Immediate Action!

There are things you need to **memorize after all**

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How often are you required to do something so quickly in your cockpit that you have no time to read your checklist, consult the crew or think? During my years as a U.S. Air Force pilot, I was fed a steady dose of what we called "bold-print" items in our checklists that had to be committed to memory.

In the civilian airplanes I've flown since, I've seen the "bold print" turned into "bold-faced" items, "boxed" items, "bracketed" items, "Phase 1" items, and even no immediate action items at all. The industry trend seems to be moving away from memorization items or at least reducing their number. But accident case studies tell us we need something to steer us in the right direction when things happen fast on the flight deck.

In 1979, as a student Air Force pilot I flew the sleek Northrop T-38 Talon. I can still remember the routine every morning. An instructor would survey the room, looking for an unsuspecting "stud" (we were not allowed to call ourselves students).

And then he'd pounce: "Lieutenant Albright, right after reaching decision speed on takeoff, you get a left engine fire light with all the indications you would expect. Tower says you are trailing flames and smoke. What will you do?"

At this point I was expected to stand at attention and rattle off the bold-print items, verbatim, assertively and without hesitation. "Sir, throttles: max. Flaps: 60%. External store: Jettison if necessary. Attain airspeed above SETOS, 10 kt. desired."

Had I missed any word, gotten any of them out of order, or even misused the SETOS (single-engine takeoff speed) acronym, I would be taken off the flight schedule for additional ground training. This ritual was called "stand-up" because we were expected to stand up, at attention, in front of our squadron mates and be put on the spot for some artificial stress.

We were quizzed daily on the memory items in both written and oral form. Failing the quiz was noted on our records, so we took it all very seriously. But the stand-up ritual paid dividends. During my last cross country T-38 sortie of the program, I got that fire light right at decision speed while taking off from Naval Air Station Point Mugu, near Ventura, California. I executed the bold print automatically. The fire light, fortunately, extinguished.

Old School vs. New School

That was the Air Force way back then: Know your bold-print immediate actions cold, become automatic in an emergency, and never have to face a moment of panic in a cockpit while strapped into an ejection seat. Then along came the F-15 Eagle, with no bold-print items at all. With its arrival, there began the memory items versus no memory items debate, something we civilians wrestle with as well.

In the early days of passenger-carrying jets, most manufacturers seemed to have agreed with the military: Flying a high-speed jet is risky business and pilots needed to have ice water in their veins. Back then, memory items were

Student and instructor approaching their Northrop T-38 Talon

U.S. AIR FORCE

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F-15 taking off from Lakenheath Air Base, England

de rigueur in any jet cockpit, with or without an ejection seat. But sampling a variety of current business and commercial aviation jets reveals an assortment of philosophies.

Dassault, for example, prescribes three phases of actions in emergency procedures. A "Phase 1" procedure "specifies immediate action to be accomplished from memory, without need for reference to the checklist." Bombardier, as a second example, says procedures "concerned with foreseeable but unusual situations in which immediate and precise crew action, as indicated by the items within the 'boxed' area at the beginning of each procedure, will substantially reduce the risk of disaster."

Most manufacturers seem to favor memory items denoted by a box, brackets or other typographical methods. In some cases, the memory items are concise steps and easily remembered. In many cases, however, the memory items include decision points and alternate procedures. The memorization process becomes complicated. Individual operators may also add or subtract from the hodgepodge of memory items.

There is another philosophy, which appears to be inspired by the F-15 example, wherein pilots are expected to analyze every situation and come up with the correct actions in a timely manner. Gulfstream seems to favor this philosophy in its newer models. You won't find any mention of memory items in its Airplane Flight Manuals (AFMs), a fact noted by the FAA in the Flight Standardization Board Report for the Gulfstream GIV-X (G350/G450), GV, GV-SP (G500/G550): "There are no memory items in the AFM for the GIV-X, GV or the GV-SP."

So, which philosophy is best? Is there one? Let's look at two engine shutdown examples to see just how badly things can get when the immediate actions are executed incorrectly. The Aviation Safety Network lists 17 incidents in which pilots of airline, military transport or business aircraft shut down the wrong engine in response to an engine indication, usually resulting in the loss of the aircraft and quite often a loss of life.

Stressed Errors

The most-notable recent example occurred to a TransAsia Airways ATR 72 aircraft departing Taipei Songshan Airport (RCSS), Taiwan on Feb. 4, 2015. The accident was made infamous because it was captured on video by an automobile dashboard camera. The public was alarmed that a professional aircrew could shut down the wrong engine, destroying the aircraft and killing 43 of the 58 persons on board.

