Aviation-Style Checklists

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Effective in the cockpit, but appropriate for healthcare? There's one sure-fire way to make them work as a patient-safety tool.

Introduction

In broadest terms, a checklist is a memory aid used to assist with the completion of a task. There are countless varieties of checklists: The "ABC's" of CPR, a 30-item grocery list, or an auto manufacturer's recommended 30,000-mile maintenance, are all examples. However, within the realm of aviation and other high-consequence industries, the checklist concept has been highly refined as a tool to compensate for limits of memory and attention, with the express purpose of reducing human errors.

When used as an error-reducing tool, an aviation-style checklist is a deceptively simple compilation of items. Indeed, the polished impression of pilots performing a pre-flight cockpit checklist has inspired many observers to conclude that it would be a great idea to start using checklists in their own line of work. But the concepts embedded within their development, utilization, and effectiveness, are complex: aviation checklists[1] are rooted in sound principles of human factors engineering.

Are aviation-type checklists practical in other industries, such as healthcare? And, if so, how should they be used? We need to examine exactly what a checklist can, and cannot do. We will first review some background science behind checklists, then see how they apply in aviation. Finally, we will address the cultural changes necessary to support proper checklist use in healthcare.

Background

The effectiveness of checklists can be attributed to their proper development, targeted situations, and complementary organizational practices. Within the commercial aviation industry, they represent a vital pillar of safety in what was once a very dangerous mission: aircraft flight.

Reducing human error. People commit errors with a predictable frequency; the rate will never be zero. The adoption of a checklist merely acknowledges this human weakness and adds a layer of safety in order to catch errors to limit their consequences. The field of cognitive psychology categorizes errors into two broad categories: *slips* and *mistakes*. Checklists are effective at reducing errors known as *slips*; they are ineffective at reducing *mistakes*.

A *slip* is an error involving *schematic behavior*. Schematic behavior tasks are those performed frequently and automatically: common job routines which become familiar and are accomplished without much conscious attention. Setting up OR instruments, preparing the anesthesia equipment, or closing and dressing a surgical incision, are all examples of common and repetitive, yet critical, components of patient care.

A pilot may perform some twenty flights during a 3-day trip. The routine may be familiar, repetitive, and seemingly safe. But the consequences of errors are high. On August 16, 1987, a Northwest Airlines MD-82 crashed on takeoff in Detroit, killing 154 people. The flaps had not been set for takeoff. The pilots

[1] NB: For the purpose of this article, the term "checklist" refers specifically to aviation-style checklists used during routine airline flight operations, in the absence of emergencies or serious failures. Within aviation, they are referred to as "Normal Procedures"; the common idea of "checklist" as used by laymen to denote pilots in the cockpit.

committed a slip. Every jet transport pilot knows that flaps must be used for takeoff. And those pilots were certainly aware of the fatal potential of attempting to depart without setting flaps. It was not a conscious decision: their error was an omission of a task they *knew* was mandatory and critical, yet they were unaware of their lapse. This is a slip which a checklist would have prevented[2].

A *mistake*, in contrast to a slip, is an error due to lack of experience or training: a failure of *attentional behavior*. This type of behavior requires active analysis and planning, for which checklists are largely ineffective. The reason for this disparity is that complex, varied, less familiar procedures cannot be efficiently reduced to a brief checklist. If a worker lacks training, knowledge, or experience, a checklist will not have any meaningful effect on his poor performance. To be sure, sit a passenger in the pilot's seat, hand him a checklist, and see if he can fly the airplane!

In summary, the purpose of an aviation-style checklist is to minimize slips in routine tasks in the workplace.

Use in the Cockpit

Boarding an airplane or visiting the cockpit, many people have watched pilots use a checklist. To the casual observer, it appears that the checklist is *prompting* or *directing* pilot action. That one incorrect assumption lies at the heart of a critical misconception surrounding checklists: they *do not* direct a pilot's behavior. While it may *appear* that the fluid, choreographed reading of a checklist is guiding the pilot's hands over the many cockpit switches, what you are actually witnessing is the pilot's habitual act of confirmation. What the untrained observer does not appreciate is that the tasks, before the checklist is started, *have already been completed*.

Completing tasks using a "flow". In the cockpit, the format, pace, and style of completing a flight is not dictated by a checklist. Rather, the exact opposite occurs: the pilots first carry out their tasks according to what is called a *flow*[3], and then use the checklist to confirm that each task has been completed. When the time comes to read the checklist, there is an understanding between the pilots that all the tasks on that checklist have already been completed: the checklist is merely a final confirmation. Thus, a checklist does not interfere with the work sequence, nor prompt for action, and never dictates any routine procedure. It simply provides verification that nothing critical has been missed.

What are the items on a checklist? A cockpit checklist is a highly-condensed version of a procedures manual. The *condensed checklist*[4] fits on a single sheet of folded cardboard; in contrast, the accompanying *expanded normal procedures* manual may be a few hundred pages. The manual completely details each

[2] The National Transportation Safety Board determined that the probable cause of the accident was the flight crew's failure to use the taxi checklist to ensure the flaps were extended for takeoff.

