***NOT* FLYING BY THE BOOK: SLOW ADOPTION OF CHECKLISTS AND PROCEDURES IN WW2 AVIATION**

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ABSTRACT

In the late 1930s, military aviators in the American Army and Navy began using aviation checklists. Checklist became part of a new paradigm for how to fly, which consisted of

- Elaborate standardized procedures for many activities,
- Checklists to ensure all critical steps had been done, and
- Quantitative tables and formulas that specified the best settings, under different conditions, for speed, engine RPM, gasoline/air mixture, engine cooling, and many other parameters.

This new paradigm, which I call *Standard Procedure Flying*, had a major influence on reducing aviation accidents and increasing military effectiveness during World War II, particularly because of the rapidly increasing complexity of military aircraft, and the huge number of new pilots.

Despite the benefits of Standard Procedure Flying for both safety and efficiency, by the end of WW2 only a few air forces had fully embraced it. This paper describes the highly varied adoption patterns of different forces:

American Army Air Force (AAF) fighter pilots

American AAF strategic bombers, in both Europe and Asia

American Naval aviation

British Royal Air Force

German Luftwaffe

American Army helicopters in Vietnam (briefly)

Some of the delays in adoption were due to pilots' desire for autonomy and their

dislike of military discipline. Experienced pilots generally preferred to use their own craft skills and decision making. Also, different flying styles were better for different military missions, such as fighters versus bombers. But when properly implemented, Standard Procedure Flying is unambiguously superior to the older methods. Today, all large military and civilian aviation organizations use it.

Slow adoption during WW2 cost many lives. Worst of all was probably the German Luftwaffe, whose new pilots suffered accidents far above 100 percent per year, partly as a result of its antiquated flying paradigm. The British Royal Air Force and the US Navy were also slow to make full use of the new technology.

Keywords: Military aviation, aviation safety, World War II, WW2, flying technique, quantitative flying, flight discipline, B-17, B-29, Luftwaffe, NATOPS, jet conversion, strategic bombing, flight training, USAAF, aviation culture, Battle of Midway, 8th Air Force;

craft versus science, art to science, technology diffusion, technology adoption, checklists, standard procedures.

***Not* Flying by the Book:**

Slow Adoption of Checklists and Procedures in Military Aviation

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A better way to fly?

Slow Adoption of checklists and procedures in WW2 Aviation

Roger E. Bohn

I. Introduction[1]

Over the course of a few years near the start of World War 2, American military aviators invented a new and better way to fly. The new paradigm was markedly superior to old methods. It was especially useful for inexperienced pilots in complex aircraft, which described most fliers early in the war. By the middle of the war (1943) the new paradigm was embedded in training material used by hundreds of thousands of new American aviators. And yet, of the many air forces that were locked in vicious combat until the war ended in 1945, only a few fully embraced it. The British paid it lip service but barely used it. The German air force ignored it completely. And it was not until the mid 1960s that it was fully implemented in the United States Navy, which had co-invented it decades earlier. Why did rational men, fighting to stay alive, ignore and even actively reject this life-saving new technology?[2]

The new technology was *Standard Procedure Flying* (SPF). SPF replaced two earlier paradigms for flying: *Heroic Craft Flying* (World War 1 until 1930), and *Rules + Instruments Flying* (beginning about 1929). The full story of these three paradigms, and two more that came later, is told in a book (*Daredevils to System Operators: How the Art of Flying Became (Mostly) a Science,* manuscript*)*. This working paper expands on a chapter of that book.

Standard Procedure Flying was adopted worldwide by 1970, and it continues to be used and to evolve today. In the 21st century it is rightly held up as a model for some aspects of health care, but implementation is controversial and uneven. The adoption issues that militaries encountered in the 1940s and 50s are recurring today in health care.

Standard Procedure Flying has three coordinated parts.

- Standard procedures – tightly defined sequences of activities.
- Checklists – lists of safety-critical actions to be double-checked before dangerous parts of each flight.
- Quantitative control – Tables and formulas that specify quantitative performance settings, such as airspeed and engine RPMs, for particular activities and situations.

