2A-78-10: General

1. General Description:

The engine nacelle exhaust section aft of the Low Pressure (LP) turbine is designed to increase the exit velocity of the fan air and turbine exhaust mixture in order to enhance airflow through the engine. The rear of the engine terminates in an exhaust cone that is surrounded by the crenelated ring of the forced air mixer that blends fan stage air with heated exhaust from the turbine stages. The shape of the base of exhaust cone within the confines of the air mixer acts as a nozzle to increase exhaust velocity. The nozzle effect is enhanced by a progressive narrowing of the nacelle exhaust cross section as gases transit aft.

The interior surface of the nacelle exhaust section is lined with sound absorbent material to reduce noise levels in conformity with Stage III regulations.

The top and bottom of the exhaust section incorporate thrust reverser doors. The doors are movable panels, shaped congruently with the nacelle, that are opened and closed with the respective left or right aircraft hydraulic system. When actuated by commands from the reverse levers on the cockpit power levers, the doors pivot open, directing engine exhaust forward to enhance aircraft braking during landing rollout or an aborted takeoff.

2. Subsystems, Units And Components:

- 2A-78-20: Thrust Reverser System

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1. General:

The engine thrust reverser doors, one on top and another on the bottom of the engine, act in concert to change the direction of engine exhaust gases to aid the braking system in slowing the aircraft. When closed, the doors are fully integrated into the shape of the exhaust section of the engine nacelle. During operation the doors pivot at hinge points, with the aft edges of the top and bottom doors moving inward to mate, forming a blocking surface to interrupt the normal exhaust flow. The forward edges of the doors pivot outward, projecting approximately sixty degrees (60°) into the airstream in order to redirect the blocked exhaust flow forward. See the illustration in Figure 1. The thrust reversers are most effective in reducing high groundspeeds in the early phase of landing or an aborted takeoff. The Full Authority Digital Engine Control (FADEC) maintains engine speed at a high idle setting for five (5) seconds to facilitate the immediate use of reverse thrust upon touchdown.

Because an inadvertent opening of a thrust reverser door during flight would cause severe aircraft control difficulties, the thrust reverser system has a multi-layered architecture to prevent in-flight door actuation. If, nevertheless, such an in-flight deployment occurs, a separate independent command circuit is available to power the door closed, supplemented by a FADEC feature that reduces engine power to idle whenever a door is not closed during flight.

2. Subsystems, Units and Components:

A. Doors and Seals:

Each engine thrust reverser employs two symmetrical doors that are integral to the engine nacelle exhaust section. The doors are positioned on the top and bottom of the aft section of the nacelle and open vertically to redirect a substantial amount of engine exhaust gases forward when actuated on landing. Not all engine exhaust is redirected due to the concave shape of the doors and because some uninterrupted flow is essential to engine performance.

The doors conform to the internal and external shape of the nacelle and are fitted with flexible rubber seals around the perimeter of each door to maintain the integrity of engine exhaust flow when the doors are not in use.

B. Primary Locks:

Each door is locked in the stowed position by two primary locks, one on the inboard and one on the outboard side of the engine. The primary locks are essentially moveable dual latch mechanisms, with each lock securing one side of both the top and bottom reverser doors. The lock is shown in Figure 2. When locked, the dual latches engage hooked catches on each reverser door and are held in the closed position by integrated springs. In order for the reverser doors to deploy, the spring force holding the primary locks closed must be overcome by hydraulic pressure routed to an internal actuator. The hydraulic actuators are pressurized to release the locks as part of the reverser deployment sequence controlled by the Electronic Engine Controller (EEC) on each engine. Once the primary locks have released and the catches on each door are free of the primary latches, hydraulic pressure is removed from the locks and the catches return to the locked position through integral spring pressure.

C. Hydraulic Actuators:

The hydraulic reverser door actuators of each engine are powered by the corresponding side hydraulic system: left engine by the left hydraulic system, right engine by the right system. There is no provision for using an alternate hydraulic system to power the reversers since hydraulic pressure loss would most likely be due to a failure of the associated engine.

Each door actuator moves in two directions: outward to extend the door to the deployed position and inward to stow the door in the faired position. Hydraulic pressure is routed to the appropriate side of the door actuator by a Directional Control Unit (DCU) in response to electrical commands from the reverse levers mounted on the cockpit power levers.