[3] A "flow" is a loosely-connected sequence of tasks which generally follow an order, but can be adapted to the situation. For example, the "Before Engine Start" cockpit tasks include receiving the current weather, setting the navigation radios, getting an air traffic control clearance, confirming the fuel load, reviewing the aircraft performance charts, etc. Only after each pilot has completed his flow, the checklist then read. The checklist *follows* the flow.

[4] See "Addendum A"

procedure to be accomplished for that phase of flight, item by item, and can be quite lengthy. It is the pilot's ultimate resource for correct and standard performance. Each item on a checklist may summarize many steps in a series of procedures or sub-routines, the completion of which is acknowledged with a single word or brief phrase. To illustrate, let's examine the "Before Takeoff" checklist for a passenger jet:

BEFORE TAKEOFF (C/R)

1. FLAPS .... __° Indicating/Verified
2. Flight Controls.................Checked (FO)
3. TRIMS...................... Three Set/Verified
4. THRUST REVERSERS ....ARMED
5. Flight Instruments and
Speed Bugs .... Checked/Verified
6. BRAKE TEMP......................... Checked
7. FMS ....Runway __Set,__/Verified
8. RADAR ....ON (FO)
9. Takeoff Briefing..............Complete (FO)
10.Cabin ....Ready (FO)

Figure 1. Excerpt from a Condensed Normal Procedures Checklist for a typical passenger jet. See "Addendum A" for the complete checklist.

Cabin.........Ready. One item on the cockpit "Before Takeoff" checklist (Figure 1.) is to verify that the cabin is ready for takeoff. In order for the pilots to reply "ready" to this checklist item, the following must have been accomplished:

1) Cabin service equipment properly stowed.
2) Passenger briefing completed on the use of seatbelts, flotation equipment, emergency oxygen, and emergency egress.
3) All passengers seated, seatbelts fastened, seatbacks upright, tray tables stowed.
4) Bags and personal items stowed.

These items are all completed by the flight attendants during taxi. The lead flight attendant confirms that all tasks are complete, then phones the cockpit via the intercom and, utilizing standard terminology, states simply "cabin ready for takeoff." That one phrase stands alone to mean that each required item listed above has been completed. And that is but one of some fifteen items on the checklist, each with their own expanded sequence of tasks, which are completed before the checklist is even read.

Note how the above example uses a situation where the pilots are verifying tasks completed by other workers, which they do not themselves witness nor check, but for which they are held responsible. This introduces concepts of both *teamwork* and *accountability* which are crucial to a well-run organization. Indeed, without the cultural framework for interdependency among team members, checklists themselves may be futile.

Discussion

The benchmark for success of a checklist is simple: were the items completed? But performing a checklist does nothing to improve safety unless the material within that checklist is *valid*. This illustrates the ultimate challenge of checklist development: what items should be *included* on a checklist?

A discussion of checklist design is beyond the scope of this article. Once formulated, though, a checklist must operate within a system which supports its requirements: a reliable, safety-oriented culture. These cornerstones must be in place prior to any expectation of realizing the full advantage of their use.

The preceding airline examples illustrate many of the facets upon which successful adaptation of checklists depend:

1) *Checklist vs. guidelines, protocols or clinical pathways*. Care must be taken not to confuse a checklist with other tools, even if they appear to be similar, since their underlying theories are profoundly different. Protocols, clinical guidelines, and clinical pathways all have lists of items to be completed, and may easily be confused with, or considered, a checklist. Those other memory aids do have their place in medicine, just as other similar tools are used in aviation. But they are profoundly distinct.

An example of a checklist "look-alike" is a tool occasionally used in the cockpit called a "QRH" -- Quick Reference Handbook[5] -- which is a substantial volume. Although it is commonly referred to, even among pilots, as a "checklist", it is a completely different entity. The QRH is rarely used except in simulator training: it covers failures of aircraft systems in flight, and is a guide for the pilots during emergencies. A good example of the QRH idea in the operating room is the Malignant Hyperthermia (MH) flow diagram available in OR suites. The similarities between engine failure in a turbojet, and an MH crisis in the OR, are striking: most will make it through a career without experiencing one. Although a QRH may be casually called a "checklist", it is actually a "flow diagram", distinctly different from a checklist in several ways:

The QRH:

a) is used in rare, non-routine situations,
b) is *prescriptive*: it dictates the work flow, rather than follows it,
c) *delivers* knowledge: used as an information source, rather than as a task confirmation,
d) involves *attentional* behavior: less common or rare situations requiring active analysis and planning.

To summarize, the term "checklist" is broadly-used, and often includes performance aids which are entirely different from the standard cockpit variety. Caution must be taken when naming these tools "checklists", in order to maintain the appreciation and respect that comes with their proper, judicious use.

