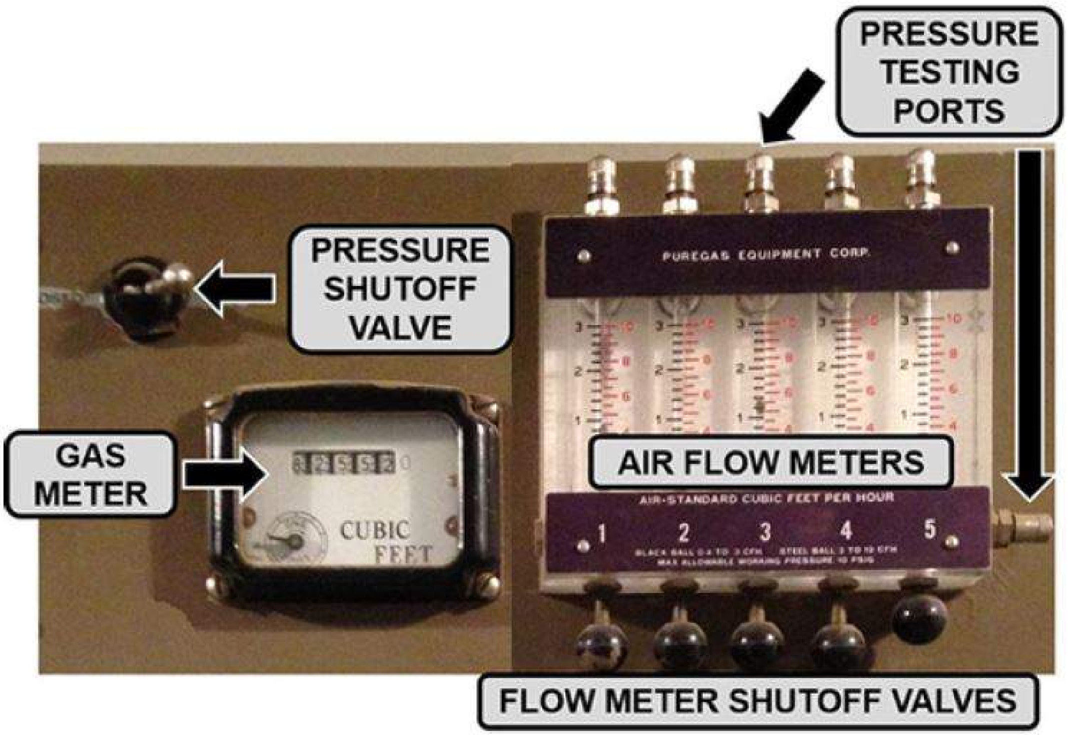
Cable Air Dryer

The CAD provides the pressurized air that is sent out to the underground cables (fig 4–6). Every Wing 1 LF has a CAD, which is necessary because of the larger square mileage of the complex. The CADs at the Wings 3 and 5 MAFs provide most of the dry, compressed air necessary to pressurize all of the cables in their flights, and additional CADs are installed at select LFs where necessary. The MAF CAD is capable of providing up to 3,100 cubic feet of compressed, dried air per day, and each CAD utilizes a desiccant system that removes moisture from the compressed air. The pressure leaves the MAF CAD and flows into the flowmeter panel.



Flowmeter Panel

The MAF flowmeter panel measures the output of the CAD and can also be used to adjust the airflow rate to each of the radial cables extending from a MAF to the encircling cable run (fig 4–7). A shutoff valve located on inlet side of each meter cuts off the airflow when necessary. Each meter also has a pressure-testing valve to measure the air pressure in each of the four cables, and these valves can be adjusted to add more air to the HICS in emergency conditions.



Pressure Monitoring Receiver-Transmitter

Each MAF has a PMRT which is located in the flight security controller's office. Its purpose is to continuously monitor all of the cable system and splice case pressure transmitters as well as the MAFCAD low-pressure alarms. The transmitter sends out two data "words" whenever it is interrogated by the PMRT: The first data word contains the location of the transmitter, and the second data word contains a coded representation of the cable air pressure at the transmitter. This helps tremendously in pneumatic fault isolation because it allows personnel on base to check the cable pressure at every junction that has a pressure transmitter. This system also provides additional security because of its ability to alert technicians of an unauthorized entry into the cable network.

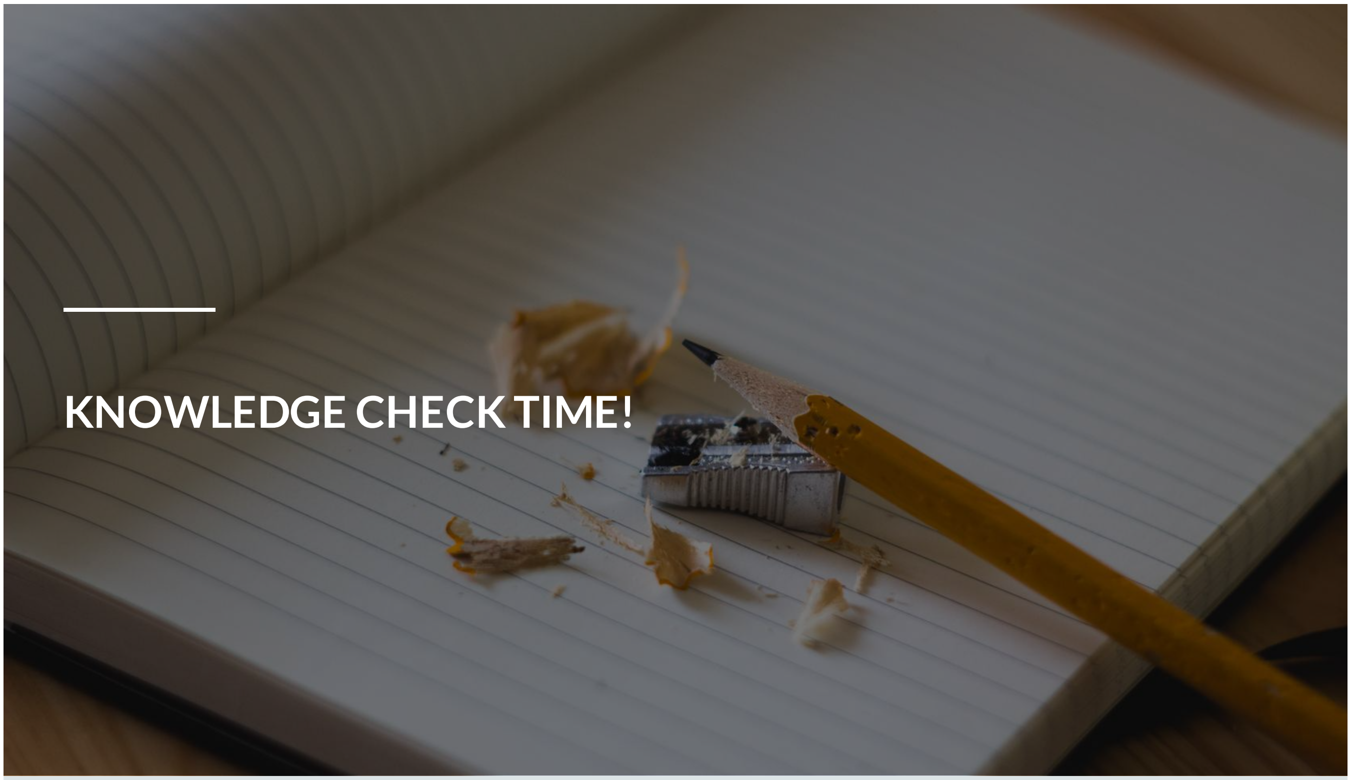
The PMRT also contains the interface for the ECS and environmental control system remote monitoring system (ERMS) that allows the Missile Maintenance Operations Center (MMOC) and facilities maintenance section (FMS) to view certain ECS parameters. Brine temperature, rack temperature, and launch tube temperature can all be monitored from the support base using the ERMS in conjunction with the PMRT, and this interface is an effective troubleshooting aid that can save countless dispatches.