The airline's SOPs for "Eng 1(2) Flameout at Takeoff" in the ATR 72-212A includes 22 lines of procedures but fails to remind the pilot to identify the failed engine. The aircraft's Engine Warning Display, however, provides excellent cues for identifying which engine has failed as well as presenting the checklist procedure.

A faulty solder joint between a torque sensor and an auto-feather system caused the No. 2 engine to automatically feather. The autopilot automatically and correctly applied corrective control inputs, but the pilot flying (PF) disconnected the autopilot and retarded the No. 1 power lever. The pilot monitoring (PM) called out the correct throttle and momentarily questioned the PF's initial actions but did not follow through. The crew shut down the incorrect engine before realizing the error, and the PF failed to keep the aircraft from stalling and rolling into a knife-edge.

The PF was noted for being a nervous pilot and had a track record of failing to properly execute emergency procedures. It is unclear if he had the correct procedures memorized, only that he failed to correctly execute them. This was a case where failed simulator checkride results could have predicted actual aircraft performance. However, there are many cases in which a pilot's simulator performance was completely satisfactory, but under stress in-flight, actual cockpit performance fell tragically short. Simulated emergency procedures can produce real stress, but this is often tempered by the realization there is no real danger to life or property. When faced with the real stress of an actual aircraft emergency, aircrews can panic and fail to adhere to standard operating procedures.

In 1989, a British Midland Airways Boeing 737 crew was faced with a left-engine compressor stall during an approach to East Midlands Airport (EGNX), United Kingdom, which caused the aircraft to vibrate and introduced the smell of fire through the air-conditioning system. The "Engine Fire, Severe Damage or Separation" procedure required initial actions be made from memory, without reference to a checklist.

TAIWAN AVIATION OCCURRENCE REPORT

ATR 72 Simulated Engine Warning Display indications

BRITISH ACCIDENT REPORT PHOTO

Crash site of Brirtish Midlands Airways Flight 092

The Operations Manual included another reference to vibration in the nonnormal procedures that warned: "If the emergency is positively corrected, the captain should evaluate the situation before proceeding with the next step. If any doubt exists as to the condition of the engine or fire warning system, complete all recall items." The recall items for the Engine Fire, Severe Damage or Separation procedure simply state:

(1) Thrust lever . . . RETARD.

(2) Flight conditions permitting . . . Reduce N1 to maintain AVM (airborne vibration monitor) below 4.0 units.

But the crew was unfamiliar with engine behavior during the initial moments of a compressor stall and was uncertain about which engine had failed. The PF failed to keep the aircraft in coordinated flight, robbing him of a clue that the right engine was still producing thrust. Because his previous aircraft experience led him to believe air-conditioning smoke could only be produced by the right engine, he shut down the right engine. While the situation was outside his training experience, the perceived need to react instantly to the situation led to his hasty decision to shut down the only operating engine. The aircraft impacted just short of the runway, killing 47 of the 134 people on board.

In both examples the perceived need to act quickly led to the shutdown of an operating engine. The ATR's memory items were long, complicated and easily forgotten during the stress of seeing an engine auto-feather. The Boeing's memory items were short and succinct but didn't mention the need to be certain of which engine was to be shut down. So, just because you have a memory item it doesn't ensure success during the stress of an actual aircraft emergency.

Getting It Right: Forcing Analysis

In both the previous examples, and indeed in most wrong engine shutdown episodes, we see that rushed and incorrect actions by the crew contributed to the tragedy. Although manuals might stress the importance of analyzing the situation and confirming actions, that doesn't always happen. It seems that in each of these incidents, that analysis was either skipped or carried out too hastily. Clearly, pilots need to be reminded.

The TransAsia Airways Flight Crew Operations Manual, for example, lists the four steps for effective decision making with the SAFE mnemonic:

S — State the problem.
A — Analyze the options.
F — Fix the problem.
E — Evaluate the result.

Many immediate action memory items skip the first two SAFE steps and either assume the pilot has done this first, or combine these steps into the "Fix the problem" step. In the case of an engine shutdown, for example, rather than say "Identify failed engine, throttle idle, fuel switch off," the procedure might say "affected throttle idle, affected fuel switch off." Both methods work, but the former forces the pilot to think about which throttle while the latter assumes the pilot's hands will make the correct selection. Don't we practice these decisions enough in the simulator to train these hasty snap judgments out of the pilot? Apparently not.

A Boeing study of a sampling of airline pilots revealed that an inflight emergency requiring timely action imposes a great deal of stress on a flight crew. Previous studies have shown that recall under high-stress conditions is more prone to errors than recall under low-stress conditions. These errors, as they relate to checklist use, may include errors in identifying the abnormal condition and selecting the correct checklist, and errors of commission (adding steps or performing steps incorrectly), omission (missing steps) or order (completing steps in the wrong sequence).