2) *Interdependency, autonomy, accountability*. The "cabin…..ready" example is one in which the pilots confirm duties required to be completed by *other* crew members: the flight attendants. The flight attendants' tasks are completed *autonomously* according to their own procedures manual, relayed to pilots in standard language ("cabin ready for takeoff"), and summarized in one single item on the pilots' before takeoff checklist. This *interdependency* is crucial to the efficient and timely completion of flight duties, relying upon proper training, standardization, and teamwork. The federal regulations governing these tasks specifically charge the Captain with ultimate *accountability* for verifying completion[6]. The flow of task completion by the cabin crew, relay of the "ready" message to the cockpit, and

[5] See "Addendum B"

[6] Code of Federal Regulations, FAR Part 91 Sec. 91.519, Passenger briefing:
(a) Before each takeoff the pilot in command of an airplane carrying passengers shall ensure that all passengers have been orally briefed on--
(1) Smoking;
(2) Use of safety belts and shoulder harnesses;
(3) Location and means for opening the passenger entry door and emergency exits;
(4) Location of survival equipment;
(5) Ditching procedures and the use of flotation equipment required under Sec. 91.509 for a flight over water; and
(6) The normal and emergency use of oxygen equipment installed on the airplane.

inclusion of that item in the checklist demonstrates effective and efficient handling of government-mandated duties by a team.

Although these concepts may be unfamiliar within healthcare, our delivery system must be properly re-structured to harness the benefits of a checklist: only through demonstrated reliability can a system relieve highly-accountable workers (i.e.: doctors) of the uneasy sense that “I must do everything myself”, and the unsafe, authoritarian behavior which follows.

3) *Standardization*. Air traffic control (“ATC”) is a fascinating example of an efficient and error-resistant verbal system. It represents perhaps the best, relevant illustration of refinement and standardization of critical communication. ATC’s primary responsibility is to provide in-flight separation of aircraft; their sole method of communication with pilots is via radio using only their voice. The language of ATC is defined by the "pilot-controller glossary", which closely controls vocabulary, sequence, and context of transmissions.

The word "takeoff" is only used in a single allowable situation, within an invariable phrase: "cleared for takeoff". They cannot ever use that word otherwise, nor vary that phrase. You will never hear an air traffic controller utter the word "takeoff" except to notify an aircraft in position to depart: "cleared for takeoff". Here's why:

On March 27, 1977 in Tenerife, Canary Islands, two Boeing 747's (Pan Am and KLM) collided on the runway, killing 583 people: the worst aircraft accident in aviation history. One of the pilots in the KLM 747 cockpit, waiting in position on the runway, transmitted "we are now at takeoff": a vague phrase which to them meant "we are now taking off", but which was so ambiguous that its true meaning was missed by all others on the frequency. Indeed, the KLM jumbo immediately applied full takeoff power, thus beginning their runway roll and initiating an accident sequence which would have 583 passengers dead in the next 30 seconds. If any others on that radio frequency, including the air traffic controllers, the Pan Am pilots, or even the crews of other aircraft, had properly interpreted the meaning of "we are now at takeoff", the accident might have been avoided.

The critical and time-sensitive nature of radio transmissions, along with the unforgiving nature of aviation, will not tolerate ambiguity or delay. Thus, the tight control and standardization of ATC is for a good reason. And the training/enforcement which accompanies these rules is matched with the seriousness of the matter: a single infraction triggers a correction, documented retraining, and possible discipline.

The value of standardization in reducing errors is illustrated above. Are there analogous, if less dramatic, examples in patient-care settings?

> “Are we amputating the right leg?” “Yes, Doctor, the left leg is the right one!”

> Dr. Norman Oshinsky initialed the correct knee “NO”.

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4) *Efficiency*. The obvious value in addressing critical duties with a checklist may prompt the assumption that every possible safety item be

included. Further, the involvement of every worker in the room may seem logical as the ultimate safeguard against errors. But checklists must respect ergonomics and flow as part of their utility. For example, counting sponges, connecting a pulse oximeter, and properly identifying the patient and site of operation are all mandatory tasks during an OR case. But must each item be read aloud to the entire team? These items indeed must be accomplished and checked, but the goal of a good checklist is to maximize effectiveness while eliminating unnecessary steps.

The proper use of checklists will result in minimal verbiage, no interruption of flow, and no involvement of non-essential personnel. Whereas the "time out" has proven to prevent wrong-site surgeries, thoughtlessly expanding the concept to include a disruptive, untimely, and lengthy delivery of a speech by the "circulator" RN, is inefficient, and certainly not a proper checklist.

5) *Teamwork*. The mere assembly of highly-trained individuals does not optimize output. Nor do pep-talks of cooperation and camaraderie. To reap the payoff in morale, quality, and efficiency that unity brings to an organization, the process must be designed so that teamwork follows naturally.

In order to promote teamwork, management must merge all requirements of the "shop floor" into an overarching process-design, within which each worker is specifically trained for his role, understands others' functions, and can depend upon all other components. By sensing the value of what he controls, as well as enjoying the reliability of the remainder, a worker will continuously feel challenged to perform optimally, rather than frustrated by a broken system. The synergy of this component reliability should not be underestimated, nor the destructiveness of its absence be ignored.

