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Integration of Multiple Non-Normal Checklist Procedures into a Single Checklist Procedure for Transport Aircraft - A Preliminary Investigation

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ABSTRACT

Checklists are used by the flight crew to properly configure an aircraft for safe flight and to ensure a high level of safety throughout the duration of the flight. In addition, the checklist provides a sequential framework to meet cockpit operational requirements, and it fosters cross-checking of the flight deck configuration among crew members.

This study examined the feasibility of integrating multiple checklists for non-normal procedures into a single procedure for a typical transport aircraft. For the purposes of this report, a typical transport aircraft is one that represents a midpoint between early generation aircraft (B-727/737-200 and DC-10) and modern glass cockpit aircraft (B747-400/777 and MD-11). In this report, potential conflicts among non-normal checklist items during multiple failure situations for a transport aircraft are identified and analyzed. The non-normal checklist procedure that would take precedence for each of the identified multiple failure flight conditions is also identified. The rationale behind this research is that potential conflicts among checklist items might exist when integrating multiple checklists for non-normal procedures into a single checklist.

As a rule, multiple failures occurring in today's highly automated and redundant system transport aircraft are extremely improbable. In addition, as shown in this analysis, conflicts among checklist items in a multiple failure flight condition are exceedingly unlikely. The possibility of a multiple failure flight condition occurring with a conflict among checklist items is so remote that integration of the non-normal checklists into a single checklist appears to be a plausible option.

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INTRODUCTION

Checklists are used by the flight crew to properly configure an aircraft for safe flight and to ensure a high level of safety throughout the duration of the flight (Turner and Huntley, 1990). In addition, the checklist provides a sequential framework to meet cockpit operational requirements, and it fosters cross-checking of the flight deck configuration among crew members (Degani and Weiner, 1990). As part of the Standard Operating Procedures (SOPs) of an aircraft, pilots carry normal and non-normal checklist procedures on every flight. Within this report, a normal checklist is defined as a procedure used by the flight crew to ensure the airplane condition is acceptable for flight and that the cockpit is correctly configured for each phase of flight. This procedure assumes that all systems are operating normally and that automated features are fully utilized (Boeing, 1990). A non-normal checklist is defined as a procedure used by the flight crew to cope with non-normal situations (i.e., a failure).

Traditionally, these normal and non-normal checklists have been paper checklists. However, checklists can exist in a variety of different formats - mechanical, audio, or electronic (Degani and Weiner, 1991). For example, the Boeing 777 has incorporated an electronic checklist (ECL) function onto the flight deck which is accessed interactively on multifunctional displays via cursor control input devices (Crane, Bang and Hartel, 1994). The ECL function contains all normal and non-normal checklists (total of 318), provides placeholding capability, and provides linkages to EICAS (Engine Indicating and Crew Alerting Systems) alert messages that ensure proper checklist access.

In older turbojet transport aircraft (e.g., B-727, B-747-200, L-1011, DC-10 and B-707) with systems having relatively little automation, multiple failures could require substantially different procedures (checklists) than when operating in normal configurations. As an example, up to eight checklists are required to fly a B-727 on approach with two engines shutdown. These checklists, each containing several steps, are:

1. Engine Failure (or Fire, Severe Damage or Separation) for first engine.
2. Engine Failure (or Fire, Severe Damage or Separation) for second engine.
3. Engine Restart for first and second engine (if appropriate).
4. Fuel Dumping (if appropriate).
5. Loss of Two Generators.
6. Cabin Notification and Preparation
7. Approach Descent Checklist.
8. Final Descent Checklist.

Integrated checklists that provided complex ordering of priorities for multiple failures (i.e. loss of more than one engine, loss of two hydraulic systems, etc.) did exist in some of the older turbojet aircraft. When Pan American Pacific Division was acquired by United Airlines in 1986, they brought with them the concept of a single integrated checklist for complex procedures (multiple failures) which replaced the need for multiple checklists in the cockpit. The integrated checklist helped to alleviate problems of pilot omission since there was just one source of information from which to work.

The proliferation of automation in modern glass cockpit transport aircraft (e.g., B747-400, MD-11, and B-777) has had a significant effect on crew procedures and crew workload. Automation has typically reduced the number of checklist items in the normal and non-normal procedures that the crew has to complete in order to properly configure the aircraft for safe flight. For example, the B-757/767's electrical system incorporates sophisticated load shedding logic, making the only pilot action that of starting the auxiliary power unit (APU) when the electrical system fails. However, modern aircraft automation, being extremely complex, can increase crew workload if the automation is confusing to the flight crew.

Since automation may fail, there are new checklists associated with these failures. This increase in checklists could potentially lead to crew confusion if there are multiple checklists that need to be performed and if these checklists had items that were in conflict. The thrust of the current study was to determine for multiple failure flight conditions:

- if such conflicts among checklists items exists
- the probability of these failures occurring
- which checklist should take precedence.

The rationale behind this research is that potential conflicts might exist when integrating multiple checklists for non-normal procedures into a single checklist. This research was conducted in partial fulfillment of the Master of Science degree with The George Washington University.

APPROACH

A twin-engine transport with advances in propulsion, aerodynamics, avionics and materials over early generation transport aircraft was chosen as the aircraft in this study because it represents a midpoint between early generation aircraft (B-727/737-200/747-200) and modern glass cockpit aircraft (B747-400/777 and MD-11). To identify the potential conflicts among checklist items during a multiple failure of this transport aircraft, an EXCEL database was developed listing the Non-Normal Checklist procedures in columns and the equipment/instruments specified as checklist items in rows. The actual operations manual for the transport aircraft chosen for this study provided the information necessary for the development of this spreadsheet. Only those non-normal checklist procedures (45 total) which required action by a crew member were included in the spreadsheet. Certain non-normal procedures had only the statement "crew awareness" with no procedural steps listed. These procedures assume the associated message is informational or that the required crew action is obvious (Boeing, 1990).

Cross-checking the EXCEL database for conflicting commands of common checklist items for the non-normal procedures provided input for another spreadsheet. This reduced spreadsheet (same row/column format as specified above) listed only the non-normal checklist procedures in which there were conflicting commands of common checklist items (Appendix A). For example, the isolation switch in this aircraft is specified ON in the Engine Fire, Severe Damage or Separation Non-Normal Checklist and specified OFF in the Bleed Duct Leak Non-Normal Checklist. Of the original 89 equipment/instruments, listed in row format, only 18 of them had conflicting commands in the non-normal checklist procedures. General descriptions of these 18 instruments and their positions in the non-normal checklists are discussed in Appendix B. The possibility of simultaneous occurrences of these non-normal checklists, thus creating conflicts, during a typical flight are also examined in Appendix B. The conclusions drawn in Appendix B were derived through in-depth discussions with an experienced transport aircraft captain (retired).

RESULTS

Table 1 identifies the six checklist items that have conflicting commands for possible multiple failure combinations in the transport aircraft chosen for this study. Table 1 also specifies the likelihood of each failure condition (where applicable) and the non-normal checklist having precedence in each of the possible multiple failure conditions.

Table 1. Conflicts in Non-Normal Checklist Items for Possible Multiple Failure Combinations

	Multiple Failure Combinations For Non-Normal Procedures						
Checklist item	Checklist name, item position and estimated qualitative probability of failure condition			Checklist name, item position and estimated qualitative probability of failure condition			Checklist name that has precedence
Landing Gear	Hydraulic System(s) Pressure	OFF	probable	Gear Doors	UP	probable	Hydraulic System(s) Pressure
Isolation Switch	Engine Failure Shutdown	ON	improbable	Bleed Duct Leak	OFF	improbable	Bleed Duct Leak
Pack Control Selector	Smoke Removal	AUTO	n/a	Pack Temperature	OFF	probable	Smoke Removal
Alternate Flaps Selector	Leading Edge Slat Asymmetry	SET flaps as require d	probable	Trailing Edge Flap Asymmetry	Set FLAPS 1	probable	Neither; Similar to a zero-flap approach
Alternate Flaps Switch	Leading Edge Slat Asymmetry	ALTN to TE switch	probable	Trailing Edge Flap Asymmetry	ALTN to LE switch	probable	Neither; Similar to a zero-flap approach
Fuel Pump Switches	Low Fuel	ON	n/a	Gear Disagree	OFF	improbable	Gear Disagree

The probability estimates featured in Table 1 are based on personal interpretations of FAR 25.1309 and AC 25.1309-1a and on discussions with an experienced transport pilot. The estimated qualitative probability of failure for the smoke removal checklist and the low fuel checklist are not specified in Table 1 since these conditions are not always directly related to a system(s) failure. Table 2 shows the relationship between the failure condition classes and failure occurrence probabilities as defined in FAA specifications (FAR 25.1309; AC 25.1309-1a, 1988).