D. Tertiary Locks:

Each door has the additional protection of a tertiary lock to prevent inadvertent deployment. (The name is actually a misnomer since it is a holdover from earlier reverser designs that incorporated a additional lock internal to the door actuators that has since been omitted - thus the “tertiary” locks are now in fact “secondary”, but the nomenclature persists.) The tertiary lock on each door is mounted on the forward edge at the center of the door. The lock incorporates a moveable concave receiver that fits a bar installed on the forward edge of the reverser door. See Figure 3. The lock is operated by a spring and electrical solenoid mechanism. When the reverser door is stowed, spring pressure maintains the lock receiver in the overcenter position to contain the door bar latch. In order for the door to open to the deploy position, the lock electrical solenoid must overcome spring pressure for the receiver to rotate out of the overcenter position to release the door. The electrical signal to the solenoid is provided by a switch on the reverse levers on the cockpit power levers and the engine

EEC, but only after the EEC has received a valid aircraft Weight-On-Wheels (WOW) signal verifying that the aircraft is on the ground, or, in the event of WOW system failure, a signal from the aircraft wheel anti-skid system indicating rotation equivalent to a ground speed of forty-seven (47) knots or more.

One the tertiary lock receiver has moved to release the door bar catch, the solenoid maintains the receiver in the release position in order to recapture the door bar latch when the reverser door is stowed. Since the solenoid is powered only when the tertiary lock is released, the EEC is able to use a feedback electrical signal from the solenoid as a reverser door position indication.

E. Linear Variable Transducers:

Each reverser door is equipped with a Linear Variable Transducer (LVT), mounted on the outboard side, to monitor door movement from the stowed to fully open position. The LVT furnishes an electrical signal proportional to door position to the EEC. The EEC uses door position to modulate engine power. The LVTs must signal the EEC that the reverser doors are open at least sixty-seven to sixty-eight percent (67% - 68%) or forty degrees (40°) before the EEC will release a relay within the reverse levers on the cockpit pedestal allowing selection of more than idle reverse thrust.

Once the reverser doors have opened to the minimum position, the EEC will program reverse thrust in accordance with cockpit reverse lever position, with an increase to maximum thrust when the doors are fully open to sixty degrees (60°) or one hundred percent (100%).

The EEC incorporates a protective feature that uses LVT door position signals during flight to reduce engine power to idle if the LVT indicates that a reverser door is open fourteen to fifteen percent (14% - 15%) or approximately nine degrees (9°).

F. Stow Switches:

Each reverser door is monitored by two (2) stow switches installed at the forward edge of the door at approximately the three (3) and nine (9) o'clock positions. The switches are compressed when the door is in the stowed position and released when the door is deployed. The stow switches furnish door position data to EEC and through direct connections, to the Modular Avionics Units (MAUs). Each door stow switch is connected to both MAU #1 and #2. Stow switch signals work in concert with data from the LVTs and the tertiary lock solenoid to provide indications and warnings of reverser door position.

3. Thrust Reverser Operation:

Thrust reverser operation is controlled by the EECs on each engine in coordination with cockpit thrust lever position and safety signals from aircraft systems. See the overview in Figure 4. A typical reverser deployment sequence includes the following events:

- The aircraft WOW system and/or anti-skid wheel sensors provide the EECs with a valid signal indicating that the aircraft is on the ground
- The flight crew retards the power levers to idle, then pulls up and aft on the reverse levers
- The EEC maintains engine speed at high idle for five (5) seconds

- The EEC signals the Isolation Control Unit (ICU) in the reverser hydraulic system to open, routing hydraulic pressure (left system to left engine, right system to right engine) to the primary door locks
- The primary door lock latches release and hydraulic pressure passes through the lock plumbing to the Directional Control Unit (DCU)
- The DCU initially routes hydraulic pressure to the retract or stowed side of the door hydraulic actuator, forcing the door forward and compressing the rubber seal around the door to enable the catch on the door to clear the primary lock latch that is being held open by hydraulic pressure
- The tertiary lock releases in response to signals from the cockpit reverser levers and the EEC after valid on the ground WOW and/or wheel speed data. The lock remains in the released position through spring pressure
- After the door catch has cleared the open primary lock, the DCU pressurizes the extend, or deploy, side of the reverser door actuator
- The reverser doors open, with position monitored by the LVT. The EEC blocks movement of the cockpit reverse levers past the idle position through an interlock until the reverser doors are open at least forty degrees (40°) or approximately sixty-seven percent (67%)
- When the reverser doors open past the idle position, the reverse levers are free to move up and aft and the EEC controls engine Low Pressure (LP) rotor speed in response to cockpit reverse lever commands in the range of idle to full reverse. Maximum engine reverse is limited to seventy percent (70%) LP or N_1
- The EEC removes all hydraulic pressure from the reverser system two (2) seconds after the doors have opened more than eighty-five percent (85%): the primary locks close due to spring pressure, the tertiary locks are held open by internal springs, and the reverser doors are held open by a combination of aerodynamic forces induced by the forward motion of the aircraft and the pressure of the engine exhaust gases impinging upon a lip or kicker plate installed on the forward (outer in the deployed position) edge of the doors.