The teamwork that follows from a properly-designed system will show measureable output improvement via personal accountability. The consequential pride, satisfaction, reduced turnover, and safety improvements justify a substantial commitment to process enhancement.

6) *Training and enforcement*. The present method of "on-the-job" training is significantly responsible for the poor control of quality in healthcare. A newly-hired nurse, for example, learns the routines of the job from an informal "this is how we do things here" orientation. The result is a loose, variable, continuously-evolving norm; a poorly-defined, uncertain, subjective workplace. Stress and friction, even downright anger among workers are a result of a weak sense of policy and standards.

The roles of hospital workers need to be defined by name, standardized in a manual, and subject to initial and recurrent training. Further, the process needs to be tightly-controlled by monitoring adherence, with consequences for failure to perform to the standard, regardless of patient outcome.

In the airline industry, workers are trained in standard job performance. Whenever feasible, a worker's personal preference is restricted in favor of a standard, even if alternatives may also be reasonably safe and acceptable. In addition to controlling "best practices", this training is important for several other reasons:

a) *Predictable component*. Although limiting individual worker discretion may seem oppressive, the benefits to the whole organization easily substantiate its necessity: standard training is what enables teams to function reliably even if their members vary day-to-day: their performance is *predictable*.

b) *Severity Bias*[7]. Rather than wait for a bad outcome to trigger enforcement, deviation from the trained standard is *itself* a violation. This notion is a vital component of any high-consequence industry to avert *normalization of deviance.* Without tight control of process, a gradual transformation allows increasingly dangerous behavior to become the new "normal": a continuous drift toward unsafe practices.

7) *Safety Culture.* Any attempt to introduce checklists must include an overhaul of the entire healthcare delivery system with the primary mission of establishing a culture of safety. Without a top-down overhaul of focus, the industry will never change.

Cultural Barriers within Healthcare

As an industry, healthcare evolved with its very own methods and traditions responsible for its success at treating disease. And while individual brilliance, steep authority, and disregard of latent hazards are part of the historic charm of medicine, we must further refine our product to deliver safety as part of the package.

"Cookbook" medicine. To be told "how to practice" may be the most objectionable perception of any patient safety initiative, including checklists. Societal admiration, choice of career, longstanding traditions, and current practice all work against any attempt at standardization. That is why the ideal method for combating this resistance is the assertion, from the highest levels of management, that the healthcare delivery process must be refined for patient outcomes and safety, even at the expense of personal preference.

Presumed validity. The reliance on "studies" may at once be medicine's biggest asset *and* handicap: the costs in time, resources, and talent needed to test efficacy according to traditional pathways in healthcare may prevent potentially groundbreaking improvements from ever being seriously considered. But if we observe the obvious similarities, accept the overwhelming proof from other industries, draw the proper analogies, design parallel mechanisms, account for industry differences, and take a leap of faith, we may be doing our patients a world of good.

The answers are there: the studies are already done, and the model highly refined: aviation. We just need to trust that the same human failings are at the core of medical errors: indeed they are. By invoking "presumed validity", we can rapidly establish a new norm for healthcare: *safety first*.

Conclusion

Aviation-style checklists are useful tools for frequent, familiar tasks in high-consequence industries like airlines and healthcare. But their development, placement, and use must be

[7] *Severity bias* is present when the severity of an actual outcome influences how we think about the person involved or how we respond to the person if we have managerial authority. In other words, the level of actual harm determines whether discipline or punishment is used. –K. Scott Griffith

undertaken carefully. If properly instituted, checklists can improve efficiency, morale, and safety, while also saving lives. Conversely, their irresponsible use will lead to skepticism, resistance, waste, and an adverse shift-of-focus away from patient safety.

Unless designed properly, and used within a supportive system, checklists will do little to assure safety. But when introduced within a framework of proper attitudes, training, teamwork, accountability, and enforcement, they are at the core of reducing errors due to limitations of human performance.

Perhaps the ready acceptance of checklists by some is the result of wishful thinking that it could be so simple to improve safety? Maybe the rejection of checklists by others is the result of widespread misuse of the term to describe look-alike devices? Regardless of their popularity, if their purpose is to improve patient safety, checklists must be part of a greater, safety-oriented system, with appropriate organizational culture and standardized training.

A checklist is merely a tool. Within other well-designed, safety-oriented cultures, they have proven to be vital in optimizing human performance. The real question is: can healthcare overcome the profound inertia of the *status quo* to truly harness the power of checklists?