Table 2. Relationship Between Failure Condition Classes and Failure Probabilities

Failure Condition	Qualitative Probability	Quantitative Probability
Minor	Probable	> 1E-05
Major	Improbable	≤ 1E-05 but > 1E-09
Catastrophic	Extremely Improbable	≤ 1E-09

The remainder of this section will have the following format to discuss the results of Table 1:

1. A brief description of the checklist item is given.
2. The commanded position of the checklist item for each non-normal procedure in the identified possible multiple failure scenario is highlighted.
3. The non-normal checklist having precedence in the multiple failure scenario is identified.

Checklist item: Landing gear

The landing gear system is controlled by the Landing Gear lever which has three positions (UP, OFF, and DN). On the ground, the Landing Gear lever is prevented from being moved to the UP position by the lever lock. The lever lock can be manually overridden by pushing the Lever Lock Override Switch if retraction is desired. In the OFF position, the landing gear system is depressurized. All gears and doors are held in the retracted position by a mechanical lock (uplock).

Non-Normal Checklist #1: Hydraulic System(s) Pressure

If there was a hydraulic system pressure failure in the left and center hydraulic systems, the landing gear is turned **OFF** and an alternate gear extension system pushes it down. Then the main Landing Gear is put in the **DN** position so that it's position is consistent with that of the alternate gear extension system. This alternative flap operation and alternative gear extension may also be required if there was a hydraulic system pressure failure in the left and center systems or in the left system only.

Non-Normal Checklist #2: Gear Doors

If the gear doors do not fully close and the gear lever is in the off position, then the pilot puts the Landing Gear **UP**.

If there were a gear doors failure and a hydraulic system(s) pressure failure occurring at the same time, the pilot would follow the checklist for the latter situation because he/she doesn't want to "scrape metal" upon landing. If the gear doors don't close, the pilot may be forced to refuel at an airport enroute or return to the departure airport because of the increase in drag associated with the open doors.

Checklist item: <u>Isolation Switch</u>

Normally, the Isolation Switch is closed (off). The Isolation Switch isolates (splits in half) the pneumatic system of the aircraft. Failure on one side of the system doesn't affect the other side. Pneumatic air is used for pressurization, starting the aircraft, and icing prevention on the wings and engines. The engine bleed air (pneumatic air) has a very high temperature and pressure and it's extracted from either the low stage or the high stage (further down the engine) source. Extracting the air reduces the thrust to the engine. During takeoff, the engine bleed air is taken from the low stage source. At low power settings, the low stage pressure isn't powerful enough to operate the system so the air is extracted from the high stage pressure source. The pneumatic air usually comes from the low stage source.

Non-Normal Checklist #1: Bleed Duct Leak

During a bleed duct leak, the pilot doesn't want to add pneumatic air to the leaking component, so he/she turns the isolation valve **OFF**.

Non-Normal Checklist #2: Engine Failure Shutdown

During this procedure, the engine is turned off. The pilot can reroute the pneumatic air by turning the Isolation Switch **ON** thus supplying hot air (from the operational engine) for the wing anti-ice (if necessary).

A conflict in the position of the isolation switch can exist if the aircraft experiences an engine failure and a bleed duct leak on the opposite side of the failed engine. In this multiple failure situation, the pilot would turn the isolation switch off and perform an emergency descent procedure. The bleed duct leak procedure takes precedence over the engine failure procedure since a bleed duct leak can damage electrical wire insulation and can weaken aluminum near the affected area of the leak. When an aircraft has a bleed duct leak, the pilot must take special caution to avoid icing situations because the isolation switch must remain off which disables the wing anti-ice for the affected side of the aircraft.

Checklist item: Pack Control Selector

There are 2 packs in this transport aircraft and either pack will maintain pressurization of the aircraft. These packs supply air through ducting to flight deck, forward cabin, and aft cabin.

Non-Normal Checklist #1: Pack Temperature

The pack temperature is automatically controlled by a specified dial setting. These settings are STBY-C (cold), STBY-W (warm), and STBY-N (normal). If an overheat or fault in the associated zone temperature system is sensed, the INOP light comes on. The pilot should select **STBY-N** first. If the compartment temperature becomes unacceptably warm or cool select **STBY-C** or **STBY-W**, respectively. If INOP light does not extinguish, turn the Pack Control Selector **OFF** for the associated zone temperature system.

Non-Normal Checklist #2: Smoke Removal

The Pack Control Selectors remain on **AUTO.** The pilot should raise the cabin altitude which will open the outflow valve to a more open position thus enabling more air flow through the cabin. The outflow valve will open wider because there's less pressure in the cabin.

A conflict occurs in the positioning of the pack control selector in the smoke removal procedure and the pack temperature non-normal procedure. Due to it's serious nature, the smoke removal procedure takes precedence over the pack temperature procedure. If the smoke can not be removed, the pilot must accomplish the earliest possible descent, landing and passenger evacuation.

Checklist items: Alternate Flaps Selector and Alternate Flaps Switch
(Note: These two checklist items are involved in the same multiple failure combination so they are discussed in detail together.)

Flap and slat position is controlled with the Flap Lever. When the Flap Lever is in the UP detent, all flaps and slats are retracted and the flap position indicator points to UP. Moving the flap lever to position 1 signals the slats and flaps to extend to position 1. Placing the flap lever to position 5, 15, or 20 signals the flaps to extend to the selected position. The slats remain in the takeoff (intermediate extended) position. Moving the flap lever to position 25 signals the flap to extend to the selected setting and the slats to extend to their landing (fully extended) position.

An alternate flap drive system allows the flap Power Drive Units (PDUs) to be driven by electric motors rather than hydraulic power. During normal operations the Alternate Flaps Selector is in the NORM (normal) position. There are two Alternate Flaps Switches, one for the leading edge drive system and one for the trailing edge drive system. When the Alternate Flaps Switch is pushed on, ALTN appears in the switch. Rotating the Alternate Flaps Selector signals the flaps and slats to move to the pilot selected position (UP, 1, 5, 15, 20 or 25). Only slat asymmetry protection is provided during alternate operations.

The electrical system is a lot slower than the hydraulic system when moving the flaps/slats. Also, the leading edge devices have a more pronounced effect on landing speed than the trailing edge devices (e.g. LE slats reduce stall speed by about 20 knots).

Non-Normal Checklist #1: Leading Edge Slat Asymmetry

When a leading edge slat asymmetry is detected hydraulic power to both PDUs is automatically shut off. The pilot should not arm the alternate leading edge drive system. The pilot should **SET** the Alternate Flaps Selector to agree with the flap lever. Then the Trailing Edge Alternate Flaps Switch is pushed on and **ALTN** is displayed. The Alternate Flaps Selector is then **SET** so that the trailing edge flaps are extended/retracted as required. The pilot attempts to get as much TE stall protection as possible without extending the LE slats any farther.

Non-Normal Checklist #2: Trailing Edge Flap Asymmetry

When a trailing edge flap asymmetry is detected hydraulic power to both PDUs is automatically shut off. The slats can be operated by the alternate system. Alternate trailing edge operation is not used due to the lack of asymmetry protection. If the asymmetry occurred at less than flaps 1, the Alternative Flap Selector is set to **flaps 1** and the LE Alternate Flaps Switch is pushed on so that **ALTN** is displayed.

Typically, in the interest of safety, landing maneuvers are performed at as low a speed as possible. In order to reduce the speed of the aircraft, the coefficient of lift and/or the wing area must be increased. Usually, this increase is accomplished through the use of slats and/or flaps on the aircraft's wings. If a simultaneous leading edge slat asymmetry and trailing edge flap asymmetry occurred on the wings, the pilot would have to maintain enough speed for landing. This multiple failure is analogous to a zero-flap approach since both the slats and flaps can not be extended due to position asymmetry.

During a zero-flap approach, the pilot should determine the stall speed and land at 30 percent above this speed.

Checklist item: Fuel Pump Switches

The Fuel Pump Switches are located in the center of the overhead panel and are used to turn the electric fuel pumps on/off. If a tank runs out of fuel, the pilot will see a low pressure light illuminated and the fuel quantity gauge will read zero.

Non-Normal Checklist #1: Low Fuel

In this event, the pilot turns the crossfeed valve switch ON and all of the Fuel Pump Switches **ON** so that both engines will operate as long as there is fuel in any of the tanks.

Non-Normal Checklist #2: Gear Disagree

In this event, the pilot turns the pack control selectors OFF to depressurize the cabin and turns the Fuel Pump Switches **OFF** to reduce the possibility of fire upon landing. Since there is a gear disagree, the plane will be "scraping metal" upon landing.

If the plane is low on fuel and the landing gear has not fully extended (gear disagree procedure), a conflict in the position of the fuel pump switches exists. Since the airplane will be "scraping metal" upon landing, the fuel pump switches are turned off to prevent a fire from occurring. The seriousness of a fire upon landing allows the gear disagree procedure to supersede the low fuel procedure.