Communications Squadron Computer

The CSC is a personal desktop computer typically located in the HICS shop that is used to monitor pressure levels in the HICS system. The CSC allows HICS technicians to monitor system pressure status and alarms, and it does this by interfacing with the PMRT at each MAF.

This lesson provided an overview of the function and operation of the HICS cables, how they're pressurized, and how we monitor the pressure in the many hundreds of miles of cable that comprise the HICS.

Complete the content above before moving on.



KNOWLEDGE CHECK TIME!

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the function and operation of the hardened intersite cable system (HICS).

1. What is the purpose of a feeder cable in the cable network?

Type your answer here

SUBMIT

1

2. What is the purpose of an inter-trunk cable in the cable network?

Type your answer here

SUBMIT

2

3. What purpose does a splice case serve in the pneumatic system?

Type your answer here

SUBMIT

3

4. What component allows a hardened intersite cable system technician to manually check the pneumatic system at different parts of the cable?

- Demi-valve assembly.
- High-energy surge box assemblies.
- Electrical arrester assemblies.

SUBMIT

5. Why would a locator peg be used instead of a marker pole for identifying splice locations?

Type your answer here

SUBMIT

5

6. What is the purpose of the high-energy spark gaps and electrical surge arresters at the missile alert facility?

Type your answer here

SUBMIT

6

7. What is the purpose of a cable air dryer?

Type your answer here

SUBMIT

7

8. What do the two data words transmitted to the PMRT from the pressure transmitters contain?

Type your answer here

SUBMIT

8

9. What interfaces with the PMRT and monitors system pressure status and alarms?

Type your answer here

SUBMIT

Complete the self-test questions above before moving forward in the lesson to learn about the cable identification and color-coding standards.

Cable Identification and Color-Coding Standards

Two HICS Cable Splicers at a Missile Alert Facility (MAF).

It is important to know which type of HICS cable you are working with when performing maintenance since you will do extensive work with the cable's internal wiring when splicing two HICS cables together in the field. You must know the standard color-coding of the wires in order to understand where the wiring is going, where it came from, and what type of signal it carries.

This will ensure that you do not cross any circuits that could prevent a critical command function from occurring. This lesson will focus on how to identify the two different types of cables as well as how to identify certain wire pairs by their color code.

Below you will learn about cable identification. Click on each tab below before moving forward in the lesson.

Cable Identification

The HICS shop has a cable yard where huge spools of spare cable are kept, and these cables are identified by metal tags tied to the outer end of the cable on each spool. The tag is marked with a cable designator showing the number of pairs, wire gauge (thickness), intended use ("B" for buried cable and "S" for submarine cable), and the total length of cable on that spool. A composite cable contains more than one size of conductor; therefore, the number of pairs is indicated by a forward slash (/) between the indicated pairs and gauge. For example, the designation 15/10 with 16/19 indicates 15 pairs of 16-gauge conductors, and 10 pairs of 19-gauge conductors.

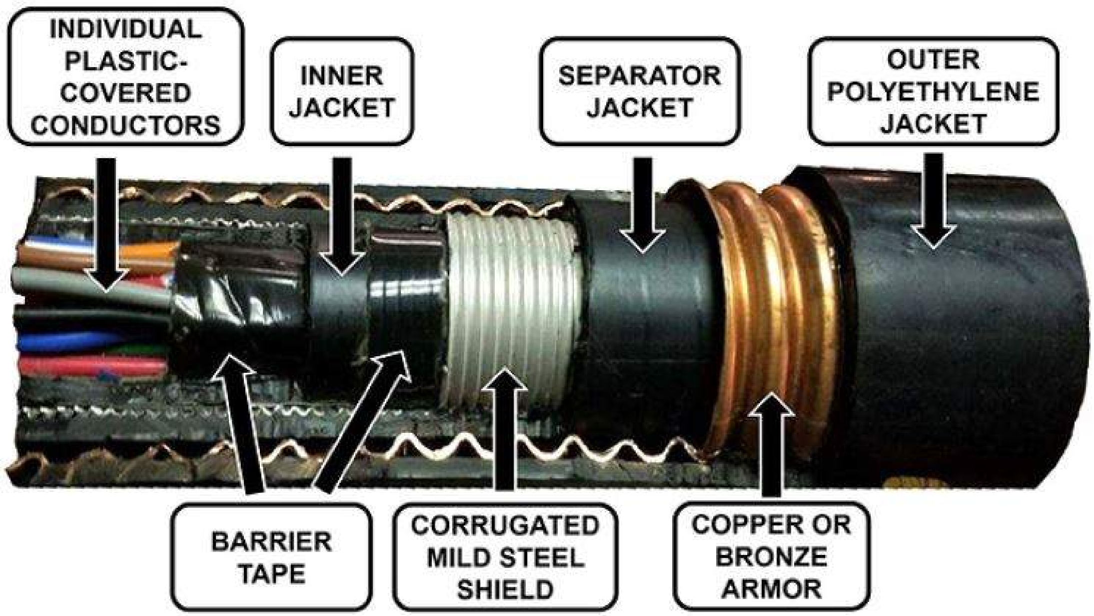
Since HICS cables are no longer manufactured, the large spools of cable that are kept in the HICS shop cable yard are maintained as if they were operational. They are pressurized by a CAD, and inspections are performed on the spare cable in the cable yard on periodic intervals.