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Addendum A. Condensed (Normal Procedures) Checklist for a passenger jet.
Entire checklist fits on a single, two-sided 8.5 x 11” tri-folded cardboard sheet.

atlantic southeast airlines

CR2
Condensed Checklist
FAA Approved
April 1, 2009

SAFETY

1. Chocks .... Checked
2. Aircraft Documents .... Checked
3. Circuit Breakers .... Checked
4. Emergency Equipment .... Checked
5. Maintenance Status .... Checked
6. NOSE WHEEL STEERING .... OFF
7. CARGO FAN .... OFF
8. HYDRAULIC Pumps .... OFF
9. GEAR Lever .... DOWN
10. SPOILER Lever .... RETRACTED
11. THRUST Levers .... SHUT OFF
12. FLAP Lever .... Set
13. RADAR .... OFF
14. ADG Handle .... Stowed
15. BATTERY MASTER .... ON
16. APU .... As Required
17. AC Electrics .... Established
18. Air Conditioning .... Established
19. HYDRAULIC Pump 3A .... ON
20. PARKING BRAKE .... ON
21. EXTERNAL LIGHTS .... Set
22. Crew O_2 and Masks .... Tested L/R

FAA APPROVED
D.O. Identifier Delta CMO(SO-27)
Effective Date APR 0 1 2009
Billy J. Smith

ORIGINATING (C/R)

1. Interior and Exterior Inspections .... Complete
2. SELECTOR VALVES (if installed) .... Normal L/R
3. Side Panels .... Tested and Set L/R
4. ELECTRICAL Panel .... Checked
5. FIRE DETECTION Panel .... Tested
6. FUEL Panel .... Checked
7. BLEED AIR Panel .... Tested and Set
8. APU Panel .... Checked
9. START Panel .... Checked
10. HYDRAULIC Panel .... Tested and Set
11. ELT .... ARM RESET
12. CABIN PRESS Panel .... Checked
13. AIR CONDITIONING Panel .... Checked
14. ANTI-ICE Panel .... Tested
15. Standby Compass .... Checked
16. Glareshield Panel .... Tested
17. L and R Instrument Panels .... Checked L/R
18. CVR .... Tested
19. EICAS and Standby Instruments .... Checked
20. Upper Pedestal .... Tested
21. Thrust Lever Quadrant .... Checked
22. Avionics .... Tested
23. STAB and MACH TRIM .... Tested/Engaged
24. AVIONICS FAN and COMPASS Panel .... NORM and MAG
25. ENGINE CONTROL Panel .... Checked
26. AILERON and RUDDER TRIM Panel .... Checked
27. YAW DAMPER .... ENGAGE
28. Source Selector Panel .... NORM
29. Lower Pedestal .... Checked

BEFORE START (C/R)

1. FMS and ACARS .... Set/Verified
2. Gear Pins .... Removed (FO)
3. LANDING ELEVATION .... Set
4. ANTI-ICE .... Standard
5. HYDRAULIC .... AUTO and ON
6. EMERGENCY LIGHTS .... ARM
7. PASSENGER SIGNS .... ON
8. Altimeters .... _ _ _ _ Set L and C/R
9. Fuel Quantity .... ____ LBS/Verified
10. ANTI-SKID .... Tested
11. PARKING BRAKE .... ON
12. Radios and Navaids .... Set L/R
13. Crew O_2 and Masks .... Tested L/R
14. Papers .... Aboard
15. Departure Briefing .... Complete
16. APU .... As Required

ENGINE START (D/R)

1. BEACON .... ON
2. FUEL PUMPS and GRAVITY XFLOW .... ON and Checked
3. Exterior DOORS .... Closed
4. Flightdeck Door .... Closed and Locked

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5. PACKS and BLEEDS .... Set for Start
6. IGNITION .... ARM
7. Engine .... Start
8. FUEL Check Valve .... Checked

AFTER START (C/R)

1. GENERATOR(S) .... ON
2. IGNITION .... OFF
3. PACKS .... ON (FO)
4. CARGO AIR .... As Required (FO)
5. ANTI-ICE .... Checked Set (FO)
6. FUEL PUMPS .... As Required (FO)
7. TRANSPONDER .... As Required (FO)
8. APR .... Tested ARM
9. ELECTRICAL .... Checked
10. Rudder .... Checked
11. NOSE WHEEL STEERING .... ARMED

Addendum A. (cont'd)

TAXI START

1. FUEL PUMPS .... ON
2. PACKS and BLEEDS .... Set for Start
3. IGNITION .... ARM
4. Engine .... Start

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5. GENERATOR .... ON
6. IGNITION .... OFF
7. PACKS .... ON
8. ANTI-ICE .... Set
9. ELECTRICAL .... Checked

BEFORE TAKEOFF (C/R)

1. FLAPS .... __° Indicating/Verified
2. Flight Controls .... Checked (FO)
3. TRIMS .... Three Set/Verified
4. THRUST REVERSERS .... ARMED
5. Flight Instruments and Speed Bugs .... Checked/Verified
6. BRAKE TEMP .... Checked
7. FMS .... Runway __Set,__/Verified
8. RADAR .... ON (FO)
9. Takeoff Briefing .... Complete (FO)
10. Cabin .... Ready (FO)

TAKEOFF (D/R)