CONCLUSIONS

As a rule, multiple failures occurring in today's highly automated and redundant system transport aircraft are extremely improbable. For this study, a twin-engine transport with advances in propulsion, aerodynamics, avionics and materials over early generation transport aircraft was chosen as a representative aircraft in the transition from older transport aircraft to highly automated glass cockpit aircraft. As shown in this analysis, conflicts among checklist items in a multiple failure flight condition for a typical transport aircraft are exceedingly unlikely. In fact, only six checklist items that have conflicting commands for possible multiple failure combinations in the transport aircraft used in this study have been identified. The estimated likelihood of each failure condition (where applicable) and the non-normal checklist having precedence in each of the possible multiple failure conditions has also been determined. The possibility of a multiple failure flight condition occurring with a conflict among checklist items is so remote that integrating multiple checklists for non-normal procedures into a single procedure could be done with relative ease. Special care would need to be taken in those few situations where conflicting commands on checklist items exist. A logical next step by interested aircraft manufacturers would be to conduct trade studies determining the feasibility of retrofitting older transport aircraft with an electronic checklist capability.

APPENDIX A

Non-Normal Checklist Procedures Having Conflicting Commands of Common Checklist Items

	NON-NORMAL CHECKLISTS					
CHECKLIST ITEMS	Cabin Altitude (Rapid Depressurization)	Cabin Automatic Inoperative	Engine Bleed Off	Engine Bleed Valve	Engine High Stage	Bleed Duct Leak
Fuel Control						
Landing Gear						
Window Heat						
Thrust Levers	close					
Outflow Valve		full open				
Engine Bleed Air Switch			off	off then on;off	off	off
Isolation Switch			on	on	on	off
Pack Control Selector						
Engine Start Selector						
Ram Air Turbine						
APU selector						
Landing Altitude Selector						
Cabin Altitude Manual Control		climb/descend				
Utility Bus Switches						
Alternate Flaps Selector						
Alternate Flaps Switches						
Crossfeed Valve Switch						
Fuel Pump Switches						
Auto Brakes Selector						

	NON-NORMAL CHECKLISTS				
CHECKLIST ITEMS	Pack Temperature	Aborted Engine Start	Engine Fire, Severe Damage or Separation	Engine Surge/Stall or Hung/Slow Acceleration	Loss of Thrust on Both Engines
Fuel Control		cutoff;run	cutoff	cutoff	cutoff then run
Landing Gear					
Window Heat					
Thrust Levers			close	close;advance	close
Outflow Valve					
Engine Bleed Air Switch				off	
Isolation Switch			on	on	
Pack Control Selector	stby-n;stby-c/stby-w;off				
Engine Start Selector		gnd;auto			flt
Ram Air Turbine					unlkd
APU selector					
Landing Altitude Selector					
Cabin Altitude Manual Control					
Utility Bus Switches					
Alternate Flaps Selector					
Alternate Flaps Switches					
Crossfeed Valve Switch					
Fuel Pump Switches					
Auto Brakes Selector					

	NON-NORMAL CHECKLISTS				
CHECKLIST ITEMS	APU Fault	Electronic Engine Control	Engine Failure Shutdown	Engine Inflight Start	Engine Limiter
Fuel Control			cutoff	rich/run;run;run	
Landing Gear					
Window Heat					
Thrust Levers		retard to mid pos.	close		retard to mid pos.
Outflow Valve					
Engine Bleed Air Switch					
Isolation Switch			on	on;off	
Pack Control Selector				off;auto	
Engine Start Selector				flt;gnd;auto	
Ram Air Turbine					
APU selector	off then on				
Landing Altitude Selector					
Cabin Altitude Manual Control					
Utility Bus Switches					
Alternate Flaps Selector					
Alternate Flaps Switches					
Crossfeed Valve Switch					
Fuel Pump Switches					
Auto Brakes Selector					

	NON-NORMAL CHECKLISTS				
CHECKLIST ITEMS	Engine Overheat	Starter Cutout	Engine Vibration	Oil Pressure	Oil Temperature
Fuel Control	cutoff		cutoff	cutoff	cutoff
Landing Gear					
Window Heat					
Thrust Levers	retard;close		retard;close	close;adjust to mid pos.	adjust to mid pos.;close
Outflow Valve					
Engine Bleed Air Switch	off	off			
Isolation Switch	on	off	on	on	on
Pack Control Selector					
Engine Start Selector		auto			
Ram Air Turbine					
APU selector					
Landing Altitude Selector					
Cabin Altitude Manual Control					
Utility Bus Switches					
Alternate Flaps Selector					
Alternate Flaps Switches					
Crossfeed Valve Switch					
Fuel Pump Switches					
Auto Brakes Selector					

	NON-NORMAL CHECKLISTS						
CHECKLIST ITEMS	Reverser Unlocked	Smoke Removal	Passenger Evacuation	Ditching Preparation	Door(s)	Electrical Smoke or Fire	AC Bus(es) Off
Fuel Control	cutoff						
Landing Gear				up & off			
Window Heat							
Thrust Levers	close						
Outflow Valve			open	close			
Engine Bleed Air Switch							
Isolation Switch	on						
Pack Control Selector	off	auto		off			
Engine Start Selector							
Ram Air Turbine							push switch
APU selector							off
Landing Altitude Selector		analog			9500 ft		
Cabin Altitude Manual Control		climb	climb				
Utility Bus Switches						off	
Alternate Flaps Selector							
Alternate Flaps Switches							
Crossfeed Valve Switch							
Fuel Pump Switches							
Auto Brakes Selector							

	NON-NORMAL CHECKLISTS						
CHECKLIST ITEMS	Utility Bus Off	Leading Edge Slat Disagree	Trailing Edge Flap Disagree	Leading Edge Slat Asymmetry	Trailing Edge Flap Asymmetry	Fuel Pump	Low Fuel
Fuel Control							
Landing Gear							
Window Heat							
Thrust Levers							
Outflow Valve							
Engine Bleed Air Switch							
Isolation Switch							
Pack Control Selector							
Engine Start Selector							
Ram Air Turbine							
APU selector							
Landing Altitude Selector							
Cabin Altitude Manual Control							
Utility Bus Switches	off then on						
Alternate Flaps Selector		set	set	set	1		
Alternate Flaps Switches		altn;off	altn;off	altn	altn		
Crossfeed Valve Switch						on;off	on
Fuel Pump Switches							on
Auto Brakes Selector							

	NON-NORMAL CHECKLISTS				
CHECKLIST ITEMS	Hydraulic System(s) Pressure	Wing Anti-Ice	Arcing/Delaminated/ Shattered or Cracked Window	Window (Heat)	Wheel Well Fire
Fuel Control					
Landing Gear	off;dn				dn
Window Heat			off	off 10 sec then on;off	
Thrust Levers					
Outflow Valve					
Engine Bleed Air Switch		off			
Isolation Switch		off			
Pack Control Selector					
Engine Start Selector					
Ram Air Turbine					
APU selector					
Landing Altitude Selector					
Cabin Altitude Manual Control					
Utility Bus Switches					
Alternate Flaps Selector	set				
Alternate Flaps Switches	altn				
Crossfeed Valve Switch					
Fuel Pump Switches					
Auto Brakes Selector					

	NON-NORMAL CHECKLISTS				
CHECKLIST ITEMS	Autobrakes	Brake Source	Gear Disagree	Gear Doors	Gear Lever Will Not Move Up
Fuel Control					
Landing Gear			off;dn	up	up
Window Heat					
Thrust Levers					
Outflow Valve					
Engine Bleed Air Switch					
Isolation Switch					
Pack Control Selector			off		
Engine Start Selector					
Ram Air Turbine					
APU selector					
Landing Altitude Selector					
Cabin Altitude Manual Control					
Utility Bus Switches					
Alternate Flaps Selector					
Alternate Flaps Switches					
Crossfeed Valve Switch					
Fuel Pump Switches			off		
Auto Brakes Selector	reselect;off	off			

APPENDIX B

Checklist Items Common to Multiple Non-Normal Checklist Procedures and Non-Normal Checklist Procedures Having Precedence in a Multiple Failure Flight Condition of a Transport Aircraft.

Checklist items Common to Multiple Non-Normal Checklist Procedures:

Fuel Control	Ram Air Turbine
Landing Gear	APU Selector
Window Heat	Cabin Altitude Manual Control
Thrust Levers	Utility Bus Switches
Outflow Valve	Alternate Flaps Selector
Engine Bleed Air Switch	Alternate Flaps Switch
Isolation Switch	Crossfeed Valve Switch
Pack Control Selector	Fuel Pump Switches
Engine Start Selector	Auto Brakes Selector

Summarized below are the non-normal procedures that had differing commands for a specific instrument or piece of equipment. After each summary, a conflict is noted if it could occur among the procedures. Then the procedure which takes precedence in this multiple failure flight situation is indicated and discussed.