When the use of reverse thrust is no longer required, the doors will return to the stowed position through action of the same elements. A typical door retraction involves the following sequence:

- The reverse levers forward of the power levers are returned to the down or stowed position
- The position switch on the reverse levers signals the EEC to pressurize the stow or retract side of the door hydraulic actuators through action by the DCU
- The hydraulic actuators stow the reverser doors, moving them first to an extended stow position, compressing the rubber seals around the door openings to allow the door catches to press against the primary door lock latches, overcoming spring pressure and lifting the latches to ride over the door catches. When hydraulic pressure is released, the primary lock latches drop into position, securing the door catches.
- Similarly the tertiary lock springs are overcome by the door locking bar latch as it is cradled by the lock receiver, moving the tertiary lock to the overcenter position to secure the door.

- The EEC will depressurize the reverser hydraulic system eight (8) seconds after the door LVTs indicate that the doors have moved past the twelve percent (12%) open position.

NOTE:

Door deployment is not synchronized.

4. Indications, Controls and Protective Features:

A. Indications:

The thrust reverser system incorporates numerous redundant indications due to the hazard presented by inflight deployment of a reverser door. The EEC and MAUs monitor reverser door position through data received from the door stow switches, LVTs and tertiary lock solenoids.

In normal reverse thrust operations, a text annunciation of reverse thrust deployment is shown on the Engine primary and compacted 1/6 window displays. When reverse thrust has be selected with the reverse levers and the doors are not fully open, the annunciation REV is shown in white within the analog LP rpm dial of the primary engine window and adjacent to the LP rpm digital indication on the compacted display. The text will be shown in green once the doors are fully open.

B. Controls and Protective Features:

During abnormal operations, the REV text will be shown in amber if an uncommanded reverser door deployment occurs on the ground or if a door deploys in flight, the REV text will be displayed in red. In both circumstances, additional indications will accompany the text display: corresponding amber or red Crew Alerting System (CAS) messages will be displayed along with illumination of the glareshield caution or warning lights and aural alerts will sound over cockpit speakers. Two additional pushbutton switches (one for each engine), located on the cockpit center pedestal, provide both an indication of inadvertent reverser deployment and a means to stow the errant reverser door. The switches are shown in Figure 5.

The switches, labelled L (or) R T/REV MAN STOW, have split internal legends: the top half will illuminate LEFT or RIGHT in red as appropriate to indicate the location of the open reverser door. The flight crew depresses the appropriate switch to employ an dedicated control circuit (the ON legend in the bottom half of the switch will illuminate amber). The switch sends an independent electric signal directly to the reverser ICU and DCU to direct hydraulic pressure to the stow side of the reverser door actuator (normally all hydraulic pressure is removed from the door system once the doors are stowed). The resulting door position can be monitored by observing the indications on the Engine window display along with CAS messages and other cockpit alerts. The reverser door actuator remains pressurized to the stowed position as long as the appropriate T/REV MAN STOW switch remains depressed.

NOTE:

When the EEC detects an uncommanded reverser deployment, it reduces engine LP rpm to idle to minimize the effect on aircraft control stability.

Maintenance procedures are established to hydraulically operate the thrust reverser doors on the ground without the engine operating. Additional procedures provide for inhibiting the operation of the reversers if maintenance is to be performed in the vicinity of the doors. The doors are also equipped with a locking pin that will disable the doors in the stowed position in order that the aircraft may by dispatched with an inoperative thrust reverser. See the appropriate section of the Aircraft Maintenance Manual for further details.