The HICS is comprised of both buried cables and submarine cables that are classified according to their intended use.

A section of a hardened intersite cable used to connect MMIII silos to launch control centers (LCCs). This came from the demolished wings around Whiteman AFB.

BURIED CABLE	SUBMARINE CABLE

The buried cable that is used at all three of the missile wings is made up of twisted, color-coded wire pairs with several layers of insulation and protective casings (fig 4–8). The individual wires are either 16 or 19 American wire gauge (AWG) solid copper covered with color-coded polyethylene insulation. Twisted cable pairs are bound together in groups of up to 25 pairs, and each group is identified with a color-coded binding tape or a braid. The jacket is the portion of the cable that holds the air pressure sent out by the CAD. The inner jacket is covered by a barrier tape, which is then covered by a corrugated mild steel shield. This shield is covered by a separator jacket, which in turn, is covered with a corrugated bronze or corrugated copper armor. The armor on Wing 1 cables is also covered with an additional rubber thermoplastic asphalt-type compound layer; this extra layer was deemed unnecessary and therefore, was never used at Wings 3 and 5.



BURIED CABLE | **SUBMARINE CABLE**

Submarine cables must be used when a HICS run must cross a body of water or marshland. It is constructed identical to buried cable, the main difference being that the outer jacket of a submarine cable is covered with a layer of jute—a natural fiber similar to cotton. Tensile strength is then added to the layer of jute by wrapping it in an armor wire mesh, which is important because submerged cables continually creep and move. A final polyethylene outer jacket is then added to the wire armor to prevent corrosion.

Click on each tab before moving on to learn about wire color-coding standards.

TIP		RING
white/blue	pair 1	blue/white
white/orange	pair 2	orange/white
white/green	pair 3	green/white
white/brown	pair 4	brown/white
white/slate	pair 5	slate/white
red/blue	pair 6	blue/red
red/orange	pair 7	orange/red
red/green	pair 8	green/red
red/brown	pair 9	brown/red
red/slate	pair 10	slate/red
black/blue	pair 11	blue/black
black/orange	pair 12	orange/black
black/green	pair 13	green/black
black/brown	pair 14	brown/black
black/slate	pair 15	slate/black
yellow/blue	pair 16	blue/yellow
yellow/orange	pair 17	orange/yellow
yellow/green	pair 18	green/yellow
yellow/brown	pair 19	brown/yellow
yellow/slate	pair 20	slate/yellow
violet/blue	pair 21	blue/violet
violet/orange	pair 22	orange/violet
violet/green	pair 23	green/violet
violet/brown	pair 24	brown/violet
violet/slate	pair 25	slate/violet

Insulation Marking

Tip and Ring Chart.

Wire Color-Coding Standards

HICS cables are composed of many pairs of color-coded wires that are twisted around each other. The color-coding is based on the color of the wire's outer insulation, but there are several other characteristics that will help you identify what function each wire pair actually serves. Let's look at some terms that will help you understand the color-coding standards.

Binder

A group of 25 wire pairs is called a binder, and each binder is color-coded with a binder braid for quick identification. In a cable that contains 50 twisted pairs, pairs 1–25 are bound in a white/blue binder braid and pairs 26–50 are bound in a white/orange binder braid.

Binder color chart.

Pair

A combination of two wires twisted together is called a pair (fig 4–9). One wire is called the tip and the other the ring.

TIP	The tip is the positive wire in a cable circuit and is coded in numerical order; pairs 1–5 have a whitetip; 6–10 have a red tip; 11–15 have a black tip; 16–20 have a yellow tip; 21–25 have a violet tip.
RING	The ring is the negative wire in a cable circuit. The ring is also color-coded, but the combinations vary to ensure there can be at least 25 different combinations of color pairs. The ring colors are blue, orange, green, brown, and slate.

Let's use wire pair #6 as an example: The positive wire (tip) is red and the negative wire (ring) is blue, and this wire pair would be tied in a white and blue binder.

A circuit record card is always prepared for each pair in a cable when performing maintenance on a HICS cable. It is important to understand the color-coding standards because you will need to know which wire pair is used for which type of circuit.

This lesson described the different HICS cables that are used in the complex. You also learned about each layer of a HICS cable as well as the color-coding and terms associated with the conductors inside of them. We will cover the use of HICS test equipment in the next lesson.