FUEL CONTROL :

General Notes on Fuel Control

The Fuel Control Switch can be placed in 3 positions: **RUN**, **RICH**, and **CUTOFF**. The **RUN** position is the normal position for flight. In this position, the selected igniter(s) are activated and the engine and spar fuel valves are opened. Turning the Fuel Control Switch to the **RICH** position initially schedules additional fuel for the start, activates the selected igniter(s), and opens the engine and spar valves. The **CUTOFF** position closes the engine and spar fuel valves and terminates ignition. In the normal checklist the Fuel Control Switch is in the **RUN** position except for the procedures BEFORE START and SHUTDOWN. For these two procedures, the Fuel Control Switch is in the **CUTOFF** position.

With the Fuel Control Switch in the RICH or RUN position, ignition can occur in the following four situations:

- start sequence
- selected by switch
- flaps not up
- engine anti-ice on

Typically the Fuel Control is in the **RUN** position for the entire flight. There are three procedures in the non-normal procedures spreadsheet in which it is always **CUTOFF**:

1. Engine Fire, Severe Damage, or Separation
2. Oil Pressure (drops below limits)
3. Reverser Unlocked

The remaining conflicting procedures are discussed below:

4. Aborted Engine Start

As the pilot pushes back from the gate, he/she starts the engine. An aborted engine start might be caused by a hung engine or by a set of inoperable igniters. If this situation is encountered, the pilot will put the Fuel Control Switch in the **CUTOFF** position and then try to restart the engine. When restarting the engine, the Fuel Control Switch is put in the **RUN** position.

5. Engine Surge/Stall or Hung/Slow Acceleration

After turning the Fuel Control Switch to the **CUTOFF** position, the pilot would try to restart the engine. He/she might be able to fix the engine which is running abnormally by easing the throttle back until the affected engine is able to produce thrust. A compressor stall is typically resolved by reducing the thrust. A hung engine occurs when the plane is operating at a low speed and the engine won't respond to the throttle. To alleviate a hung engine, the pilot would perform a shutdown and then restart.

6. Loss of Thrust on Both Engines

Loss of thrust might occur if there's no fuel, extremely heavy precipitation (very unusual) or an encounter with volcanic ash. In any case, the pilot would shutdown the engines (Fuel Control Switch in the **CUTOFF** position) and then try to restart (Fuel Control Switch in the **RUN** position).

7. Engine Failure/Shutdown

The pilot would close the thrust levers, turn the Fuel Control Switch in the **CUTOFF** position, and start the APU (if available).

8. Engine Overheat

The pilot would retard the throttle and try to control the aircraft at a reduced thrust level. If the engine overheat light remains illuminated, the pilot would accomplish the Engine Failure/Shutdown procedure which states that the Fuel Control Switch is put in the **CUTOFF** position.

9. Engine Vibration

The pilot would try to find a power setting where the vibration is eliminated or tolerable. If an appropriate setting isn't found, the engine is shut off (Fuel Control Switch is put in the **CUTOFF** position).

10. Oil Temperature

The pilot will try to operate the plane at an increased power level (more fuel flow) to cool the oil. Oil is cooled by the fuel and the fuel is warmed by the oil. Once the engine reaches it's temperature limit, the pilot would shut if off (Fuel Control Switch in the **CUTOFF** position).

SUMMARY FOR FUEL CONTROL ***no conflict***

Pilot actions within the 10 procedures aren't really in conflict. If a limit is reached and retarding the throttle doesn't alleviate the problem, the fuel control is put in the **CUTOFF** position. For 3 specific cases, the fuel control switch is always turned to the **CUTOFF** position. For thrust aberrations in the engine, the fuel control switch is turned to the **CUTOFF** position and then the pilot restarts the engine (Fuel Control Switch in the **RUN** position). If the problem is not corrected by restarting the engine, then the fuel control switch is turned to the **CUTOFF** position.

LANDING GEAR:

General Notes on Landing Gear:

The landing gear system is controlled by the Landing Gear lever which has three positions (UP, OFF, and DN). On the ground, the Landing Gear lever is prevented from being moved to the UP position by the lever lock. The lever lock can be manually overridden by pushing the Lever Lock Override Switch if retraction is desired.

In the OFF position, the landing gear system is depressurized. All gears and doors are held in the retracted position by a mechanical lock (uplock).

1. Ditching Preparation

Ditching only occurs when the plane is unflyable and over water. During ditching, the landing gear is raised **UP** and then turned **OFF**. Turning the Landing Gear off removes the hydraulic pressure from the system and secures the landing gear in uplocks.

2. Hydraulic System(s) Pressure

If there was a hydraulic system pressure failure in the left and center hydraulic systems, the landing gear is turned **OFF** and an alternate gear extension system pushes it down. Then the main Landing Gear is put in the **DN** position so that it's position is consistent with that of the alternate gear extension system. This alternative flap operation and alternative gear extension may also be required if there was a hydraulic system pressure failure in the left and center systems or in the left system only.

3. Wheel Well Fire

Within a few minutes of takeoff, the brakes may become too hot because of a malfunctioning brake or bad piloting technique. To cool the brakes off, put the Landing Gear **DN** and let the air cool them. After 20 minutes, the Landing Gear may be retracted.

4. Gear Disagree

If the Landing Gear lever is DN and if any gear down lights are not illuminated, then the pilots puts the Landing Gear lever in the **OFF** position and uses the alternate gear extension system. Then the Landing Gear lever is put in the **DN** position so that its position is consistent with that of the alternate gear extension system.

5. Gear Doors

If the gear doors do not fully close and the gear lever is in the off position, then the pilot puts the Landing Gear **UP**.

6. Gear Lever Will Not Move Up

Since the Landing Gear lever can't be positioned in the UP position, the pilot pushes the lever lock override switch. Then, he/she puts the Landing Gear lever in the **UP** position.

<u>SUMMARY FOR LANDING GEAR</u> ***conflict***

The likelihood of conflicting procedures happening is very rare. If there were a gear doors and a hydraulic system(s) failure occurring at the same time, the pilot would follow the checklist for the latter situation. If the gear doors don't close, the pilot may be forced to refuel at an airport enroute or return to the departure airport because of the increase in drag associated with the open doors. A flight would not depart over water with any landing gear malfunction; hence the ditching conflict is not an issue.

WINDOW HEAT:

1. Shutdown

The Window Heat is turned **OFF**.

2. Arcing/Delaminated/Shattered or Cracked Windows

In arcing, the material fails so the window overheats and this could cause window failure. In a delaminated window, the conductive film begins to separate from the windshield. A shattered or cracked window is an extremely rare occurrence. Each pane in the airplane is capable of withstanding the pressure on the aircraft. If a window cracks, the pilot should go to a lower altitude to depressurize. For all 3 cases, the pilot should turn the Window Heat **OFF**.

3. Window (heat)

The pilot should switch the Window Heat **OFF** for 10 seconds and then back **ON**. If the problem is not corrected, the pilot should switch the window heat **OFF**.

<u>SUMMARY FOR WINDOW (HEAT)</u> ***no conflict***

The 3 procedures for the Window Heat do not conflict with each other. In almost all circumstances when the integrity of the window has been compromised, the Window Heat is turned off.

THRUST LEVERS:

General Notes on Thrust Levers:

The thrust levers are provided to control engine forward thrust requirements from idle to maximum power.

1. Cabin Altitude (Rapid Depressurization)

Bombs or structural failures are some of the causes of rapid depressurization. During flight, air (high pressure and very hot) is bled from the engines and then cooled through the air conditioning pack. This cooled air is then pumped into the aircraft cabin. Pressurization is controlled by how much air flows out of the cabin.

The FAA has a prescribed time in which an aircraft cabin must become a habitable environment after depressurization occurs. The FAA procedure assumes the plane is structurally intact. At very high altitudes (above 35000 feet), a person (depending on age and physical condition) can stay conscious about 30 seconds (Jeppesen, 1994). Below 14000 ft, most people can work without oxygen.

During rapid depressurization, the aircraft crew has 5 seconds to don their oxygen masks. To descend to an acceptable altitude, the pilot pulls the throttle back (**CLOSES** the Thrust Levers) and uses the speed brake to enable the plane to have a high rate of descent.

2. Engine Fire, Severe Damage or Separation

During these situations, the pilot **CLOSEs** the Thrust Levers to identify which engine to shutdown. Each engine has a separate fuel shutoff, fire handle and thrust lever.

3. Engine Surge/Stall or Hung/Slow Acceleration

A compressor (engine) stall sounds like the engine has exploded. People in the aircraft feel a tremendous vibration. An air flow disruption during compression is the typical cause of an engine stall. To alleviate this problem, the pilot will **CLOSE** the Thrust Levers to try to eliminate the compression stall. Then, he/she will slowly **ADVANCE** the Thrust Levers to try to restart the engine if the EGT is stabilized or decreasing.

4. Loss of thrust on Both Engines

This situation is extremely rare. When it occurs, the pilot **CLOSEs** the Thrust Levers so that he/she can shutoff the engines.