The result was a new concept of flying, informally dubbed *flying by the numbers* or *flying by the book*. Pilots learned "the right way" to go through a complex sequence such as taking off, and followed it closely every time. Flying became more standardized, more consistent, more efficient, and safer, although the vicissitudes of weather, mechanical problems, and combat still created many situations where judgment and personal skills were critical to survival.

A *procedure* is the written analog of a computer program for people: "Do A, then do B, then under certain conditions do C, otherwise do D." (Figure 1) I define a formal procedure as *a detailed explicit sequence of actions intended to accomplish a specific outcome, starting from specified initial conditions*. Often some of the steps are conditional, and should be done differently or omitted under specified circumstances. Procedures are often nested, with larger procedures made up of sequences of small procedures. For-

mal procedures are absolutely fundamental and universal in all of aviation today. Quantitative control does the same things for quantitative knowledge. With them, a pilot can get the benefits of detailed knowledge devised from a variety of experiences that she will never personally encounter.

Standard Procedure Flying was a better way to fly. It made vital knowledge more explicit, as opposed to tacit knowledge that had to be learned through long and risky experience and apprenticeship. The US Army and Navy aviators developed it in 1937, in reaction to the difficulty of flying the B-17, one of the complex aircraft being built in anticipation of what became the Second World War. These new aircraft had a dozen novel subsystems that had to be monitored and adjusted, such as retractable landing gear, engine turbochargers, electrical systems, hydraulic systems, flaps, engine cooling systems, adjustable propellors, and more. For the first time, both the Navy and Army air forces wrote manuals for pilots that described how to fly, not just how the aircraft worked. Inexperienced pilots who followed the SPF approach had fewer accidents and better aircraft performance than those who didn't.

Despite its superiority, adopting Standard Procedure Flying was resisted by pilots in every air force. One reason was the fundamental conflict which had bedeviled American manufacturing's adoption of standard procedures in the 1920s: the tension between personal expertise and discretion versus standardization and uniformity. Standard Procedure Flying appeared rigid and was viewed as antithetical to the qualities that made an outstanding pilot. It ordered pilots to ignore their instincts, and fly "by the book."

For the newer pilots who had been shown Standard Procedure Flying from the start it was not especially radical, although it was also not as much fun as unconstrained

flight. But for the expert pilots who led, mentored, and served as role models for the newcomers, SPF was unnecessary. They flew by the earlier Rules + Instruments method, with a heavy dose of the earliest flying paradigm, Heroic Craft. An expert could beat a "by the book" flyer in actual combat. The advantages of SPF came not during combat, but during the routine activities that make up 99 percent of flying, even in wartime. And even during routine tasks, such as landing, the experts had fewer accidents than the novices. So, as I will show, many of the senior pilots who led the fighting units did not use or advocate Standard Procedure Flying.

Standard Procedure Flying also had a major image problem. In the 1930s, Hollywood popularized flyers as hard-drinking, discipline-flouting artists of the air. Actors like Cary Grant and Fred McMurray soared through the skies, defied the odds, and always got the girl. Many American WW2 pilots liked that image, and thought going through checklists was beneath them. What newcomer would want to be seen flying according to standard procedures, even if he had been taught that way? It would be like a rookie basketball player doing underhand free throws: perhaps superior, but an admission that you were not an expert.[3] There were a few widely admired expert pilots who used their own versions of Standard Procedure Flying, including Charles Lindbergh, but their examples did not have much effect.