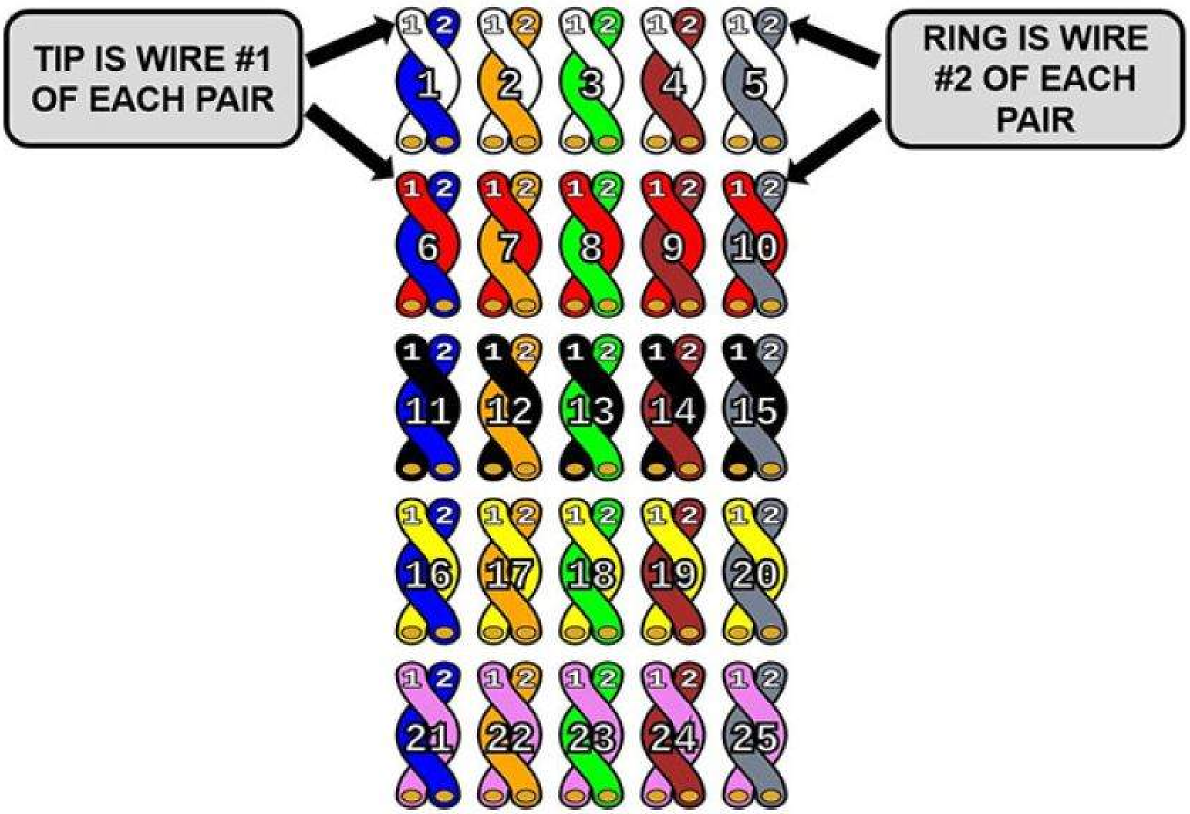
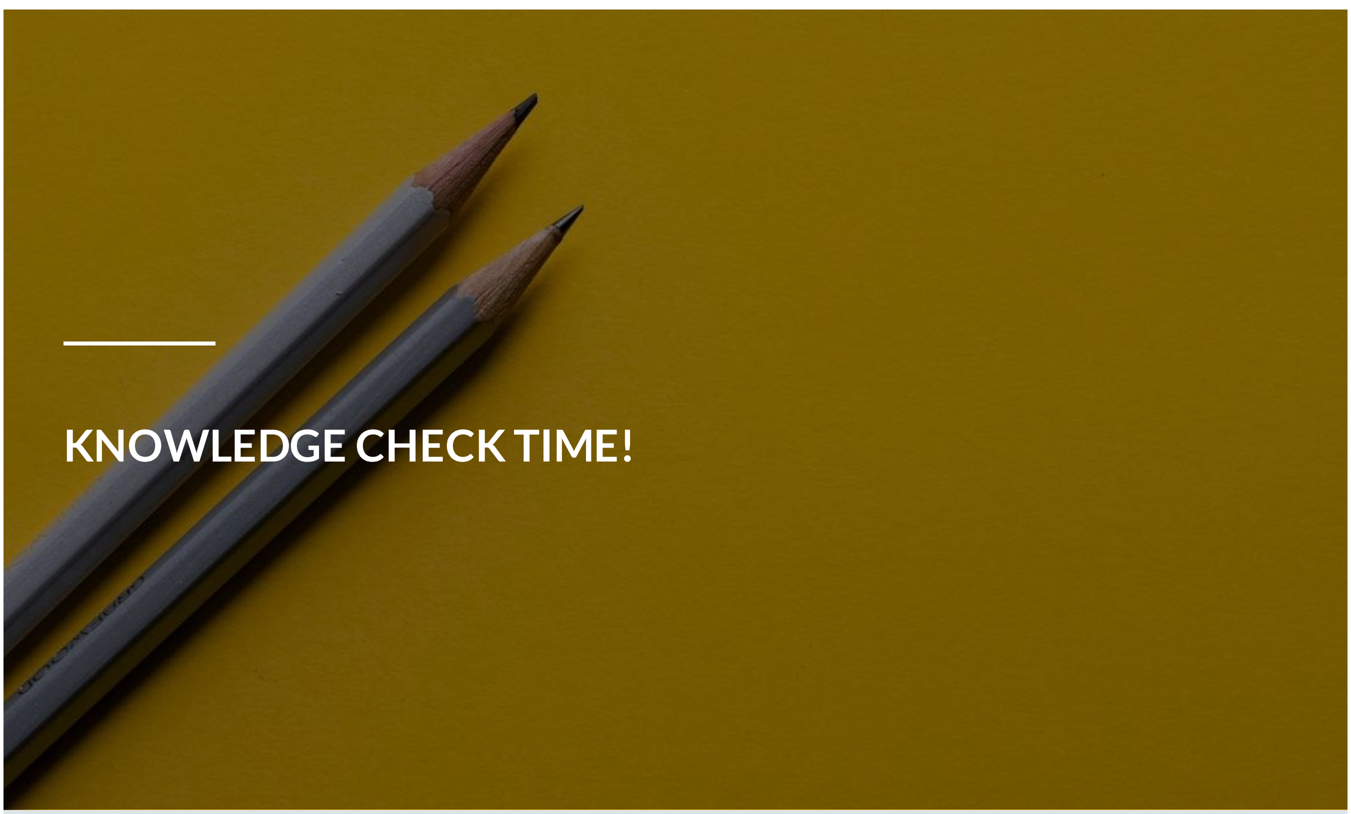


Figure 4–9. Conductor Tip and Ring Colors.



KNOWLEDGE CHECK TIME!

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the cable identification and color-coding standards.

1. How are the different sizes and pairs of a composite cable identified on the metal tags attached to the end of a cable reel?

Type your answer here

SUBMIT

2. What size conductors are typically used in a buried cable?

- 19 or 25 American wire gauge.
- 25 American wire gauge.

16 or 19 American wire gauge.

SUBMIT

10

3. Why do the buried cables at Wings 3 and 5 not have an additional layer of the rubber thermoplastic asphalt-type compound?

Type your answer here

SUBMIT

11

4. When is a submarine cable used?

Type your answer here

SUBMIT

12

5. What is a binder?

Type your answer here

SUBMIT

13

6. What are the terms for the positive and negative conductors of a cable circuit?

Type your answer here

SUBMIT

Complete the questions above before moving forward to learn about using hardened intersite cable system test equipment.

Time Domain Reflectometer.

Using Hardened Intersite Cable System Test Equipment

As a HICS technician, you are probably already familiar with most of the test equipment you use. Both FMS and HICS technicians use the same equipment, but there are some notable exceptions where you will use equipment in the HICS shop that you have likely never seen before. Two of these pieces of equipment are the splicer's headset and the time domain reflectometer (TDR). This lesson will introduce you to these two pieces of equipment, and give you step-by-step instructions on how they are used.

Using the Splicer's Headset

The splicer's headset is a very handy tool that is used to identify wire pairs and aid in detecting cable faults and splicing errors (fig 4–10). The headset consists of an earpiece, microphone, and a flexible cord with dual alligator clips. The headset's capacitor aids in testing live wire pairs and provides a great method of identifying wire pairs when the circuit record card is incorrect due to a splicing error.