5. Electronic Engine Control

Each fuel controller has an electronic control. If the electronic control fails, then the automatic protection in the plane's throttle system is lost. The automatic overboost protection is disabled when the electronic control fails. To protect the system, the pilot **RETARDs** the Thrust Levers **TO MID POSITION** so that the system isn't overboosted.

6. Engine Failure/Shutdown

This procedure is initiated for a host of reasons including low oil pressure, engine vibration and fuel system failure. During this procedure, the pilot **CLOSEs** the Thrust Lever to the affected engine. Unless there's an obvious cause for the engine failure, the pilot should always try to restart the engine.

7. Engine Limiter

This procedure is the same as the electronic engine control. The electronic engine control component won't allow the pilot to exceed the maximum rate of thrust.

8. Engine Overheat

The compressed air is hot so it is cooled through the air condition pack. If the air is too hot, the pilot **RETARDs** the Thrust Levers so that the pressure and heat are reduced. Hopefully at some lower power setting, the engine will reach an acceptable temperature. If not, the pilot will have to perform the Engine/Failure Shutdown procedure which tells him/her to **CLOSE** the Thrust Lever of the affected engine.

9. Engine Vibration

The pilot will **RETARD** the Thrust Lever to try to eliminate the vibration. Typically, ice can cause engine vibration. If the vibration can't be eliminated, the pilot will have to perform the Engine/Failure Shutdown procedure which instructs him/her to **CLOSE** the Thrust Lever of the affected engine.

10. Oil Pressure

If the oil pressure limits are exceeded, the pilot always performs the Engine/Failure Shutdown procedure which instructs him/her to **CLOSE** the Thrust Lever of the affected engine. If the oil pressure is in the amber band, then the pilot **ADJUST**s the Thrust Levers **TO MID POSITION**.

11. Oil Temperature

Assuming the engine has become too hot at idle, the pilot will **ADJUST** the Thrust Levers **TO MID POSITION** to try to reach the appropriate temperature limits. In aircraft, the (hot) oil and (cool) fuel are used to stabilize each other's temperature. If the oil temperature is too hot, then more fuel is used to try to cool it. If the temperature doesn't decrease below the red line limit, then the pilot accomplishes the Engine/Failure Shutdown procedure which tells him/her to **CLOSE** the Thrust Lever of the affected engine.

12. Reverser Unlocked

This situation occurs when any component of the thrust is not in the forward thrust position. The pilot **CLOSE**s the Thrust Levers as soon as possible to shut the engine off. He/she might have to pull back on the other engine throttle to maintain directional control.

SUMMARY FOR THRUST LEVERS ***no conflict***

Pilot actions within the 12 procedures aren't really in conflict. If a limit is reached and PLACING the Thrust Levers IN THE MID POSITION doesn't alleviate the problem, then they are CLOSED. If there is a serious problem (rapid depressurization, engine fire, loss of engine thrust, etc.), the Thrust Levers are always CLOSED.

OUTFLOW VALVE:

General Notes on Outflow Valve:

The cabin outflow valve is controlled by three systems, two automatic and one manual, to maintain proper cabin pressurization in the aircraft. A single outflow valve is located at the rear of the aircraft. Besides the outflow valve, there are small calibrated leaks throughout the aircraft. The emergency relief valve which prevents overpressurization of the aircraft is another "hole" in the plane.

1. Cabin Automatic Inoperative

If the cabin automatic is inoperative, the pilot should use the cabin altitude manual control. During landing, the Outflow Valve should be **FULL OPEN** so that there is no cabin pressurization. If a problem occurred during landing and the outflow valve wasn't full open, the cabin pressurization would inhibit the airplane door from opening and the passengers and crew would be trapped inside the plane.

2. Passenger Evacuation

During passenger evacuation, the aircraft is on the ground. The Outflow Valve should be **OPEN** (no cabin pressurization) so the passengers and crew can get off the plane.

3. Ditching Preparation

During ditching preparation, the aircraft is in the water. The Outflow Valve should be **CLOSEd** so that no water enters the cabin. The aircraft floats because of the buoyancy force caused by the air that has replaced the used fuel in the wings. (Prior to landing in the water the Outflow Valve should have been opened to equalize the cabin pressure and the ambient air pressure.)

<u>SUMMARY FOR OUTFLOW VALVE</u> ***no conflict***

If the cabin automatic positioning for the outflow valve is inoperative and the pilot is performing a ditching maneuver, the following actions should be performed. For ditching, the aircraft cabin needs to be depressurized so that the doors will open once in the water and the slides can be put out. However, once the slides are out, the outflow valve needs to be closed so that the aircraft is a little more seaworthy. If the cabin automatic positioning for the outflow valve is inoperative, then manual positioning of the outflow valve is used to maintain proper cabin pressurization. During landing, the outflow valve should be full open so that there is no cabin pressurization. No conflict occurs because the operation (close/open) of the outflow valve happens at different times during the conflict.

ENGINE BLEED AIR SWITCH:

General Notes on Engine Bleed Air:

Engine bleed air (pneumatic air) is used for air conditioning (a/c) packs, starting the engines, and de-icing of wings and engine lip. The engine bleed air has a very high temperature and it's extracted from either the low stage or the high stage (further down the engine) source. Extracting the air reduces the thrust to the engine. During takeoff, the engine bleed air is taken from the low stage source. At low power settings, the low stage pressure isn't powerful enough to operate the system so the air is extracted from the high stage pressure source.

In a typical transport aircraft, the engine bleed is on during takeoff (t/o). If additional thrust is needed at takeoff (because of high gross weight, high temperature, short runway, high altitude airport, etc.), the pilot turns the engine bleed off.

The a/c packs provide pressurization and air conditioning to the aircraft. The starter for the jet engine is a pneumatic starter. A pneumatic leak is a serious condition because of the very hot air and it's treated almost with the same amount of concern as a fire.

1. Engine Bleed Off

If there's a fault in one side of the system (i.e., a leak develops or the pilot can't control temperature), the pilot turns the Engine Bleed Air Switch **OFF** for that side of the system. During takeoff and roll, the bleed air in the system comes from the initial stages of compression. During landing, the bleed air is taken from the high pressure part of the engine.

2. Engine Bleed Valve

The engine bleed valve is electrically armed and operated by the pressure of the medium it's controlling. If pneumatic pressure is available, the valve will open/close. If the engine valve is open even though it should be closed, the pilot should try to cycle through the system once (Engine Bleed Air Switch turned **OFF/ON**). If cycling through the system doesn't alleviate the problem, the Engine Bleed Air Switch should be turned **OFF**. In flight, bleed air is used for a/c packs and for anti-icing. If just one engine valve switch is working during flight, it should be used primarily for anti-icing. The Bleed Air Switch is turned **OFF** for the inoperative engine bleed valve.

3. Engine High Stage

Engine High Stage is caused by over pressure in the engine bleed system. The pilot can't reset the system so he/she should close the engine bleed valve by turning the Bleed Air Switch **OFF**.

4. Bleed Duct Leak

A temperature sensor runs along the outside of the bleed duct. If a duct leak occurs, the temperature sensor will sense a temperature rise. The pilot then shuts down that half of the system (Engine Bleed Air Switch **OFF**).

5. Engine Surge/Stall or Hung/Slow Acceleration

The engine bleed system takes air away from the engine so the engine efficiency is reduced. If the engine bleed air switch is not operating properly, an engine surge might develop. During an engine surge, the engine is speeding up and down. A stall is caused by a disruption in the airflow. Typically, a severe vibration is felt. The pilot might also see fire coming out of the engine. For either of these situations, the pilot should turn **OFF** the Bleed Air Switch.

6. Engine Overheat

The pilot will turn the Engine Bleed Air Switch **OFF** because a temperature regulator has failed.

7. Starter Cutout

Pneumatic air is provided to the starter. At a certain rpm, the starter is shutoff. If the signal to the starter fails, the starter will continue to run. The starter will eventually burn out if it continues to run. If the starter fails to cutout, the pilot shuts **OFF** the Engine Bleed Air Switch.

8. Wing Anti-Ice

After landing the Engine Bleed Air Switch is turned **OFF** because the wing anti-ice is designed to be used in flight not on the ground. Since the wings are made of aluminum, they can be weakened by the high temperature bleed air. If the wing anti-ice is stuck in the "on" position, there will be no cooling airflow available once the aircraft has landed and stopped on the ground.

SUMMARY FOR ENGINE BLEED AIR SWITCH ***no conflict***

There are no conflicts among the 8 procedures. If the bleed air system isn't functioning properly, the Engine Bleed Air Switch is turned off. If the valve is in the wrong configuration, the pilot tries cycling the switch on and off to correct the fault. If cycling doesn't correct the fault, the Engine Bleed Air Switch is turned off.