C. Circuit Breakers:

The thrust reverser system is powered by the following circuit breakers (CBs):

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L TR CONT	POP	F-9	L MAIN DC Bus
R TR CONT	CPOP	F-9	R MAIN DC Bus
L TR LOCK	LEER	A-11	L MAIN DC Bus
R TR LOCK	REER	A-13	R MAIN DC Bus
L TR MAN STOW	POP	F-10	L ESS DC Bus
R TR MAN STOW	CPOP	F-10	R ESS DC Bus

D. Crew Alerting System (CAS) Messages:

The following CAS messages are associated with the thrust reverser system:

Area Monitored:	CAS Message:	Message Color:
EEC, MAUs, WOW (ground)	Aircraft Configuration	Red
EEC, MAUs	L-R Thrust Reverser Unlock	Red
EEC, MAUs, WOW (ground)	L-R Thrust Reverser Unlock	Amber
EEC, MAUs	L-R Thrust Reverser Fail	Amber
EEC, MAUs	L-R Thrust Reverser Maint	Amber
EEC, MAUs	L-R TR Switch Miscompare	Blue
EEC, MAUs	L-R Engine Maintenance LTD	Blue

5. Limitations:

A. Flight Manual Limitations:

The following limitations apply with respect to use of the thrust reversers:

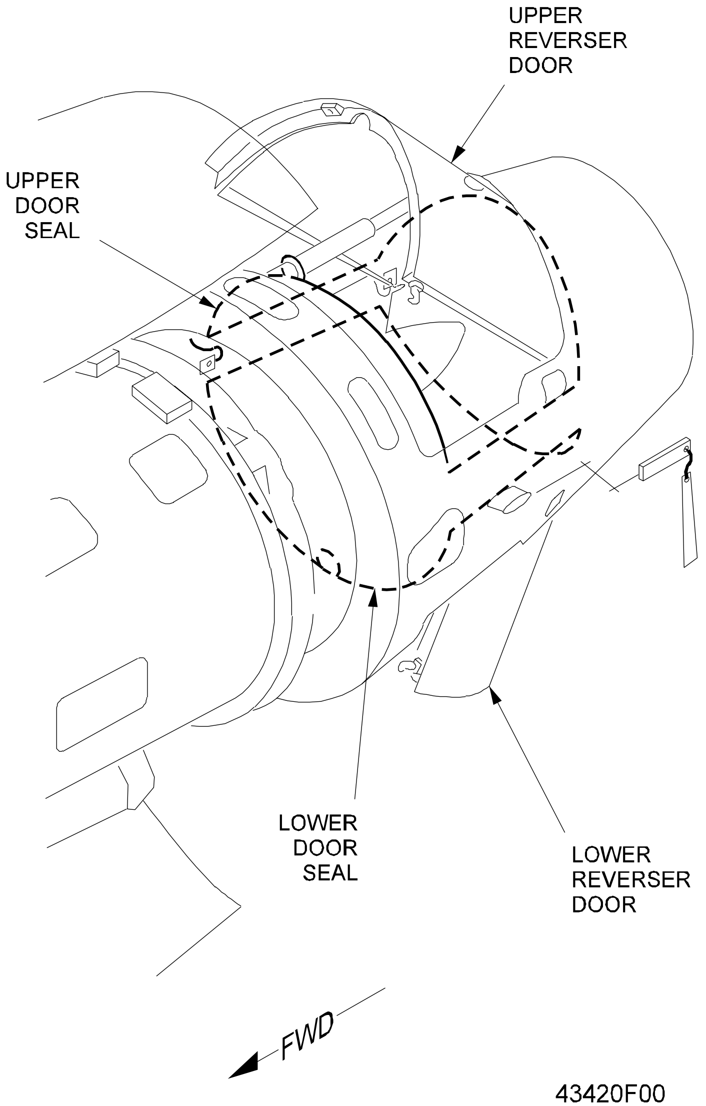
(1) Cancellation of reverse thrust should be initiated so as to be at the reverse idle position by 60 KCAS.

(2) Use of idle reverse thrust is available for taxi purposes without time limit.