	Period	***Aphorism***	***Status end of WW2***	***Full SPF adoption***
US fighters	1942-45	Fly by instinct	Checklists only	Late 1940s
B-17s bombing Germany	1943-45	Precision and discipline	Checklists + procedures	1944

B-29s bombing Japan	1944-45	Less fuel, more bombs	same + heavy quantitative flying	1945
Medevac helicopters in Vietnam	1966	Like the air force in 1942	NA	Not studied
US Navy	1942-45, 1957-70	Flying is inherently dangerous	Checklists	Late 1960s
British Royal Air Force	1938-45	Jolly good fun (for the survivors)	Verbal checklists	1960s?
German Air Force	1940-45; 1954-58	What is decisive is the warrior spirit	None	Late 1950s

Table 5-1 Seven air forces' adoption of Standard Procedure Flying

To put it crudely, fighter pilots did not like being told what to do, and in most air forces fighter pilots dominated both the command structure and the culture. As a result, most air forces did not fully adopt SPF until ten years or more after WW2 ended. (Table 5-1) The main exception was the US Air Force strategic bombing groups -- first the B-17s and B-24 which attacked Germany, and later the B-29s which devastated Japan. Even bomber pilots did not like Standard Procedure Flying. But General Curtis LeMay and his colleagues forced it down the throats of their pilots, because the political/military imperative to improve their bombing superseded the cultural desires of "middle managers," the front-line leaders. Pilots who refused to change were shot down or rotated home; by 1944 all pilots were indoctrinated into the new paradigm as soon as they arrived at a front line unit.

On the other hand, all of the fighter forces made much less use of formal procedures, right through the end of the war. The American fighters (both Navy and USAA) did use checklists, which were often directly visible in the cockpit. But even the Ameri-

can fighters generally did not carefully follow standard procedures. As for "flying by the numbers," the key tables and graphs were included in American manuals, but it appears that in most cases they were followed only loosely, if at all.

The next pages sketch an academic perspective on this paper, and very briefly compare the evolution of flying to the evolution of health care. Section II describes the technology under study. Sections III through IX describe the experiences of seven different aerial forces, following the sequence of Table 5-1. Finally Section X draws some conclusions.

Academic Introduction

This paper is part of broader study of how technological knowledge and practice evolved over the history of a single "production" process, namely flying. The general theme is that technologies tend to evolve from craft to science. Why and how does this happen? What does it really mean to say that a technology has become "more of a science?" This paper is a detailed investigation of "how" evolution happened, for one of the four major transformation of flying between 1910 and today. No technological innovation is adopted immediately, and history is full of examples where a superior but novel technology was adopted only slowly or not at all. The phenomena of technology adoption and diffusion have been studied from a variety of perspectives.

One of the contributions of this paper is to examine the diffusion of a major technology as a natural experiment. I present multiple case studies of adoption, partial adoption, or non-adoption. Starting from very similar initial conditions - parallel aircraft technology, parallel flying methods, and an international aviation culture which shared ideas

widely up to the mid 1930s -- different military organizations took very different approaches. Any of them could have adopted Standard Procedure Flying, which was a "soft" technology that was within all of their grasps.[4] And in fact three American air forces, the US Navy, USAAF (US Army Air Force) heavy bombers, and USAAF fighters, started down that road and were at approximately the same level of theory and implementation in 1942. Thereafter they diverged dramatically, with one ending the war far ahead of the other two.

The explanation I propose for different degrees of adoption is two-fold. First, virtually all experienced pilots resisted the new methods, which was antithetical to the culture of flying as it existed before the war. Much more than the previous paradigm shift to Rules + Instruments Flying in the 1930s, experienced flyers hardly needed the new paradigm themselves.[5] Second, although all of the air forces suffered heavy losses which could have been reduced by the new paradigm, only a few of them faced actually losing their portions of the war. These were the American heavy bombers in 1943 in Europe, their counterparts in the Pacific in 1945, and the German fighter forces in 1944-45. And only the risk of losing was enough to persuade the American generals to go through the painful process of cultural change. Even losing was not enough to persuade the Germans to change, although this may have been partly due to conflicts in the Nazi leadership.

Part of the American air generals' fear of losing was motivated by internal military politics. The US Army Air Force wanted to become an independent service, equal to the US Army and US Navy. The British had made such a shift 20 years earlier, as had the Germans and others nations. But the United States Army was reluctant to lose control of its air force, fearing (correctly, as it turned out) that an independent air force would pur-

sue its own objectives to the detriment of supporting troops on the ground. The two groups of senior generals (regular army and Army Air Force) declared a truce in this conflict until the end of the WW2. But the success of its "daytime precision bombing" campaign was going to be crucial to the USAAF post-war argument for independence. Therefore, USAAF leadership knew that if this campaign were not perceived as having "won the war," their bid for independence would be in serious jeopardy.