ISOLATION SWITCH

General Notes on Isolation Switch:

Normally, the Isolation Switch is closed (off). The Isolation Switch isolates (splits in half) the pneumatic system of the aircraft. Failure on one side of the system doesn't affect the other side. Pneumatic air is used for pressurization, starting the aircraft, and icing prevention on the wings and engines. The engine bleed air (pneumatic air) has a very high temperature and pressure and it's extracted from either the low stage or the high stage (further down the engine) source. Extracting the air reduces the thrust to the engine. During t/o, the engine bleed air is taken from the low stage source. At low power settings, the low stage pressure isn't powerful enough to operate the system so the air is extracted from the high stage pressure source. The pneumatic air usually comes from the low stage source.

1. Engine Bleed Off

If there's a fault in one side of the system (i.e., a leak develops or the pilot can't control temperature), the pilot turns the engine bleed air switch off for that side of the system. The Isolation Switch is turned **ON** in order to use the pneumatic air from the other side of the system for wing anti-ice (if necessary).

2. Engine Bleed Valve

The Isolation Switch is **ON** in order to use the pneumatic air for wing anti-ice (if necessary). See notes from #1 on Engine Bleed Off procedures.

3. Engine High Stage

The Isolation Switch is **ON** in order to use the pneumatic air for wing anti-ice (if necessary). See notes from #1 on Engine Bleed Off procedures.

4. Bleed Duct Leak

During a bleed duct leak, the pilot doesn't want to add pneumatic air to the leaking component, so he/she turns the isolation valve **OFF**.

5. Engine Fire, Severe Damage or Separation

During this procedure, the engine is turned off. The pilot can reroute the pneumatic air by turning the Isolation Switch **ON** thus supplying hot air (from the operational engine) for the wing anti-ice (if necessary).

6. Engine Surge/Stall or Hung/Slow Acceleration

The same procedure is followed as described in the Engine Fire, Severe Damage or Separation procedure (#5 in this section).

7. Engine Failure Shutdown

The same procedure is followed as described in the Engine Fire, Severe Damage or Separation procedure (#5 in this section).

8. Engine Inflight Start

If the engine is wind-milling at a certain speed and altitude, the pilot might need to use the engine starter. If this is the case, the pilot would turn the Isolation Switch **ON** and then turn it **OFF** after the engine inflight start.

9. Engine Overheat

The same procedure is followed as described in the Engine Fire, Severe Damage or Separation procedure (#5 in this section).

10. Starter Cutout

During starter cutout, the valve is stuck open. The pilot should turn the Isolation Switch **OFF** and use the bleed air switches to remove the pneumatic air from the system.

11. Engine Vibration

If the vibration is severe enough, the pilot will shut down the engine. Wing anti-ice might be necessary so the Isolation Switch should be in the **ON** position.

12. Oil Pressure

The same procedure is followed as described in the Engine Fire, Severe Damage or Separation procedure (#5 in this section).

13. Oil Temperature

The same procedure is followed as described in the Engine Fire, Severe Damage or Separation procedure (#5 in this section).

14. Reverser Unlocked

The same procedure is followed as described in the Engine Fire, Severe Damage or Separation procedure (#5 in this section).

15. Wing Anti-Ice

After landing, the pilot turns the Isolation Switch **OFF** to prevent wing anti-ice from operating.

SUMMARY FOR ISOLATION SWITCH ***conflict***

A conflict in the position of the isolation switch can exist if the aircraft experiences an engine failure and a bleed duct leak on the opposite side of the failed engine. In this multiple failure situation, the pilot would turn the isolation switch off and perform an emergency descent procedure. The bleed duct leak procedure takes precedence over the engine failure procedure since a bleed duct leak can damage electrical wire insulation and can weaken aluminum near the affected area of the leak. When an aircraft has a bleed duct leak, the pilot must take special caution to avoid icing situations because the isolation switch must remain off which disables the wing anti-ice for the affected side of the aircraft.

PACK CONTROL SELECTOR

General Notes on Pack Control Selector

There are 2 packs in the transport; either pack will maintain pressurization. The packs supply air through ducting to flight deck, forward cabin, and aft cabin.

1. Pack Temperature

The pack temperature is automatically controlled by a specified dial setting. These settings are STBY-C (cold), STBY-W (warm), and STBY-N (normal). If an overheat or fault in the associated zone temperature system is sensed, the INOP light comes on. The pilot should select **STBY-N** first. If the compartment temperature becomes unacceptably warm or cool select **STBY-C** or **STBY-W**, respectively. If INOP light does not extinguish, turn the Pack Control Selector **OFF** for the associated zone temperature system.

2. Engine Inflight Start

Turn one pack control selector **OFF** to reduce pneumatic load so that all of the engine bleed air (pneumatic air) is available for the starters. Once the engine starts, turn the one Pack Control Selector to **AUTO**.

3. Reverser Unlocked

During Reverser Unlock, the pilot must perform an engine shutdown so the Pack Control Selector is turned **OFF**. The pilot turns the Pack Control Selector off so that there is no pneumatic air on that side.

4. Smoke Removal

The Pack Control Selectors remain on **AUTO**. The pilot should raise the cabin altitude which will open the outflow valve to a more open position thus enabling more air flow through the cabin. The outflow valve will open wider because there's less pressure in the cabin.

5. Ditching Preparation

The Pack Control Selectors are turned **OFF** so that the airplane depressurizes and the passengers can be evacuated. The outflow valve should be manually closed.

6. Gear Disagree

Typically during landing, the cabin pressure is reduced to low limits. As the plane touches down, the outflow valve opens fully to depressurize the aircraft. If there is a gear disagree (one part of the landing gear is up), the aircraft won't automatically depressurize. The pilot can depressurize the aircraft before landing by turning the Pack Control Selector **OFF**.

SUMMARY FOR PACK CONTROL SELECTOR ***conflict***

A conflict occurs in the positioning of the pack control selector in the smoke removal procedure and the pack temperature non-normal procedure. Due to it's serious nature, the smoke removal procedure takes precedence over the pack temperature procedure. If the smoke can not be removed, the pilot must accomplish the earliest possible descent, landing and passenger evacuation.

ENGINE START SELECTOR

General Notes on Engine Start Selector

Pushing in and rotating the Engine Start Selector to the GND position, opens the start valve, engages the air driven starter to the N3 spool, and closes the engine bleed air switch if it is open. The Engine Start Selector is in GND position until the engine meets a certain speed (approximately 50% N3) and then it automatically turns to AUTO position. In the AUTO position, the starter automatically cuts out and the start valve closes stopping the flow of air to the starter.

The Engine Start Selector controls operation of the starter and the ignition switch, and it is normally in the AUTO position during flight. The ignition system always operates when the flaps are in any position other than the UP position. In the FLT position, both igniters act continuously. This position is used during adverse weather conditions such as heavy precipitation.

(note: The Rolls Royce engine has 3 spools and the Pratt Whitney engine has 2 spools, N1 and N2.)

1. Aborted Engine Start

The engine rotates and the fuel is on but the pilot discontinues the start because the engine isn't engaging. To discontinue the start, the pilot turns off the fuel control switch. To purge fuel from engine, the pilot uses the starter motor for another 20 seconds. As the engine rotates, at 50 percent N3, the switch automatically goes from **GND** position to the **AUTO** position which automatically turns off the starter and terminates ignition.

2. Loss of Thrust on Both Engines

The pilot puts the Engine Start Selector in the **FLT** position (both igniters) to try to get thrust back before both engines have a chance to spool down.

3. Engine Inflight Start

If the engine is rotating fast enough, then the pilot doesn't need pneumatic pressure to start the engine so he/she uses the **FLT** position. If pneumatic pressure is needed to start the aircraft, then the pilot uses the **GND-AUTO** procedure.

4. Starter Cutout

If the starter cuts out, there will be a rise in pneumatic pressure. If the pilot doesn't see a rise in pressure, he/she must manually attempt to close the starter valve. The pilot attempts this action by moving the Engine Start Selector to **AUTO.** If this action doesn't alleviate the problem, the pilot must shut down the engine because the aircraft should not be flown with the starter valve "open". If the starter valve is "open" at a speed above 50% N3, it could be damaged by the engine.

<u>SUMMARY FOR ENGINE START SELECTOR</u> ***no conflict***

The inflight engine start procedure could end up with an aborted engine start but the procedures are similar at this point. So, there are no conflicts among the procedures.

RAM AIR TURBINE

General Notes on Ram Air Turbine

There is no manual reversion of flight controls on modern transport aircraft because of it's size and weight. The forces felt by the control surfaces are too great for a pilot to manually fly. Without hydraulic pressure, the pilot has no flight controls. To provide redundancy in hydraulic pressure, a Ram Air Turbine drops into the slipstream and gives the pilot enough hydraulics to handle the essential controls of the aircraft. With the Ram Air Turbine, the propeller turns the hydraulic pump and the hydraulic lines run through the aircraft.