The study notes that even though pilots receive regular training in emergency procedures in simulators, that does not mean they are unaffected by the stress of an actual emergency. As already noted, an emergency in a simulator is not perceived as life threatening. If the pilot fails, the simulator can be reset for another attempt. As the study concludes, "Unless a pilot has had repeated experience in dealing with a truly dangerous emergency, performance in a real emergency could be similar to a novice."

It has been shown that people are able to inhibit fear and prevent it from affecting their performance only if they are repeatedly exposed to a dangerous situation. Due to the reliability of today's commercial aircraft, it is unlikely for the average professional pilot to have had that kind of exposure in an airplane.

The perceived requirement to perform checklist steps quickly from memory during high-stress situations is at odds with the need to perform those checklist steps accurately. There is a potential for loss of accuracy as the performance speed increases. However, attempting 100% accuracy can require so much time to complete a checklist that other flying tasks would be disrupted. Clearly there is a tradeoff between getting the procedure done quickly, and getting it done while minimizing the possibility of error.

A similar unfamiliarity with these kinds of stresses is experienced by all novice pilots, even those flying jets with hardly any experience of any kind. I had a total of 25 flight hours in my logbook when I first flew the Cessna T-37B. The Air Force forced me to learn the emergency procedures with a steady dose of memory drills. I believe this will work in the civilian world, too.

The Value of Memory Drills

How do you get a lieutenant with barely enough hours to solo a primary trainer (Cessna 152) to fearlessly fly a fully aerobatic jet (Cessna T-37B)? You have to train the fear out of the young student pilot so that any emergency procedure does truly become automatic. The Air Force did that with memory drills.

Cessna designed the T-37B "Tweet" to spin. It could not only be easily flown into a spin, it could sustain the spin all the way to the ground unless you

Cessna T-37B

accurately applied the recovery procedures. A stabilized T-37 spin was normally characterized by a constant pitch attitude (approximately 40- to 45-deg. nose low), a constant rate of rotation and steady airspeed. The altitude loss was approximately 550 ft. per turn and the duration of one turn is approximately 3 sec.

So, spinning a Tweet can be a stomach-churning maneuver sure to stir up any fear of flying; the recovery was made even more difficult because it was long and involved. The procedure, all 43 words and six lines, had to be committed to memory:

(1) Throttles — Idle.
(2) Rudder and ailerons — Neutral.
(3) Stick — Abruptly full aft and hold.
(4) Rudder — Abruptly apply full rudder opposite spin direction (opposite turn needle) and hold.
(5) Stick — Abruptly full forward one turn after applying rudder.
(6) Controls — Neutral after spinning stops and recover from dive.

Missing a single step could prevent recovery, but missing a single word during the pre-brief could keep you from flying. The task of committing the procedure to memory appeared near impossible to us student pilots on Day One. But we learned a few secrets along the way that made it easier.

How to Memorize, Verbatim

First, you need to handwrite the procedure over and over again. Your hands are connected to your brain in many ways, and the physical act of writing helps cement the words into your memory. You don't even have to write legibly nor ever read what you write.

My first instructor recommended that I write the spin entry and recovery procedures down at every spare moment until I got them 100% correct. And then he recommended that I keep doing that at least a few times each day. You couldn't solo until you had the procedures down cold and you couldn't get your wings unless you could fly the maneuver flawlessly.

Once you've memorized your immediate action items you need to keep them memorized. In one of my squadrons we were required to incorporate each of our five bold-print action items into the pre-takeoff briefing. After a while the immediate actions became ingrained and when we had to do them for real, they came to us naturally.

Of course, many of today's aircraft have immediate action memory items that are too long and complicated to memorize. We've also seen that few checklists include the analysis step up front, where it's needed. Perhaps we can fix both problems.

How to Improve Memory Items

A 2013 European Aviation Safety Agency (EASA) study notes the problem with emergency procedure memory items: They must be performed immediately and without reference to any checklist, but limitations of human memory mean accuracy can suffer. The study recommends that memory items should normally be at the start of a checklist, should be clearly indicated (e.g. by color shading, or by "boxing"), and should be kept to a minimum (preferably fewer than four and certainly no more than six for multi-crew operations).

The study also criticizes checklist memory items that have the crew implement steps without first allowing for an analysis of the issue since that can lead to the selection of the wrong checklist, or can draw the crew's focus away from additional inputs as the situation unfolds.