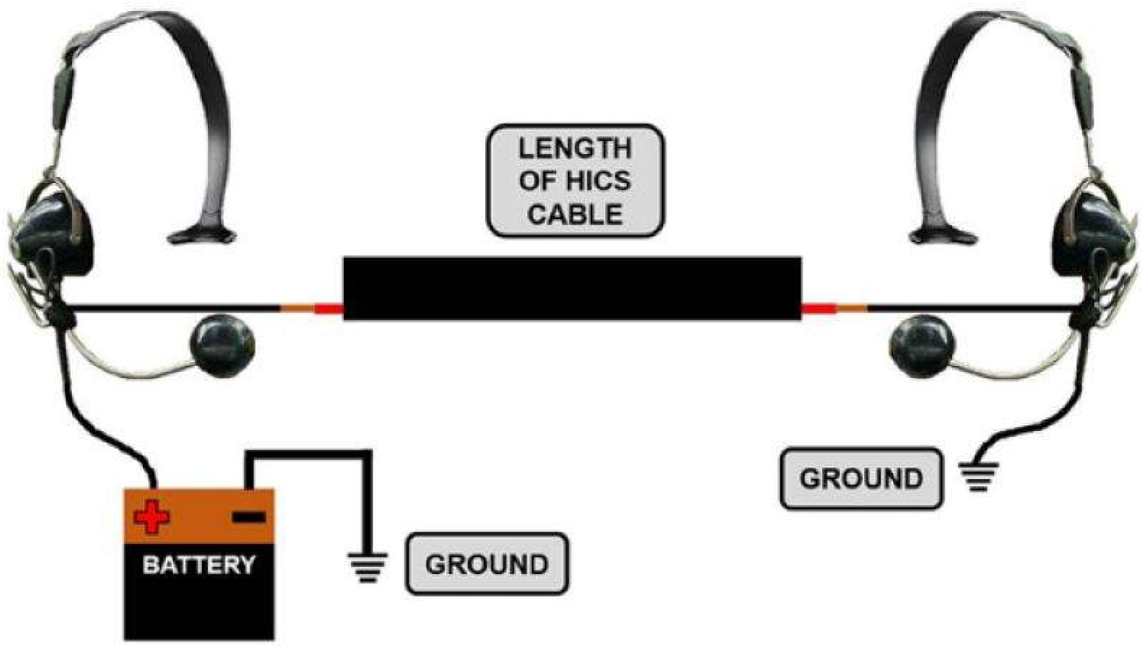
Figure 4–10. Splicer's Headset.

Click on each (+) sign below to learn about using the splicer's headset.

Establishing a Talking Circuit

To identify wire pairs with a headset, you must first establish a talking circuit (fig 4–11), which is a voice communication circuit that is established between two technicians at two different locations along a run of cable. These locations could be at a splice case, a terminal splice case at an LF or MAF, or any other open point in the cable. Two headsets connected to a battery source are required to establish a talking circuit.

Depending on where you are checking, you normally need at least two technicians and two headsets. Technician #1 connects the positive headset lead to the positive terminal on the battery, and then connects the negative side of the battery to ground. Technician #1 then connects the other headset lead to the wire pair that needs to be tested. Technician #2 simply connects the negative headset lead to ground and then touches the positive headset lead to each wire pair one by one until an audible "click" is heard in the headset earpiece. This click indicates that the circuit is connected to the battery source. Once the talking circuit has been established, two technicians at either end of a long run of HICS cable can speak to each other through their headsets.



Conductor Testing

Now that the talking circuit is established, you are ready to identify and test the cable. Testing wire pairs is done before, during, and after the installation of a cable, or when problems exist in the cable.

Testing a cable uses the same procedures that were used for establishing a talking circuit. Teams on both ends of the cable move the free headset lead to different wire pairs and listen for a “click” in the headset earpiece. Using the circuit record card on both cable ends and the color-coding standards, you will be able to identify which wire pairs are connected properly and which ones are mismatched.

Splicing Errors

The headset’s primary purpose is to verify if a cable is spliced correctly, and to detect where the incorrect splice is if a cable is not working properly. Three common splicing errors are the reversed pair, split pair, and transposed pair (fig 4–12).

The reversed pair is the easiest splicing error to detect because it only involves one pair of conductors. The split pair and transposed pair will take more time to identify and repair because they involve two or more pairs of conductors.

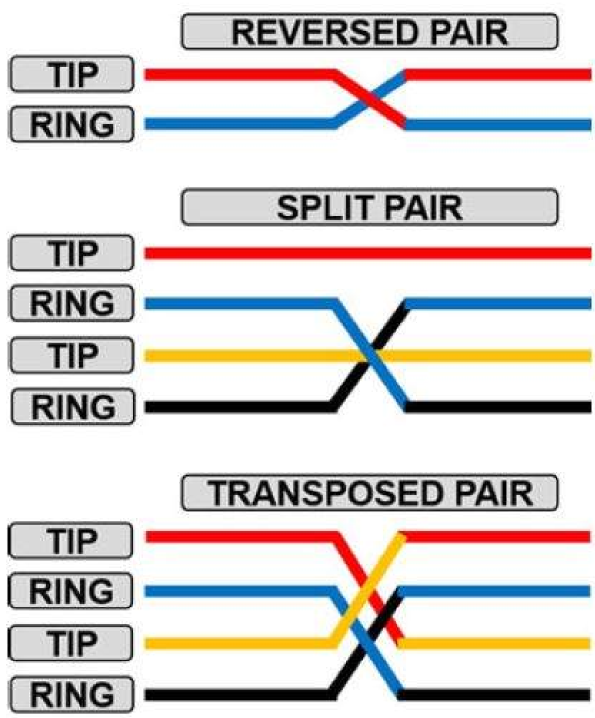


Figure 4–13. Time Domain Reflectometer.

Using the Time Domain Reflectometer (TDR)

Remember that runs of HICS cable are buried and can be miles long. Once a team determines that a fault exists, the TDR (fig 4–13) is used to see where the fault is in the run of cable. The TDR transmits a series of half-sine wave pulses along the circuit being tested and will display impedance mismatches along the cable line based on the pulses that are returned. A technician can measure the exact distance to the cable fault using the TDR's digital readout.

Click on each (+) sign below to learn about using the time domain reflectometer (TDR).

Precautions

—

Certain precautions must be taken when using the TDR in order to avoid unusual responses from the weapon system. Depending on the type of fault, test pulses from the TDR may have the capability to activate a command or status circuit on a HICS cable. For example, if a short exists in a command or status circuit, the test pulse generated by the TDR will also obviously flow to that circuit. This can be avoided by adjusting the TDR to its maximum range because doing so blocks communication between the LF and MAF lines. The downside of setting the TDR to its maximum range is that when a communication blockage occurs, the following indications could result:

- Communications failure printouts at the LCC console.
- Possible ground maintenance response (GMR)–24 indicating an LF line loss failure.
- Worst-case scenario, the LCC could receive an LF DOWN indication.