1. Loss of Thrust on Both Engines

If thrust is lost on both engines, the Ram Air Turbine automatically drops down into the slipstream and a light illuminates which says **UNLOCKED**.

2. AC Bus(es) Off

Each engine has an engine driven hydraulic pump and each hydraulic pump has an electric pump. There is a left and right (L&R) system associated with each engine. There is a center system corresponding to operation by electrical pumps and ram air turbine pump. If center system fails, then the Ram Air Turbine is activated by **PUSHING THE SWITCH** (Ram Air Turbine Switch). All pumps (hydraulic and electric) except the Ram Air Turbine pump are always on in normal flight.

SUMMARY FOR RAM AIR TURBINE ***no conflict***

There are no conflicts among the two procedures.

APU SELECTOR

General Notes on APU Selector

The APU is used normally as a source of electrical and pneumatic power for the air conditioning on the ground. It is also used as pneumatic power for start on the ground. It is the backup source for the two engine driven generators. In the air, the APU is used only as an electric source not as a pneumatic source. Everything on the APU is automatic.

1. APU Fault

When starting the aircraft, if the pilot turns on the APU and the fault light doesn't go out then the system automatically shuts down. The pilot can reset the faulted circuits by turning the APU Selector **OFF** then **ON**.

2. AC Bus(es) Off

If there's been a massive electrical failure, the L or R bus would be isolated and the APU power wouldn't be able to get through the system. Therefore, the APU Selector should be turned **OFF**.

SUMMARY FOR APU SELECTOR ***no conflict***

There are no conflicts among the two procedures.

CABIN ALTITUDE MANUAL CONTROL

General Notes on Cabin Altitude Manual Control

The Cabin Altitude Manual Control controls the cabin outflow valve position with the Altitude Mode Selector in the Man mode. The pilot positions the outflow valve with respect to the cabin altitude rate of climb. For level flight, the cabin altitude rate is equal to zero. If the outflow valve is opened to a more full position, the pressure differential between cabin pressure and the outside air is lessened and an increase in the cabin altitude is indicated. This technique is used for smoke removal because the increase in air flow through the cabin gets rid of the smoke quicker. This technique is also used for passenger evacuation because the pilot wants to depressurize the aircraft so that the doors will open. The cabin altitude essentially reduces to zero at landing. If a slight altimeter error exists, there might be a small pressure differential which would keep the aircraft door from opening. On landing, the outflow valve is in the full open position so that there is no cabin pressure differential.

As the engine thrust increases, the pneumatic pressure in the packs increases and this increase tends to drive down the cabin altitude.

The Cabin Altitude Manual Control can be rotated to the CLIMB or DESCEND position. In the CLIMB position, the cabin outflow valve opens to increase cabin altitude. In the DESCEND position, the valve closes to reduce cabin altitude.

1. Cabin Automatic Inoperative

The pilot manually adjusts the cabin outflow valve by rotating the Cabin Altitude Manual Control either toward the **CLIMB** or **DESCEND** markings. The captain pays close attention to the cabin rate of climb indicator, the cabin pressure differential indicator, and the cabin altimeter.

2. Smoke Removal

The pilot manually adjusts the cabin outflow valve by rotating the Cabin Altitude Manual Control toward the **CLIMB** marking. Thus there is more air flow through the cabin so the smoke is removed more quickly.

3. Passenger Evacuation

The pilot manually adjusts the cabin outflow valve by rotating the Cabin Altitude Manual Control toward the **CLIMB** marking. On landing, the outflow valve is in the full open position so that there is no cabin pressure differential. By depressurizing the aircraft, the doors can be opened for passenger evacuation.

<u>SUMMARY FOR CABIN ALTITUDE MANUAL CONTROL</u> ***no conflict***

There are no conflicts among the three procedures.

UTILITY BUS SWITCHES

General notes on Utility Bus Switches

Power to the utility and galley buses is controlled by the Utility Bus Switches and the Load Shed system. The Utility Bus Switches can always be used to disconnect the buses from the main AC buses. The switches can also connect the buses, but only if there is no load shed signal.

The Utility Bus Switch can be in the ON or OFF position. In the ON position, if there is no load shed signal present the utility and galley buses are connected to the main bus. In the OFF position, the utility and galley buses are disconnected from the main AC bus.

1. Electrical Smoke or Fire

The likely source of smoke or fire in the cabin would be in the galley. Therefore, the Utility Bus Switch is turned **OFF**.

2. Utility Bus Off

The pilot manually turns the Utility Bus Switch **OFF** and then **ON**.

SUMMARY FOR UTILITY BUS SWITCHES ***no conflict***

There are no conflicts among the two procedures because electrical smoke or fire always takes precedence.

ALTERNATE FLAPS SELECTOR

General Notes on Alternate Flaps Selector

Flap and slat position is controlled with the Flap Lever. When the Flap Lever is in the UP detent, all flaps and slats are retracted and the flap position indicator points to UP. Moving the flap lever to position 1 signals the slats and flaps to extend to position 1. Placing the flap lever to position 5, 15, or 20 signals the flaps to extend to the selected position. The slats remain in the takeoff (intermediate extended) position. Moving the flap lever to position 25 signals the flap to extend to the selected setting and the slats to extend to their landing (fully extended) position.

An alternate flap drive system allows the flap Power Drive Units (PDUs) to be driven by electric motors rather than hydraulic power. During normal operations the Alternate Flaps Selector is in the NORM (normal) position. There are two Alternate Flaps Switches, one for the leading edge drive system and one for the trailing edge drive system. When the Alternate Flaps Switch is pushed on, ALTN appears in the switch. Rotating the Alternate Flaps Selector signals the flaps and slats to move to the pilot selected position (UP, 1, 5, 15, 20, or 25). Only slat asymmetry protection is provided during alternate operations.

The electrical system is a lot slower than the hydraulic system when moving the flaps/slats. Also, the leading edge devices have a more pronounced effect on landing speed than the trailing edge devices (e.g. LE slats reduce stall speed by about 20 knots).

1. Leading Edge Slat Disagree

This situation occurs when the slats are not in or are not driving toward their commanded position. Hydraulic power to both PDUs is automatically shut off. The pilot **SET**s the Alternate Flaps Selector to agree with the flap lever. Then the Alternate Flaps Switch is pushed on and ALTN is displayed. The Alternate Flaps Selector is then **SET** so that the flaps are extended/retracted as required.

2. Trailing Flap Disagree

This situation occurs when the flaps are not in or are not driving toward their commanded position. Hydraulic power to both PDUs is automatically shut off. The pilot **SET**s the Alternate Flaps Selector to agree with the flap lever. Then the Alternate Flaps Switch is pushed on and ALTN is displayed. The Alternate Flaps Selector is then **SET** so that the flaps are extended/retracted as required.

3. Leading Edge Slat Asymmetry

When a leading edge slat asymmetry is detected hydraulic power to both PDUs is automatically shut off. The pilot should not arm the alternate leading edge drive system. The pilot should **SET** the Alternate Flaps Selector to agree with the flap lever. Then the Trailing Edge Alternate Flaps Switch is pushed on and ALTN is displayed. The Alternate Flaps Selector is then **SET** so that the trailing edge flaps are extended/retracted as required. The pilot attempts to get as much TE stall protection as possible without extending the LE slats any farther.

4. Trailing Edge Flap Asymmetry

When a trailing edge flap asymmetry is detected hydraulic power to both PDUs is automatically shut off. The slats can be operated by the alternate system. Alternate trailing edge operation is not used due to the lack of asymmetry protection. If the asymmetry occurred at less than flaps 1, the Alternative Flaps Selector is set to **flaps 1** and the LE Alternate Flaps Switch is pushed on so that ALTN is displayed.

5. Hydraulic System(s) Pressure

If the Left and Right Hydraulic Systems are inoperative, the alternate flap operation is required. The pilot should **SET** the Alternate Flaps Selector to agree with the flap lever. Then the Alternate Flaps Switches are pushed on and ALTN is displayed. The Alternate Flaps Selector is then **SET** so that the flaps are extended/retracted as required.

SUMMARY FOR ALTERNATE FLAPS SELECTOR ***conflict***

Typically in the interest of safety, landing maneuvers are performed at as low a speed as possible. In order to reduce the speed of the aircraft, the coefficient of lift and/or the wing area must be increased. Usually, this increase is accomplished through the use of slats and/or flaps on the aircraft's wings. If a simultaneous leading edge slat asymmetry and trailing edge flap asymmetry occurred on the wings, the pilot would have to maintain enough speed for landing. This multiple failure is analogous to a zero-flap approach since the both the slats and flaps can not be extended due to position asymmetry. During a zero-flap approach, the pilot should determine the stall speed and land at 30 percent above this speed.

ALTERNATE FLAPS SWITCH

General Notes on Alternate Flaps Switch

See discussion in previous section entitled "General Notes on Alternate Flaps Selector".