1. FUEL XFLOW .... MANUAL
2. ANTI-ICE .... As Required
3. APU and BLEEDS .... As Required
4. IGNITION .... As Required
5. TRANSPONDER .... ON
6. Altimeters .... Checked
7. CAS .... Checked and Cleared
8. FUEL .... Checked

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9. EXTERNAL LIGHTS .... ON

FAA APPROVED
D.O. Identifier Delta CMO (SO-27)
Effective Date APR 0 1 2009
Billy J. Smith [signature]

AFTER TAKEOFF

1. GEAR .... UP
2. FLAPS .... Up
3. FUEL XFLOW .... AUTO
4. BLEEDS .... Set
5. APU .... As Required
6. Climb Power .... Set
7. THRUST REVERSERS .... OFF
8. CAS .... Checked and Cleared

CLIMB (D/R)

1. SEAT BELT SIGN .... As Required
2. Altimeters .... _ _ _ _ Set L and C/R
3. EXTERNAL LIGHTS .... Set

DESCENT AND APPROACH (C/R)

1. Landing Data .... Set
2. Approach Briefing .... Complete
3. SEAT BELT SIGN .... ON
4. LANDING ELEVATION .... Checked
5. FUEL .... Checked
6. CAS .... Checked and Cleared
7. Altimeters .... _ _ _ _ Set L and C/R
8. EXTERNAL LIGHTS .... Set

(D/R)

9. APU and BLEEDS .... Set
10. Flight Attendant .... Notified

LANDING (D/R)

1. GEAR .... DOWN/Verified
2. THRUST REVERSERS .... ARMED
3. EXTERNAL LIGHTS .... Set
4. CAS .... Checked and Cleared

(D/R)

5. FLAPS .... __° Indicating

AFTER LANDING

1. EXTERNAL LIGHTS .... Set
2. IGNITION .... OFF
3. ANTI-ICE .... Set
4. FLAPS .... UP
5. RADAR .... OFF
6. TRANSPONDER .... As Required

TAXI SHUTDOWN

1. GENERATOR .... OFF
2. THRUST Lever .... SHUT OFF
3. FUEL PUMPS .... OFF

SHUTDOWN (C/R)

1. PARKING BRAKE .... ON
2. SEAT BELT SIGN .... OFF
3. ANTI-ICE .... OFF
4. APU/Ground Power .... As Required
5. ELECTRICAL .... SET
6. [1] FUEL Check Valve .... Checked
7. THRUST Levers .... SHUT OFF
8. FUEL PUMPS .... OFF
9. HYDRAULICS .... Checked/OFF
10. BEACON .... OFF
11. NOSE WHEEL STEERING .... OFF
12. TRANSPONDER .... STBY
13. CVR Circuit Breaker .... As Required

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14. PACKS and BLEEDS .... OFF
15. CARGO AIR .... OFF
16. EMERGENCY LIGHTS .... OFF
17. Standby Attitude Indicator .... Caged
18. APU GENERATOR .... OFF
19. APU .... OFF
20. EXTERNAL LIGHTS .... OFF
21. DC SERVICE .... OFF
22. BATTERY MASTER .... OFF
23. Internal Lights .... OFF

A post-flight inspection shall be accomplished prior to leaving the aircraft.

Addendum B. Quick Reference Handbook (QRH) for a typical passenger jet.
Unlikely event: engine failure. Note the density of information *and* flow-diagram design.

ATLANTIC SOUTHEAST AIRLINES — REGIONAL JET SERIES 200

ABNORM 1-2
REV 26 03/21/2008

Single Engine Procedures

In-Flight Engine Shutdown:

Accomplish an engine shutdown only when flight conditions permit.

(1) Affected thrust lever......CONFIRM & IDLE
(2) Affected thrust lever......CONFIRM & SHUTOFF
(3) 14TH STAGE ISOL......SELECT OPEN

NOTE
The OPEN light will not illuminate unless Wing Anti-Ice is selected ON.

Shutdown due to a hydraulic system high temperature condition:

Yes

(4) Proceed to step (5). Disregard HYD 1 (2) LO PRESS caution message.

No

(4) Affected HYDRAULIC B pump:
- Left engine shut down......1B ON
- Right engine shut down......2B ON

(5) Affected BOOST PUMP......CONFIRM & OFF
(6) Affected COWL ANTI-ICE......OFF
(7) APU (if available, 30,000 feet and below)......START
(8) APU GEN......ON
(9) Fuel system......CHECK
- Crossflow......AUTO
- Quantity/Balance......CHECK

NOTE
1. Leave icing conditions to prevent ice accumulation on inoperative engine cowl.
2. Powered crossflow may not be able to correct fuel imbalance during single engine operations.
3. Do not attempt to relight an engine that is suspected to be damaged (engine fire, rotor burst, reverser deployed, etc.).