This will only happen at a given MAF, but other MAFs can still monitor those affected LFs through the inter-trunk cables. If cable maintenance is necessary, a missile combat crew (MCC) should transfer control of all of its LF monitoring to another MCC to ensure proper monitoring of those sites.

Isolating Faults From a Launch Facility (LF) or Missile Alert Facility (MAF)

—

You initially will not know the exact location of a fault in a HICS cable, but you will know which flight or squadron is reporting communication issues. It is for this reason that you will typically begin your troubleshooting efforts at either a MAF or LF.

Once you're inside of the MAF or LF ESA vault, you will use the circuit record card to identify which wire pairs to test based on the type of fault that is occurring. Once you locate the wire pairs that need to be tested, verify the absence of voltage and then disconnect the wires at their termination points. Similar to isolating a component in a circuit for resistance testing, this method will isolate the circuit that needs to be tested so that stray voltages don't cause erroneous indications on your test equipment.

For your initial test, connect the TDR test leads to the tip and ring and then set a short-range distance of 0.5 feet with a multiplier of 10. If the display of the TDR does not indicate a fault, you will continue to increase the distance setting until a fault indication appears. To calculate how far down the HICS line the fault is, multiply the distance knob setting and the multiplier you set. This will give you a close approximation of where the fault exists. Once you identify the location of a fault, it is imperative that you document the results. Now that you have identified the fault and how far from your test point the fault exists, it is time to physically dig up the malfunctioning cable or splice case.

Isolating Exact Faults

Next, you will use the information that you gathered from the cable test in the previous step to identify the splice case that is closest to the location of the fault. Always visually check the area in the vicinity of the splice case for any above-ground evidence of a problem before you dig up the splice case to perform TDR checks. You might find a local construction project, areas washed out by flooding or runoff, or other soil disturbances that could have damaged the cable. If you find any visible evidence of damage to a HICS cable, start your investigation there. If no evidence is found, it is time to excavate the splice case.

Once the splice case has been unearthed, check for incorrect splices, broken wires, corrosion, or other possible symptoms that could be causing the fault. To test the cable using the TDR, disconnect the wire pairs in the splice case, and check for faults in both directions from the splice. Use the same procedure from the LF/MAF test to verify each line, starting with a short distance and expanding until you locate the fault. There may be a fault both up- and down-stream from the splice case, so always be sure to test the cable in both directions.

The TDR will indicate how far the fault is from the splice case. Using the fault's distance from the splice case in conjunction with a cable route map, locate and mark the spot for excavation and cable repair.
Once the cable has been repaired, use the TDR at the splice case to verify the fault has been repaired. You will then re-accomplish the TDR test at the LF or MAF to verify overall circuit performance.

Complete the content above before moving on.

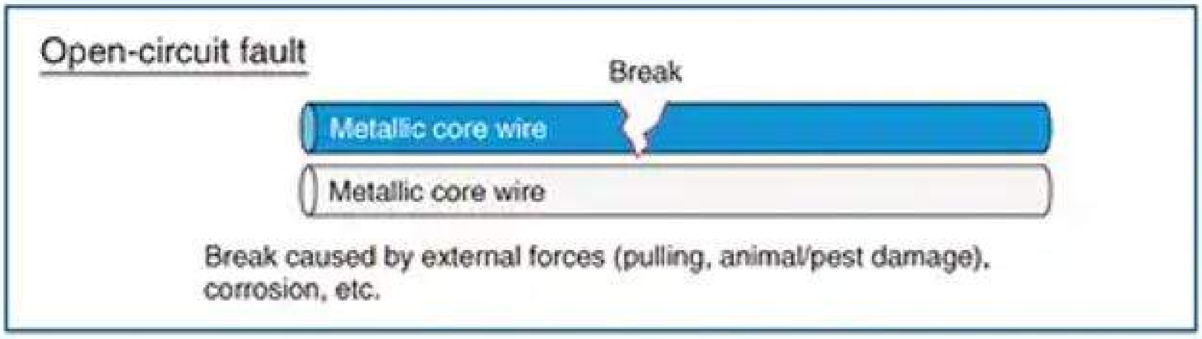
Click on each (+) sign below to learn about cable faults.

CABLE FAULTS	OPENS	SHORTS

Now that we have seen how to use a TDR, let's take a look at the kinds of faults a TDR will detect. Opens and shorts are the two most common faults in a cable line, so we will examine what they are and explain how they will appear on the TDR's display. The TDR will display the test pulse you send out on the line, as well as the return pulse.

CABLE FAULTS	OPENS	SHORTS

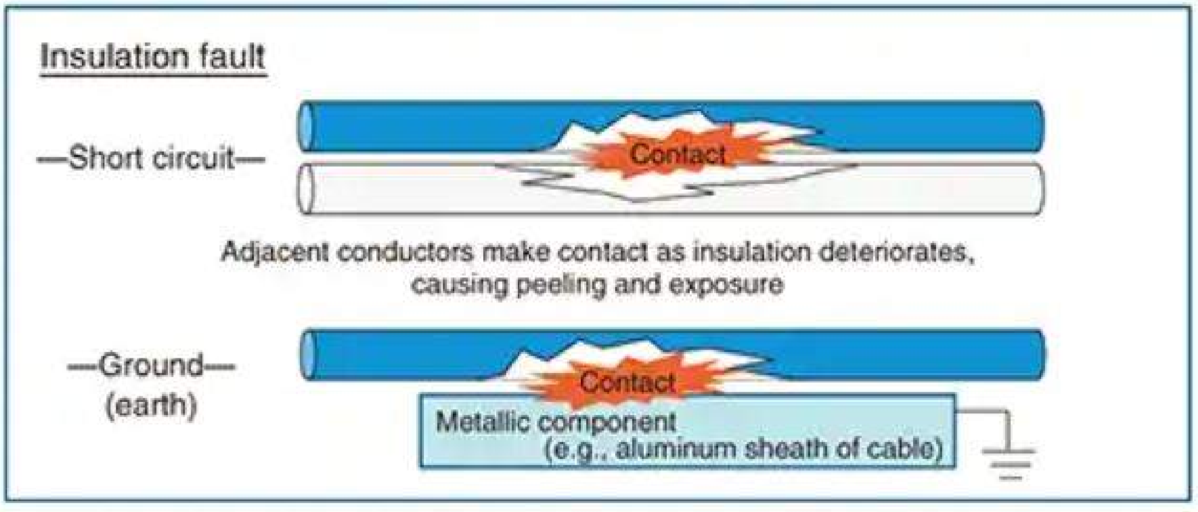
An open is when there is not continuity between either the tip and/or ring throughout the entire length of the cable—in other words, a broken wire. An open in both the tip and ring will have a large, positive return pulse. If the open is in only the ring or only the tip, the return pulse will still be positive, but the wave will be smaller.