1. Leading Edge Slat Disagree

This situation occurs when the slats are not in or are not driving toward their commanded position. Hydraulic power to both PDUs is automatically shut off. The pilot sets the Alternate Flaps Selector to agree with the flap lever. Then the Alternate Flaps Switch is pushed on and **ALTN** is displayed. If, after selecting ALTN, the LE or TE light remains illuminated, the pilot positions the associated Alternate Flaps Switch **OFF** and accomplishes the applicable asymmetry procedure. The Alternate Flaps Selector is then set so that the flaps are extended/retracted as required.

2. Trailing Flap Disagree

This situation occurs when the flaps are not in or are not driving toward their commanded position. Hydraulic power to both PDUs is automatically shut off. The pilot sets the Alternate Flaps Selector to agree with the flap lever. Then the Alternate Flaps Switch is pushed on and **ALTN** is displayed. If, after selecting ALTN, the LE or TE light remains illuminated, the pilot positions the associated Alternate Flaps Switch **OFF** and accomplishes the applicable asymmetry procedure. The Alternate Flaps Selector is then set so that the flaps are extended/retracted as required.

3. Leading Edge Slat Asymmetry

When a leading edge slat asymmetry is detected hydraulic power to both PDUs is automatically shut off. The pilot should not arm the alternate leading edge drive system. The pilot should set the Alternate Flaps Selector to agree with the flap lever. Then the Trailing Edge Alternate Flaps Switch is pushed on and **ALTN** is displayed. The Alternate Flaps Selector is then set so that the trailing edge flaps are extended/retracted as required. The pilot attempts to get as much TE stall protection as possible without extending the LE slats any farther.

4. Trailing Edge Flap Asymmetry

When a trailing edge flap asymmetry is detected hydraulic power to both PDUs is automatically shut off. The slats can be operated by the alternate system. Alternate trailing edge operation is not used due to the lack of asymmetry protection. If the asymmetry occurred at less than flaps 1, the Alternative Flaps Selector is set to flaps 1 and the LE Alternate Flaps Switch is pushed on so that **ALTN** is displayed.

5. Hydraulic System(s) Pressure

If the Left and Right Hydraulic Systems are inoperative, the alternate flap operation is required. The pilot should set the Alternate Flaps Selector to agree with the flap lever. Then the Alternate Flaps Switches are pushed on and **ALTN** is displayed. The Alternate Flaps Selector is then set so that the flaps are extended/retracted as required.

<u>SUMMARY FOR ALTERNATE FLAPS SWITCH</u> ***conflict***

Typically in the interest of safety, landing maneuvers are performed at as low a speed as possible. In order to reduce the speed of the aircraft, the coefficient of lift and/or the wing area must be increased. Usually, this increase is accomplished through the use of slats and/or flaps on the aircraft's wings. If a simultaneous leading edge slat asymmetry and trailing edge flap asymmetry occurred on the wings, the pilot would have to maintain enough speed for landing. This multiple failure is analogous to a zero-flap approach since the both the slats and flaps can not be extended due to position asymmetry. During a zero-flap approach, the pilot should determine the stall speed and land at 30 percent above this speed.

CROSSFEED VALVE SWITCH

General Notes on Crossfeed Valve Switch

The Crossfeed Valve Switch is used to equalize the fuel loads in the wing tanks so that the aircraft is kept balanced. It is also used to keep the aircraft balanced in the event of an engine loss. The Crossfeed Valve Switch is usually in the OFF (valve closed) position. The only time it is turned ON (valve open) is if there is a slight difference in the engine burn between the main engines. There are two center tanks (L and R) which feed the left and right engines. There are two main tanks (L and R) located in the wings. The center tank pumps have more pressure than the main tank pumps so the fuel is consumed out of the center tanks first and then the main tanks.

If the R tank pumps have too much fuel, the pilot will open the crossfeed valve and turn the L tank pumps off. The fuel for the engines will then be coming from the R tank pumps. This process continues until the wing tanks are balanced. Then, the L tank pumps are turned back on and the crossfeed valve is closed.

1. Fuel Pump

If one of the center pumps fails, then the pilot turns **ON** the Crossfeed Valve Switch so that the operating center pump fuels both the left and right engines. Once the center tank is empty, the pilot turns **OFF** the Crossfeed Valve Switch to maintain balance in the wing tanks.

2. Low Fuel

In this event, the total fuel quantity is low. An indication light comes on when the fuel quantity reaches 2200 lbs in either of the main tanks (L or R). The pilot turns the Crossfeed Valve Switch **ON** so that any fuel that is available for the engines can be used.

SUMMARY FOR CROSSFEED VALVE SWITCH ***no conflict***

There are no conflicts among the two procedures. The center tanks are emptied first (Fuel Pump procedure) and then the main tanks are used (Low Fuel procedure).

FUEL PUMP SWITCHES

General Notes on Fuel Pump Switches

The Fuel Pump Switches are located in the center of the overhead panel and are used to turn the electric fuel pumps on/off. If a tank runs out of fuel, the pilot will see a low pressure light illuminated and the fuel quantity gauge will read zero.

1. Low Fuel

In this event, the pilot turns the crossfeed valve switch ON and all of the Fuel Pump Switches **ON** so that both engines will operate as long as there is fuel in any of the tanks.

2. Gear Disagree

In this event, the pilot turns the pack control selectors OFF to depressurize the cabin and turns the Fuel Pump Switches **OFF** to reduce the possibility of fire upon landing. Since there is a gear disagree, the plane will be "scraping metal" upon landing.

SUMMARY FOR FUEL PUMP SWITCHES ***conflict***

If the plane is low on fuel and the landing gear has not fully extended (gear disagree procedure), a conflict in the position of the fuel pump switches exists. Since the airplane will be "scraping metal" upon landing, the fuel pump switches are turned off to prevent a fire from occurring. The seriousness of a fire upon landing allows the gear disagree procedure to supersede the low fuel procedure.

AUTO BRAKES SELECTOR

General Notes on Auto Brakes Selector

The Auto Brakes Selector has 5 settings (1, 2, 3, 4 and MAX AUTO) corresponding to increasing auto brakes deceleration rates. The auto brakes system permits automatic braking at a preselected deceleration rate following touchdown. The maximum autobrakes deceleration rate (MAX AUTO) is less than the amount produced by full manual braking.

After landing with the auto brakes system armed, the brakes are applied when both Thrust Levers are at idle. The preselected deceleration rate is maintained throughout the landing by reducing the auto brakes pressure when other deceleration devices (speedbrakes and thrust reversers) are operating.

There are four ways to disengage the auto brake system:

1. Rotate the Auto Brakes Selector to the DISARM or OFF position
2. Manual braking
3. Pushing the speedbrake handle forward
4. Advancing either throttle

It depends on pilot preference on whether the auto brake system is using during landing. However, both Boeing and Lockheed have stated that brake wear on the aircraft is less when the auto brake system is used consistently than when it's not used.

1. Autobrakes

If the pilot sees the auto brakes message light illuminated, then he/she **RESELECT**s the appropriate deceleration rate with the Auto Brakes Selector. If the auto brakes light re-illuminates, then the Auto Brakes Selector is turned to the **OFF** position.

2. Brake Source

If the brake source light illuminated, then the normal and alternate brake system pressure is low. For this situation, the pilot turns the Reserve Brake Switch on. If the reserve brake source light remains illuminated, then the pilot turns the Auto Brakes Selector **OFF**. At this point only accumulator pressure is available for the brakes so the pilot applies steady, increasing brake pressure and holds this pressure until the aircraft comes to a full stop.

SUMMARY FOR AUTO BRAKES SELECTOR ***no conflict***

There are no conflicts among the two procedures.

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13. ABSTRACT *(Maximum 200 words)*

Checklists are used by the flight crew to properly configure an aircraft for safe flight and to ensure a high level of safety throughout the duration of the flight. In addition, the checklist provides a sequential framework to meet cockpit operational requirements, and it fosters cross-checking of the flight deck configuration among crew members.

This study examined the feasibility of integrating multiple checklists for non-normal procedures into a single procedure for a typical transport aircraft. For the purposes of this report, a typical transport aircraft is one that represents a midpoint between early generation aircraft (B-727/737-200 and DC-10) and modern glass cockpit aircraft (B747-400/777 and MD-11). In this report, potential conflicts among non-normal checklist items during multiple failure situations for a transport aircraft are identified and analyzed. The non-normal checklist procedure that would take precedence for each of the identified multiple failure flight conditions is also identified. The rationale behind this research is that potential conflicts among checklist items might exist when integrating multiple checklists for non-normal procedures into a single checklist.

As a rule, multiple failures occurring in today's highly automated and redundant system transport aircraft are extremely improbable. In addition, as shown in this analysis, conflicts among checklist items in a multiple failure flight condition are exceedingly unlikely. The possibility of a multiple failure flight condition occurring with a conflict among checklist items is so remote that integration of the non-normal checklists into a single checklist appears to be a plausible option.

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