We can speculate what would have happened to the Americans without this political pressure. The British RAF strategic bomber force also bombed Germany, and like the Americans, it took unsustainable casualties at first. The RAF chose to deal with the problem differently; they shifted from day to night bombing, and from "strategic bombing" of military targets to mass attacks on German cities.Very possibly, the American air generals would have followed the same path if they had not been so afraid of losing out to the Army.[6]

A comment on sources is in order. This section is based on three types of sources: first-person accounts of how pilots were actually trained and flew, historians' analyses, and contemporary flight documentation, principally aircraft manuals for pilots, which described how pilots were supposed to fly. Only the official contemporary official documents are detailed enough to fully distinguish among the different elements of Standard Procedure Flying. But they show only how pilots were *supposed* to fly, according to official doctrine. In some cases the other sources show a different picture of how they *actually* flew. Of course, these discrepancies provide valuable information.

My unit of analysis is usually an entire air force, with tens of thousands of pilots. Although an entire air force would use one set of official instructions and doctrine, prac-

tices within an air force inevitably differed. For example, when RAF (British) pilots were trained in Egypt in 1939 they had one set of experiences. When they were trained in 1942 in Canada, the training was quite different. Those trained in the US in 1942 were trained to still another version of "the right way to fly." Similarly, different front-line units flew differently, depending on personalities and beliefs of their commanding officers, the tactical requirements of their military situations, and other factors.

It is impossible to present a statistical analysis of this within-air-force heterogeneity. Surviving first-person accounts are too few, and too widely scattered, especially in the Luftwaffe from which few pilots survived the entire war. My approach is to present the norms for each air force, as described by multiple sources of evidence. Discrepancies are mentioned mainly in footnotes.

21st Century Medicine

The idea that the health care community should implement something similar to Standard Procedure Flying has gained wide attention in the last 10 years. A number of medical researchers and practitioners are pursuing the ideas, and in many cases they make explicit analogies to aviation.[7] Atul Gawande's book, *Checklists*, introduced the ideas to a broader community. The medical literature that compares medicine to aviation tends to emphasize checklists, with little attention to standard procedures or quantitative "flying," but all three elements of SPF have clear analogs in health care.

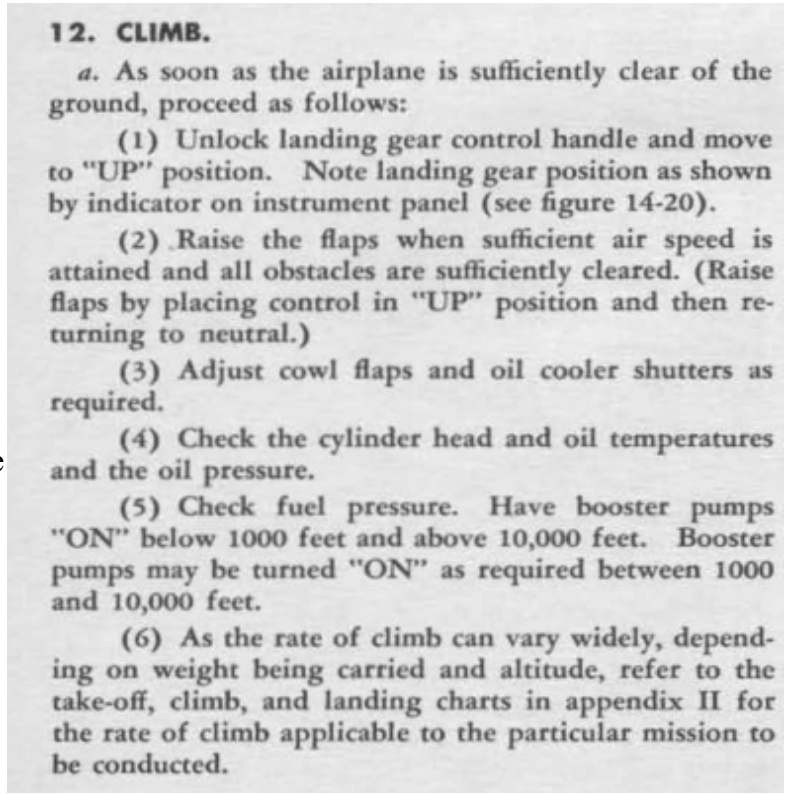
The long delays in pilots' adoption of SPF may therefore be a cautionary tale for health care. Many health care system innovations diffuse only slowly.[8] What's more,