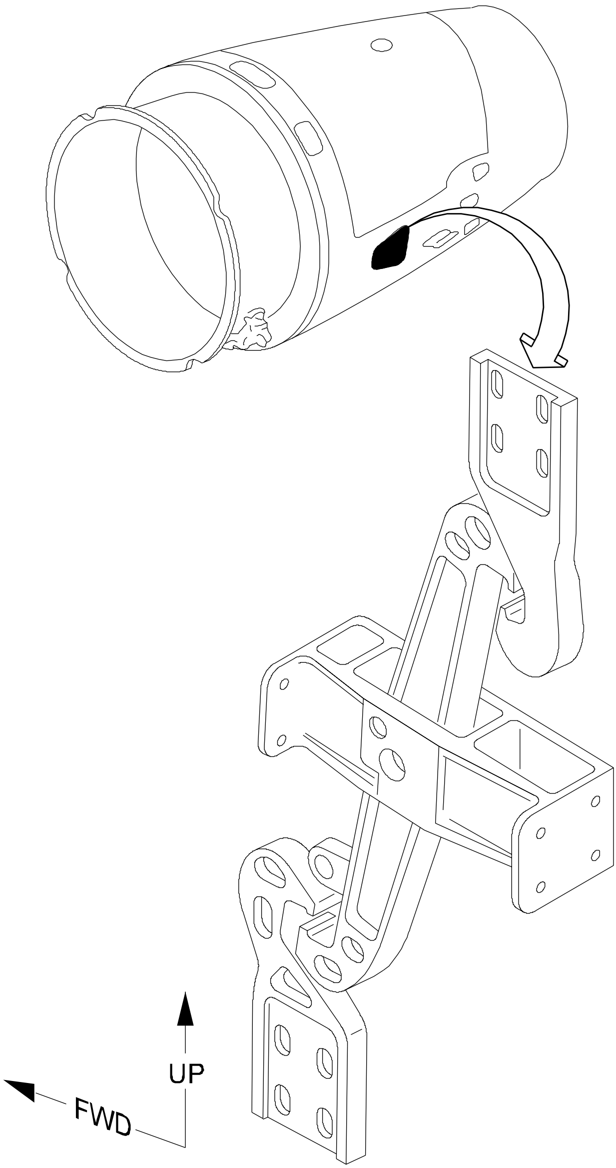
(3) The thrust reversers shall be deployed and stowed at least once every 100 hours.

(4) If in an emergency, reverse thrust is used to bring the airplane to a halt, record and report such an operation for maintenance action.

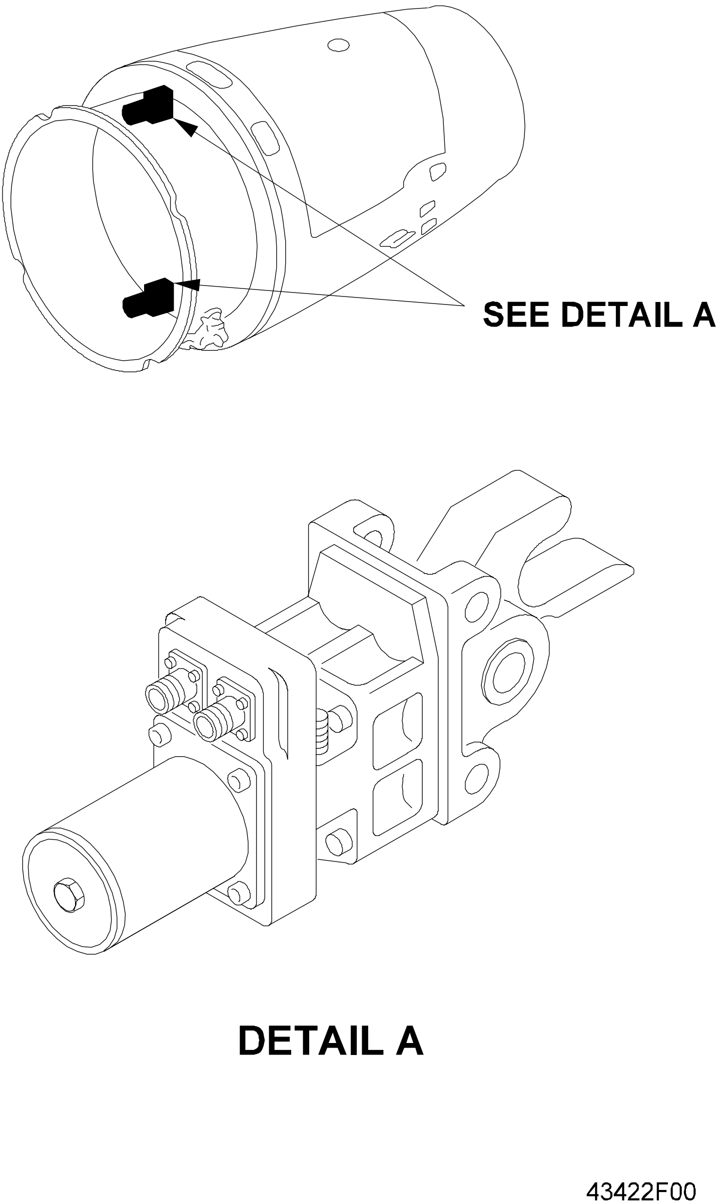
(5) Use of thrust reversers for power back is not approved.