▼

QUICK REFERENCE HANDBOOK | POWER PLANT MALFUNCTIONS

ATLANTIC SOUTHEAST AIRLINES — REGIONAL JET SERIES 200

ABNORM 1-3
REV 15 05/15/2005

Single Engine Procedures (Cont'd)

In-Flight Engine Shutdown (Cont'd):

Engine damage is suspected / intentional shutdown:

Yes

(10) Land at nearest suitable airport.
(11) Single Engine Approach & Landing (See ABNORM 1-8)......ACCOMPLISH

- END -

No

(10) Descent......INITIATE to 21,000 feet or below.
(11) Appropriate Engine Relight Procedure......ACCOMPLISH
- Starter-Assisted / Cross Bleed Relight (See ABNORM 1-4)
- Windmilling Relight (See ABNORM 1-6)

Relight engine using starter-assisted crossbleed whenever possible.

▼

QUICK REFERENCE HANDBOOK | POWER PLANT MALFUNCTIONS

ATLANTIC SOUTHEAST AIRLINES — REGIONAL JET SERIES 200

ABNORM 1-4
REV 31 03/15/2009

Single Engine Procedures (Cont'd)

Starter Assisted / Cross Bleed Relight:

(1) Relight envelope (See table below)......REVIEW

Starter-assisted / Cross Bleed Relight Envelope

ALTITUDE	AIRSPEED	ITT	% N_2
21,000 ft to 15,000 ft	160 KIAS to V_{MO}	90°C or less	28 to 55
15,000 ft to SL	V_{REF} to V_{MO}		

(2) Affected GEN......CONFIRM & OFF
(3) FUEL BOOST PUMPs......BOTH ON

Packs on engine bleeds:

Yes

(4) Operative 10TH STAGE BLEED......CONFIRM OPEN
(5) Affected PACK......OFF
(6) ECS Duct pressure......NOT LESS THAN 60 psi
- Increase operating engine's N_2 as required. Do not reduce thrust until relight procedure is complete.

When ready to start:
(7) CONT IGNITION......ON
(8) Affected ENG START......PRESS and hold until N_2 is increasing.

When ITT is below 90°C and N_2 reaches at least 28%.
(9) Affected thrust lever......IDLE
(10) Engine indications......MONITOR

Engine relights (within 25 seconds) and stabilizes at IDLE:

Yes

(11) Thrust levers......AS REQUIRED
(12) 14TH STAGE ISOL......SELECT CLOSED
(13) Affected PACK......SELECT ON
(14) Affected GEN......ON
(15) CONT IGNITION......OFF
(16) WING & COWL ANTI-ICE......AS REQUIRED
(17) Affected HYDRAULIC B pump......AUTO
(18) APU......AS REQUIRED

- END -

No

(11) Affected thrust lever......CONFIRM & SHUT OFF
(12) Affected ENG STOP......PRESS
(13) Wait 30 seconds, then repeat relight procedure, if desired.

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ATLANTIC SOUTHEAST AIRLINES — REGIONAL JET SERIES 200

ABNORM 1-5
REV 31 03/15/2009

Single Engine Procedures (Cont'd)

Starter Assisted / Cross Bleed Relight (Cont'd):

Packs on engine bleeds (Cont'd):

No (Cont'd)

Engine relight still unsuccessful:
(14) CONT IGNITION......OFF
(15) Land at nearest suitable airport
(16) Single Engine Approach & Landing (See Page ABNORM 1-8)......ACCOMPLISH

- END -

No

Packs on APU bleed:
(4) 10TH STAGE ISOL......SELECT CLOSED
(5) APU LCV......SELECT CLOSED
(6) Operative 10TH STAGE BLEED......SELECT OPEN
(7) Affected PACK......OFF
(8) ECS Duct pressure......NOT LESS THAN 60 psi
- Increase operating engine's N_2 as required. Do not reduce thrust until relight procedure is complete.

When ready to start:
(9) CONT IGNITION......ON
(10) Affected ENG START......PRESS and hold until N_2 is increasing.

When ITT is below 90°C and N_2 reaches at least 28%.
(11) Affected thrust lever......IDLE
(12) Engine indications......MONITOR

Engine relights (within 25 seconds) and stabilizes at IDLE:

Yes

(13) Affected thrust lever......AS REQUIRED
(14) 14TH STAGE ISOL......SELECT CLOSED
(15) L and R 10TH STAGE BLEED......CLOSED
(16) APU LCV......OPEN
(17) 10TH STAGE ISOL......OPEN
(18) Affected PACK......SELECT ON
(19) Affected GEN......ON
(20) CONT IGNITION......OFF
(21) WING & COWL ANTI-ICE......AS REQUIRED
(22) Affected HYDRAULIC B pump......AUTO

- END -

No

(13) Affected thrust lever......CONFIRM & SHUT OFF
(14) Affected ENG STOP......PRESS
(15) Wait 30 seconds, then repeat relight procedure, if desired.