there are cautionary analogies between medicine and aviation. Aviation's delays had a lot to do with pilots' identities, personalities, and culture. Expert pilots felt they had no need of the new methods, and young pilots wanted to emulate their role models, the experts. The stereotypes of some physician personalities, to the extent they are accurate, suggest the possibility of similar difficulties. And the air force generals had an ironic advantage when trying to change flying culture and practices: American front-line pilots were either killed or rotated to other jobs within one year of entering combat. Turnover in health care, in contrast, takes far longer.

II. Standard Procedure Flying on Paper

The diffusion of SPF knowledge can be traced through aircraft manuals written over the course of the war . These manuals were the first large-scale and systematic effort to convert tacit flying knowledge into explicit (written and formulaic) knowledge. Before them, there were written books on how to fly, but they were not aircraft specific. The belief had been that a good pilot should be able to fly any aircraft after an hour of dual instruction. Manuals did exist for a few aircraft, but they were entirely on how to "rig" the aircraft, i.e. remove it from packing boxes and turn it into a flying machine.

Figure 1 Short procedure from a 1943 manual for B-25 bombers
Each procedures spells out the required activities and their sequence. Note the reference in section 12.a.6 to a numerical appendix for determining optimal control settings.



12. CLIMB.

a. As soon as the airplane is sufficiently clear of the ground, proceed as follows:

(1) Unlock landing gear control handle and move to "UP" position. Note landing gear position as shown by indicator on instrument panel (see figure 14-20).

(2) Raise the flaps when sufficient air speed is attained and all obstacles are sufficiently cleared. (Raise flaps by placing control in "UP" position and then returning to neutral.)

(3) Adjust cowl flaps and oil cooler shutters as required.

(4) Check the cylinder head and oil temperatures and the oil pressure.

(5) Check fuel pressure. Have booster pumps "ON" below 1000 feet and above 10,000 feet. Booster pumps may be turned "ON" as required between 1000 and 10,000 feet.

(6) As the rate of climb can vary widely, depending on weight being carried and altitude, refer to the take-off, climb, and landing charts in appendix II for the rate of climb applicable to the particular mission to be conducted.

The July 1937 manual for the American B-17 heavy bomber, and the April 1937 manual for the Navy SBU-2 dive bomber, were probably the first in the world to include formal procedures and checklists.[9] The B-17 manual contained 3 ex-

plicit checklists totaling 30 items: "Before taxi," "Before takeoff," and "Before landing." Other procedures are scattered around the manual for various purposes, such as starting and shutting down the engines, but they are not reduced to checklists.[10] By the 1943 manual for the B-17F, checklists had become more thorough and more formalized, and were also provided on special cards for use during flight. A separate checklist was provided for the bombardier.[11] The three pilot/copilot checklists for the early B-17s had expanded into nine with a total of 72 steps for the same phases of flight.[12]

Checklists were only a small part of these manuals. Originally, manuals were mostly text descriptions of what each control and instrument did. Over time, American manuals became more oriented toward the pilot/crew and what they should do. Procedures, initially only a few paragraphs in a few sections, grew to many pages covering most of the activities in the aircraft, copiously illustrated with carefully labeled photos and color diagrams. (Figure 2. Figures for this section appear at the end of the section, starting on page 22.) The instructions became more quantitative, with elaborate tables and graphs. (Line and right scale in Figure 2) By 1949, the manual for the B-17G had thousands of numbers in tables and graphs.