Memory items for an engine fire will typically either omit any verification step to ensure the correct engine is identified or will combine the verification step into the action steps. The Citation X AFM "Engine Fire (ENG FIRE LIGHT AND ENGINE FIRE L-R CAS MESSAGE)" procedure, for example, includes verification in the first step:

(1) Throttle (affected engine) — IDLE.
(2) IF ENG FIRE LIGHT REMAINS ON (15 SECONDS) PROBABLE FIRE.
(3) ENG FIRE switch — CONFIRM, then LIFT COVER and PUSH.

Cessna 750 Citation X, Moscow

(4) Either illuminated BOTTLE ARMED light — PUSH (bottle armed light goes off).

The procedure then continues with several steps that are completed with reference to the checklist. The problem with making the first memory item an action step is that it may push the pilot into making a hasty decision on which is the "affected engine." It may be better to insert a separate verification step. Once that is done, there is still the assumption the pilot remembered to time the fire light. The remaining steps can be simplified to make memorization easier:

(1) Affected engine — Identify.
(2) Affected throttle — IDLE.
(3) Time — 15 seconds.
(4) If light remains on, affected ENG FIRE switch — PUSH.

(5) Either BOTTLE ARMED light — PUSH.

(6) Refer to checklist.

Even with the added verification step, we've reduced the number of words to memorize from 34 to 26.

The Gulfstream G450 often requires oceanic driftdown procedures be initiated immediately.

Adding Missing Memory Items

You may argue that your AFM contains too many memory items and that may

PARFAITS

be true; that is a discussion you need to have with the manufacturer. Yet what about those items that need to be completed immediately but do not have an associated AFM memory item? You can write your own. Your list will be unique to your aircraft and operation, and there is no better example of this need for tailored memory items than the need for oceanic driftdown procedures.

Such procedures are designed to get a multiengine aircraft from high altitudes to lower altitudes following an engine failure with a minimal loss of altitude while maximizing forward distance traveled. Picture an airplane between California and Hawaii at or near its optimal long-range altitude. If an engine were to fail, the aircraft would no longer be able to maintain altitude and the crew will need to find a suitable airport to land as soon as possible. Ideally the aircraft will end up at the optimal engine-out altitude after traveling as far as possible during the descent.

Does this procedure need to be done immediately, hence requiring memorization, or will the crew have time to pull out the checklist, consider options and notify the oceanic control area's air traffic control first? That depends. Most large-cabin Gulfstream pilots would do well to memorize the following:

(1) Identify failed engine.

(2) Set operating engine maximum continuous thrust.

(3) Turn to avoid tracks or toward alternate.

(4) Begin a 300-600 fpm descent.

(5) Look up driftdown speed and altitude.

In the Gulfstream G450, that all happens instantaneously because normal cruise speeds are very close to driftdown speeds at most weights and altitudes. Any delays in crew action will reduce the forward distance the aircraft will cover on its way to a lower altitude. But this need to act quickly after an engine failure at altitude isn't true for most aircraft.

A Bombardier Challenger 605, for example, drifts down at a much slower speed than that at which it cruises and will have almost 2 min. before having to descend. In this airplane, I would simply remember to set max continuous thrust on the operating engine and know exactly where to find the appropriate checklist.

A Falcon 900 has an even longer delay, over 15 min. in some scenarios, because the loss of one engine on a three-engine aircraft is less detrimental than losing one engine on a two-engine aircraft.

Lessons Learned

You can get impassioned defenses for and against having to memorize immediate action items. Those "for" argue you are apt to get it wrong in the heat of battle unless you have it memorized.

Those "against" say not every situation is the same and you get paid the big bucks for making the tough calls. I think I've had a higher than average number of things go wrong in an airplane and perhaps developed a higher tolerance to stress. But I can see myself making mistakes when things move over into the abnormal category. So, I vote for memory items to stack the odds in my favor.

I remember when I first heard the F-15 Eagle had zero memory items and its pilots were expected to think every problem through before acting. I had just earned my Air Force pilot's wings and with the wisdom that 182 hr. of jet time instilled in me, I came to the conclusion that McDonnell Douglas, the airplane's manufacturer, was nuts.

Over the years I've grown to appreciate the wisdom of thinking before acting, even when traveling supersonic. But, as it turns out, even Eagle drivers have their own list of informal memory items. My favorite was for engine failure during takeoff. It had one step:

(1) Climb to safe a altitude and then investigate.

While there are aircraft without published memory items, I am not aware of any aircraft that provides its pilots the luxury of referencing a checklist for every imaginable situation. It's true that these days few airplanes require us to dive into our emergency procedures more than a few times in a career.

But no matter how many procedures must be done immediately without the aid of a checklist, you should have each memorized. That way you will still have enough control of the situation to pull up the checklist when time permits. **BCA**