CABLE FAULTS	OPENS	SHORTS

This type of fault can also be detected with the splicer's headset, but the TDR will provide you with the exact distance from the splice case to the fault. The test pulse sent from the TDR will be positive with a negative return pulse. When you see this, it means that there is a short between the tip and ring of a wire pair.

This lesson focused on the steps necessary to operate the splicer's headset and the TDR. These are two excellent tools that you will use as a HICS technician to troubleshoot cable faults in the missile field.



Complete the content above before moving on.

FINAL KNOWLEDGE CHECK.

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to using hardened intersite cable system test equipment.

1. What is the purpose of the splicer's headset?

Type your answer here

SUBMIT

2. Once a click is heard on the headset with the leads connected, what action is taken to verify the connection is good and the talking circuit is established?

Type your answer here

SUBMIT

15

3. How does a TDR indicate impedance mismatches along a cable line?

Type your answer here

SUBMIT

16

4. If a communications blockage occurs at a missile alert facility when using a TDR, how else can a launch facility still be monitored?

Type your answer here

SUBMIT

17

5. When using the TDR, what is the initial setting for your first test?

- 0.1 feet with a multiplier of 10.
- 0.5 feet with a multiplier of 10.
- 1.0 feet with a multiplier of 100.
- 0 feet with a multiplier of 10.

SUBMIT

18

6. How do you calculate how far down the HICS line a fault exists when using the TDR?

Type your answer here

SUBMIT

19

7. When identifying the exact location of HICS fault, what should be done before excavating a splice case?

Type your answer here

SUBMIT

20

8. What is done after using the TDR at a splice case to identify the distance to the fault?

Type your answer here

SUBMIT

21

9. What will be displayed on the TDR for an open in both the tip and ring in a wire pair?

Type your answer here

SUBMIT

22

10. What will be displayed on the TDR for a short between the tip and ring of a wire pair?

Type your answer here

SUBMIT

You have completed Lesson 4. This is the last lesson in Module 2. The practice exam for Module 2 is located in myLearning.

Module 2: Self-Test Question Answers

LESSON 1: Spacelift and Research & Development

201. Space Domain Overview

1. Sustaining/maintenance.

2. The space domain.

202. Mission of Spacelift Organizations

1. Air Force Space Command (AFSPC).

2. Cape Canaveral Air Force Station (CCAFS), Florida, and Vandenberg AFB, California.

3. Vandenberg Air Force Base (AFB), California.

4. The 45th Space Wing (45 SW).

203. Functions of Spacelift Units

1. Weather.

2. The reuse of deactivated intercontinental ballistic missiles for a variety of new missions.

3. Place medium/heavy lift satellites into polar orbit.

4. Mission assurance technicians.

5. 45th Space Wing.

6. Patrick Air Force Base or Patrick Space Force Base.

7. Launch Complex–41.

8. Spacecraft launch operations, training and certification of engineers, operators, and maintenance personnel.

204. Atlas V Vehicle Configuration and Infrastructure

1. Common core booster, Centaur upper stage, payload fairing.

2. A hot gas generator, main turbopump assembly, and a single turbine.

3. Propellant tank, stub adapter, Centaur forward adapter, and tank insulation.

4. Mobile service tower.

5. Launch support building.

6. Fixed launch platform.

205. Delta IV Vehicle Configuration and Infrastructure

1. Liquid hydrogen and liquid oxygen.

2. A Pratt & Whitney RL–10B2 engine.

3. 13-foot and 16.5-foot variants.

4. Several hours before launch.

5. Mobile assembly shelter.

6. Launch table.

7. Horizontal integration facility.

206. Spacecraft Systems

1. (1) Communications.

   (2) Navigation.

   (3) Weather.

   (4) Research.

   (5) Surveillance and early warning.

   (6) Military.

2. Solar, battery, or nuclear power.

3. Methanol or ammonia.

4. Electro-thermal, electrostatic, and electromagnetic.

5. Overcoming the motion of the satellite generated by atmospheric drag, gravity, and solar winds.

6. Information on the mission of the satellite and information on the general health of the satellite.

207. Mission of Research and Development Organizations

1. (1) c.

   (2) b.

   (3) a.

   (4) g.

   (5) f.

   (6) e.

   (7) d.

2. Headquarter United States Air Force.

3. Test and evaluate new warfighting capabilities.

4. Critical issues regarding a system's performance in combat-like environments when operated by field personnel.

LESSON 2: Publications

208. Categories and Types of Standard Publications

1. A supplement cannot be less restrictive than its parent publication.

2. A memorandum is published when there is insufficient time to process a directive.

3. All personnel in the unit or subordinate unit who developed them.

4. They should only be displayed for 180 days or less and the expiration date should be printed on the bottom.

5. The office of primary responsibility listed on the website.

209. Description of The Technical Order System

1. Operations and maintenance technical order.

2. Methods and procedures technical order are not required to be available and used at the job site.

3. Any technical order applicable to a specific weapon system and its related items.

4. Directing and providing instructions for modifications and the performance of one-time inspections.

5. “IMMEDIATE ACTION” is printed in red at the top center of the first page and a series of red Xs are printed around the border of the first page.

6. The equipment or item must be removed from service until the time compliance technical order is accomplished.

7. A validation-verification must be performed on its procedures.

8. Procedures on special tools.

9. One technician reads the step; the technician other completes the step, and then verbally responds to indicate that the step was complied with.

10. Accept/reject criteria.

11. Inform your supervisory personnel to obtain a technical order waiver.

210. Typical Technical Order Format

1. It ensures that you have the most recent version of the technical order.

2. To ensure that you are familiar with any changes to tasks or additional tools and test equipment you may need.

3. Before starting any maintenance task.

4. It will help develop your system knowledge.

5. Perform the next step.

6. Alarm indications section.

7. Perform the applicable procedure to establish the required mode of operation.

8. Only when used in conjunction with trouble analysis procedures.

9. A vertical black line will be printed next to the changed content.

211. Technical Order Improvement Report

1. To correct errors or omissions of a technical nature, which prevent adequate performance of functions required for mission accomplishment.