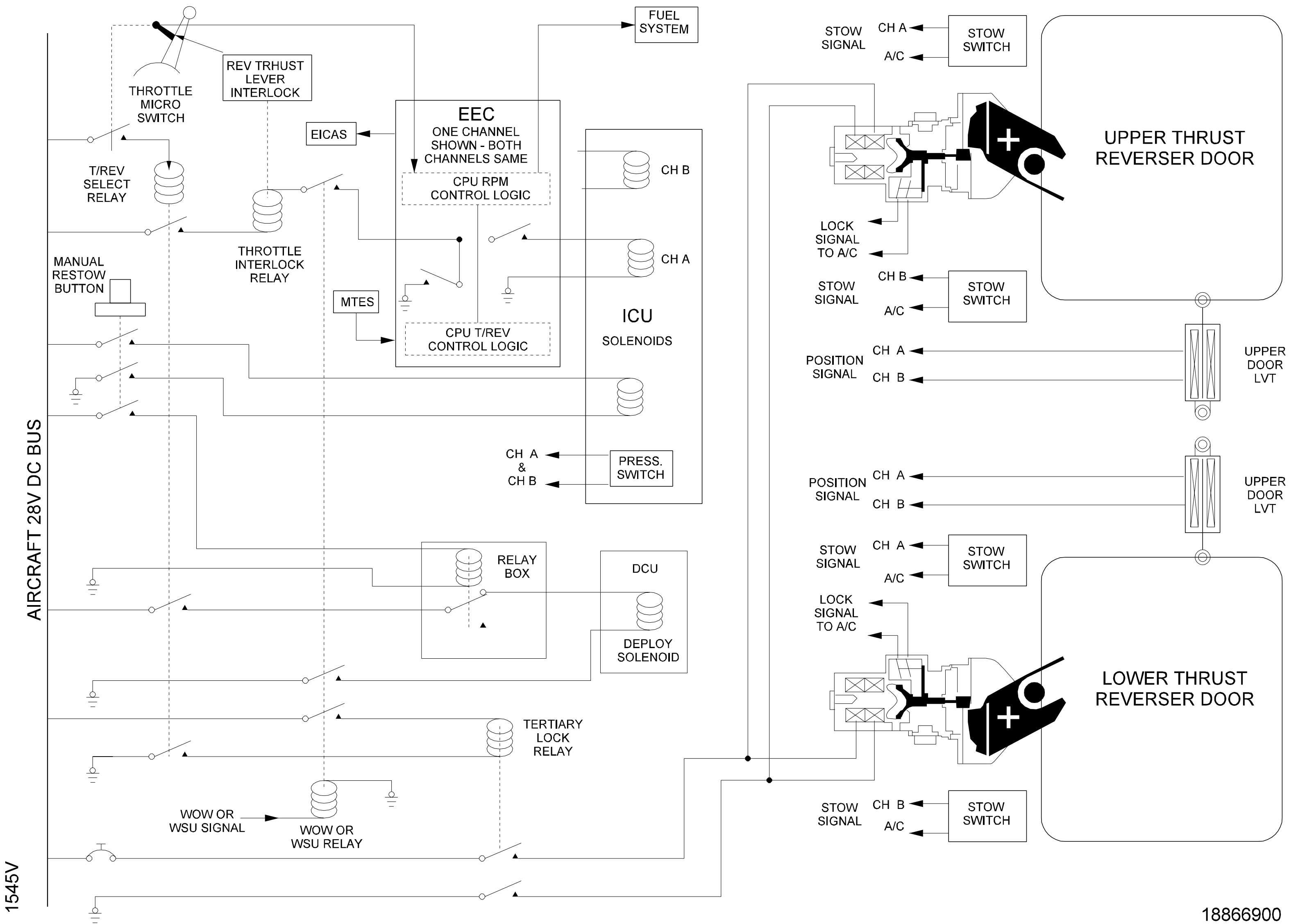
Trust Reverser Installation
Figure 1



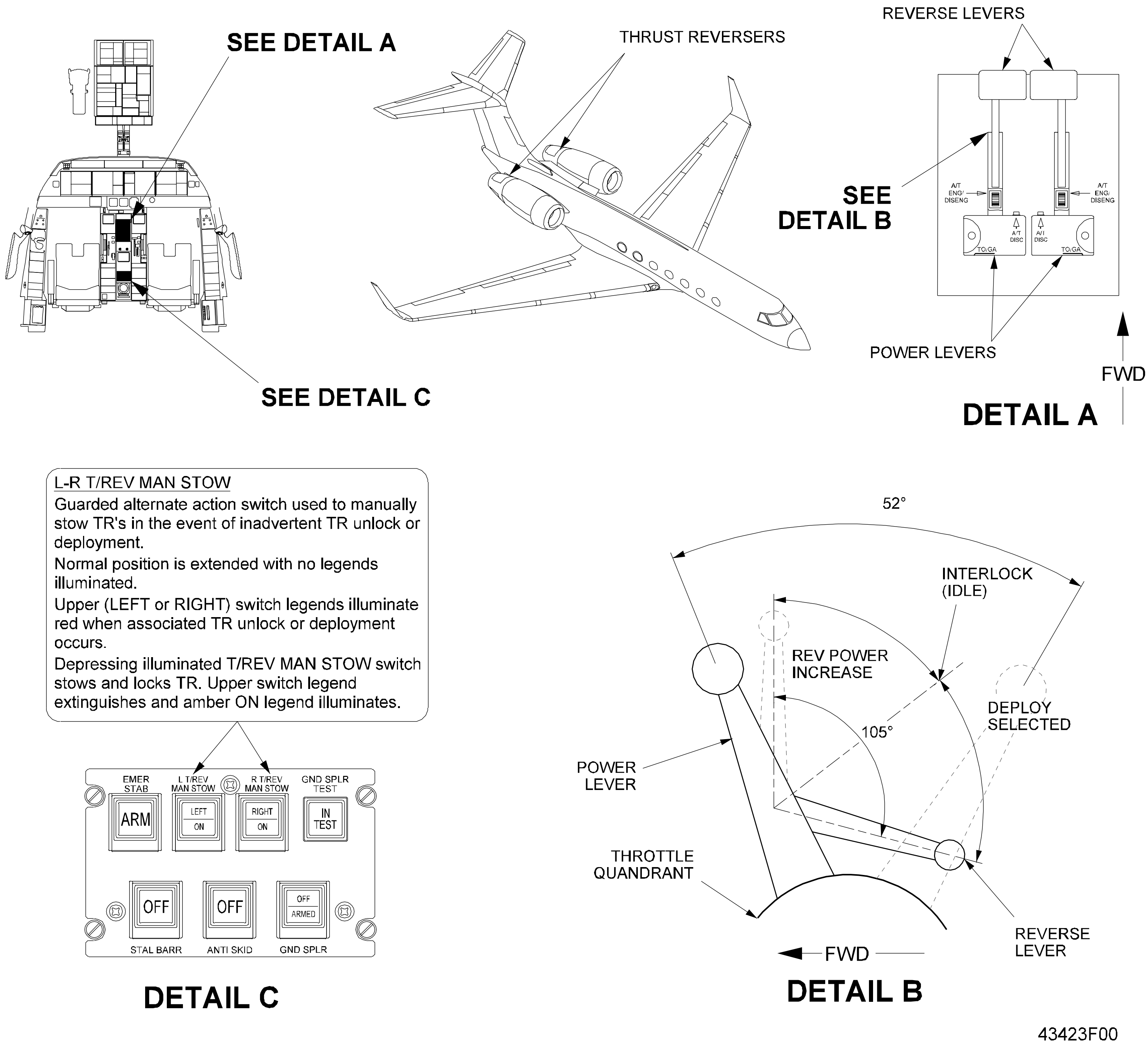
Trust Reverser Primary Lock
Figure 2



Trust Reverser Tertiary Lock
Figure 3



Thrust Reverser Electrical System Simplified Block Diagram
Figure 4



Thrust Reverser Controls
Figure 5