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QUICK REFERENCE HANDBOOK | POWER PLANT MALFUNCTIONS

ATLANTIC SOUTHEAST AIRLINES REGIONAL Jet SERIES 200	ABNORM 1-6
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Single Engine Procedures (Cont'd)

Engine relight still unsuccessful:

(16) CONT IGNITION .... SELECT OFF
(17) L & R 10TH STAGE BLEED .... CLOSED
(18) APU LCV .... OPEN
(19) L & R 10TH STAGE ISOL .... OPEN
(20) L & R PACKs .... AS REQUIRED

NOTE

1. Use only one air-conditioning pack during single engine operations, when the operating engine is the only 10^{TH} stage bleed source.
2. Airplane altitude maximum 25,000 feet during single pack operations.

(21) Land at nearest suitable airport.
(22) Single Engine Approach & Landing
(See Page ABNORM 1-8) .... ACCOMPLISH

- - - - - - - - - - END - - - - - - - - - -

Windmilling Relight:

(1) Relight envelope (See table below) .... REVIEW

Windmill Relight Envelope	
ALTITUDE	AIRSPEED
21,000 ft to 15,000 ft	300 KIAS to V_{MO} / M_{MO}
15,000 ft to SL	

NOTE

1. Windmill airstart efficiency is enhanced by attaining the highest practical airspeed and N_2 within the relight envelope.
2. If windmill speeds of 9% N_2 and 12% N_2, at below 15,000 feet and above 15,000 feet respectively, are not achieved, an approximately 1.5% to 2.5% increase in N_2 may be obtained by disconnecting the corresponding IDG using the IDG DISC. (Once a disconnect has been performed however, the IDG cannot be re-connected in flight).

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QUICK REFERENCE HANDBOOK	POWER PLANT MALFUNCTIONS

ATLANTIC SOUTHEAST AIRLINES REGIONAL Jet SERIES 200	ABNORM 1-8
	REV 29 09/01/2008

Single Engine Procedures (Cont'd)

Single Engine Approach and Landing:

(1) APU (if available, below 30,000 feet) .... START

NOTE

1. Use only one air-conditioning pack during single engine operations, when the operating engine is the only 10^{TH} stage bleed source.
2. Airplane altitude maximum 25,000 feet during single pack operations.

(2) APU GEN .... ON

Below 15,000 feet:

(3) L and R PACKs .... TRANSFER to APU bleed.
(4) Go-around thrust reference .... SET N_1 bug accordingly.
(Refer to GO AROUND THRUST SETTINGS, PERF-04.)
(5) GRND PROX, FLAP .... OVRD

Approach and Landing:

(6) FLAPS .... 20°
(7) Approach speed .... Not less than $V_{REF\ (FLAPS\ 20)}$ + Factor
(8) Actual landing distance is increased by a factor of:

With or without the use of Reverse Thrust
1.25 (25%)

CAUTION

If required, use remaining thrust reverser carefully upon landing.

NOTE

1. If Ground Lift Dumping fails to deploy upon touchdown, select the flight spoilers lever to MAX deployment.
2. Category II operations are prohibited with this failure.

- - - - - - - - - - END - - - - - - - - - -

L (R) REV UNLOCKED Msg

L (R) UNLOCKED Msg (refer to EMER 1-12).

- - - - - - - - - - END - - - - - - - - - -

QUICK REFERENCE HANDBOOK	POWER PLANT MALFUNCTIONS

ATLANTIC SOUTHEAST AIRLINES REGIONAL Jet SERIES 200	ABNORM 1-7
	REV 31 03/15/2009

Single Engine Procedures (Cont'd)

Windmilling Relight (Cont'd):

(2) Affected GEN .... CONFIRM & OFF
(3) Affected PACK .... OFF
(4) FUEL, BOOST PUMPs .... BOTH ON

When ready to start: ◄

(5) CONT IGNITION .... ON
(6) Airspeed .... INCREASE TO 300 KIAS or greater.

NOTE

Maintain airspeed throughout light-off until engine start is complete (stable idle). Monitor engine parameters carefully.

When relight envelope is established:

(7) Affected thrust lever .... IDLE

NOTE

N_2 acceleration should be positive and uninterrupted. Stable idle speed must be reached within 2 minutes.

Engine relights (within 25 seconds) and stabilizes at IDLE:

Yes

(8) Thrust levers .... AS REQUIRED
(9) Airspeed .... NOT MORE THAN 250 KIAS if the ADG is deployed.
(10) 14TH STAGE ISOL .... SELECT CLOSED
(11) Affected GEN .... ON
(12) Affected PACK .... SELECT ON
(13) CONT IGNITION .... SELECT OFF
(14) WING & COWL ANTI-ICE .... AS REQUIRED
(15) Affected HYDRAULIC B pump .... AUTO

- END -

No

(8) Affected thrust lever .... CONFIRM & SHUTOFF
(9) Affected ENG STOP .... PRESS
(10) Wait 30 seconds, then repeat relight procedure, if desired. →

Engine relight still unsuccessful:

(11) CONT IGNITION .... SELECT OFF
(12) Land at nearest suitable airport.
(13) Single Engine Approach & Landing
(See Page ABNORM 1-8) .... ACCOMPLISH

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QUICK REFERENCE HANDBOOK	POWER PLANT MALFUNCTIONS