2. Select the proper category or disapprove the recommendation.

3. An interim time compliance technical order or rapid action change.

4. If they cause misinterpretation or affect the meaning of instructions that would impede the mission.

5. Brief summaries of the deficiency and recommended change.

212. Description of Civil Engineering Manuals

1. Instructions for operation and maintenance of a real property installed equipment system.

2. Commercial owner’s manuals.

3. All of the information needed to complete a modification or one-time inspection.

213. Format of Civil Engineering Systems and Equipment Manuals

1. Not all components may be listed in the component lists.

2. Particular pieces of equipment or how to fabricate locally manufactured tools or equipment.

3. Perform the corrective action listed.

4. Do what the corrective action says while complying with standard maintenance practices.

5. Equipment manual.

6. When procedures have been exhausted or are leading you astray.

7. The civil engineering manual, civil engineering manual interim change.

8. Description of the component, part information, the page number where the component information is located, and the sequence number.

9. Alphabetically.

214. Submitting Civil Engineering Manual Improvement Reports

1. Civil engineering manual changes are limited to those essential for weapon system reliability, safety, and protection of personnel and equipment.

2. Talk to your supervisor and quality assurance to see if a change has already been submitted for this content.

3. The complete number of the civil engineering manual or civil engineering manual interim that you're submitting the change for.

4. When a change is being proposed to a page in a civil engineering manual interim that has been changed in the past.

5. The figure number is located under the figure.

6. Creating a simple table in Microsoft Word or Excel to mimic a table in a civil engineering manual interim.

7. Your supervisor's name, grade, duty phone number, office symbol, signature, and date.

8. Name of the evaluator who reviewed the change, whether it was approved, disapproved, or put on hold, and comments regarding the submitted change.

LESSON 3: Maintenance Fundamentals

215. Using Digital Multimeters and Clamp-on Ammeters

1. So that you can quickly and accurately identify what type of measurement you're taking.

2. The letter "V" with a wave line above it.

3. The letter "V" with a one dashed and one solid line above it.

4. Clamp-on ammeter.

5. Make sure to have extra batteries or request another meter.

6. One or both of the test leads is defective, or the multimeter is malfunctioning.

7. It will automatically switch to auto-range mode.

8. Taking in-line amperage readings.

9. The negative common communications input jack and the red input jack labeled for voltage readings.

10. One million ohms.

11. Environmental control system procedures.

12. By measuring the intensity of the magnetic field around a conductor.

13. You may not get an accurate reading, or may not get one at all.

14. Connect test leads to the two input jacks on the bottom of the meter and turn the rotary selector switch to the resistance ("Ω") setting.

216. Troubleshooting Techniques

1. Follow a troubleshooting procedure until it is exhausted or leads to the fault.

2. Use the schematics and diagrams in conjunction with your technical order procedures.

3. You would be able to smell them.

4. Match indications to a specific troubleshooting procedure if you don’t already have one.

5. The system descriptions.

6. A neat and permanent-type.

7. No voltage.

8. Between the two points your test leads are connected to when you receive an overload, over limit, or open loop indication.

9. The positive conductors of two or more independent circuits making contact.

10. The contacts of a switch or relay are stuck together.

11. Because amperage readings won't be accurate due to a higher start-up draw.

12. The circuit breaker or switch is faulty or isn't working correctly.

13. Identify what the pieces and components of a schematic represent.

14. A big picture view of the system.

15. It shows point-to-point connections between components.

16. A reference designator of where it is going and where it originated from.

217. Hardware

1. It must meet more strict standards, and be made of lighter and stronger materials.

2. Authorized sources.

3. To fasten one or more objects together.

4. If they strip out, a larger hole will need to be drilled and new threads cut.

5. Because they're installed and removed by hand, without the need for tools.

6. Evenly distributes pressure from the nut or bolt and protects the mounting surface.

7. Pressing the release button on the head of the quick release pin.

218. Electrostatic Discharge Control

1. A lightning strike.

2. You will not always know when a discharge of static electricity has occurred.

3. A triangle with a depiction of a hand that looks as if it is picking up an object. A circle that contains three arrows that all originate outside of the circle and point to the inside of the circle.

4. The use of an electrostatic discharge wrist strap.

5. Simply avoid contact with the electrical connectors on a sensitive device.

219. Deficiency Reporting

1. A generic product used for recording, submitting, and transmitting deficiency data.

2. Any problem or issue with a product where it does not perform as it is required.

3. An acceptance inspection.

4. Major defect.

5. Category I.

6. Category II.

7. Matching question:

(a) Secures the exhibit. **Originator**

(b) Submits the validated deficiency report within time limits. **Originating point**

(c) Provides exhibit disposition instructions. **Screening point**

(d) Responsible for technical and administrative actions necessary to resolve deficiency reports. **Action point**

(e) Provides status updates and closing actions. **Action point**

(f) Conducts investigations, trend analysis, and recommends corrective actions. **Support point**

220. Integrated Maintenance Data System

1. How many personnel are needed to do the job, what high-failure parts are needed to keep on hand, and/or what systems are outdated and need upgrade.

2. Database updates.

3. Job data documentation.

4. Training management.

5. Work center supervisors.

LESSON 4: Hardened Intersite Cable System Fundamentals

221. Function and Operation of The Hardened Intersite Cable System

1. Attach each launch facility to the encircling cable ring around a MAF.

2. Connect different missile flights together.

3. Provides continuity for the pneumatic system.

4. Demi-valve assembly.

5. When a splice was needed to repair a broken cable.

6. Provides protection for the launch control center equipment from lightning and electromagnetic pulse disturbances.

7. Provides pressurized air needed to maintain pressure on the underground cables.

8. The first data word contains the location of the transmitter and the second is a coded representation of the pressure at the transmitter.

9. Communications squadron computer.

222. Cable Identification and Color-Coding Standards

1. By a forward slash (/) between the indicated pairs and gauges.

2. 16 or 19 American wire gauge.

3. The additional layer was deemed unnecessary after its first use at Wing 1; therefore, was never used at Wings 3 and 5.

4. When a cable needs to cross a body of water or marshland.

5. A group of 25 wire pairs in cable.

6. Tip and ring.

223. Using Hardened Intersite Cable System Test Equipment

1. Identify wire pairs and aid in detecting cable faults and splicer's errors.

2. Speak into the headset microphone to establish communication with the technician at the other end of the cable.

3. It transmits a series of half sine wave pulses down the circuit under test and looks for the return signal.

4. By another missile alert facility through the inter-trunk cables.

5. 0.5 feet with a multiplier of 10.

6. Multiply the distance knob setting to the multiplier you set.

7. Check the area in the vicinity of the splice for any visible evidence of a problem.

8. Using the time domain reflectometer information and a cable route map, find the spot on the cable map that is the correct distance from the splice case. Locate and mark the spot for excavation and cable repair.

9. A large, positive return pulse.

10. A negative return pulse.

This is the end of the self-test answers for Module 2.