American aircraft also had placards scattered around the cockpit with notes, numerical information, and checklists. Figure 3 (page 22) shows two such notes, in the crowded cockpit of a fighter aircraft. The warning not to open cowl flaps above 225 knots of indicated air speed is especially useful for pilots used to a different aircraft, which would have a different limit speed. The other note, about emergency release of the canopy, is an example of providing key information redundantly, rather than relying on the pilot's memory.

By 1944, the serious subject matter of the manuals was lightened by cartoons. (Figure 4) Additional documentation included elaborate training manuals for each crew position including gunners -- textbooks, as opposed to reference books. The training manuals were generally between 100 and 200 pages, and written in a less formal style than the aircraft manuals.

Checklists were emphasized in training. First person accounts of flight training by Army Air Force (AAF) pilots often mention them. A Tuskegee Airman recalls moving up to Basic Training (second level, with a closed cockpit aircraft). "Inside the cockpit was something new, a printed checklist we had to memorize: CIGFTPR"[13] Figure 6 shows how checklists were physically attached and always visible. A Marine trainee, describing the same transition in training, wrote[14]

> "Reviewing the pilot's checklist, a preflight ritual forevermore, became vital to survival… We became compulsive in all facets of our lives because our lives depended on our ability to do everything right and in just the right order. We knew that there was some leeway for errors but we never really knew what would get us by and what would not, and none of our dead classmates could tell us at what point they flew beyond the ability of their airplanes to bring them home."

Manuals were filled with exhortations to follow procedures and use checklists. From a 1944 pilot training handbook for B-25:[15]

> **Use your checklists**. You are entrusted with the lives of a highly trained crew and valuable equipment. The plane and its crew are your only business while you are its pilot. There are too many controls which must be set properly, too many instruments and indicators to be checked, to allow for any but the most definite procedures, always systematically planned and executed.
>
> These checks and inspections will not take a lot of your time….

And in a B-17 training movie:

> "No matter how good you are, flying means fatigue, and fatigue does things to your memory. So if you want to bring in this thing without an insurance claim, use your checklist."[16]

As shown by the 1937 manual, the US Navy began using checklists at almost the same time as the Air Force – possibly even sooner. In the first years of WW2, Navy manuals were generally shorter and less detailed than the Air Force's, and they were written by the aircraft's manufacturer rather than the military.[17] But in mid-1944, both the Navy and Air Force standardized on an elaborate format for flight manuals. Each manual had front information including table of contents and a page listing updates, five main sections, and appendices. The sections for "Pilot's Operating Instructions" and "Emergency Operating Instructions," always consisted of procedures and illustrative diagrams, typically totaling one third of the pages in the main body of the manual. Long appendices contained the tables for quantitative flying. Checklists varied in format and complexity over the course of the war, but once the standardization of manuals occurred around 1944, manuals contained long and detailed procedures (sometimes called check-off lists), while terse checklists were provided on laminated cards used in the cockpit – and sometimes on cockpit displays, as in Figure 6.[18] These manuals had all three elements of Standard Procedure Flying: Checklists, formal procedures, and quantitative instructions.

A very parallel structure is used in 21st century flight manuals for Boeing airliners, although modern manuals are 2000 page instead of 100. Thus most of the basic features of modern Standard Procedure Flying were laid down 60 years ago. The unchanged features include:

- *Detailed procedures, with separate sections for normal operations and emergencies.*
- *Separate brief in-cockpit checklists that only check key settings for normal operations. If there are two pilots, one reads aloud while the other checks.*
- *Long tables and diagrams covering recommended quantitative flying settings.*

So Standard Procedure Flying was firmly established *on paper* in both the USAAF and the US Navy during WW2. But actual adoption was mixed. It was disseminated in manuals throughout the US Air Force and Navy, but it took much longer to be fully adopted by many pilots. By the end of 1944, the USAAF fully embraced Standard Procedure Flying, but only in its strategic bombing forces. The US Navy used it sparingly until the Navy's transition to jets forced its adoption during the 1960s.

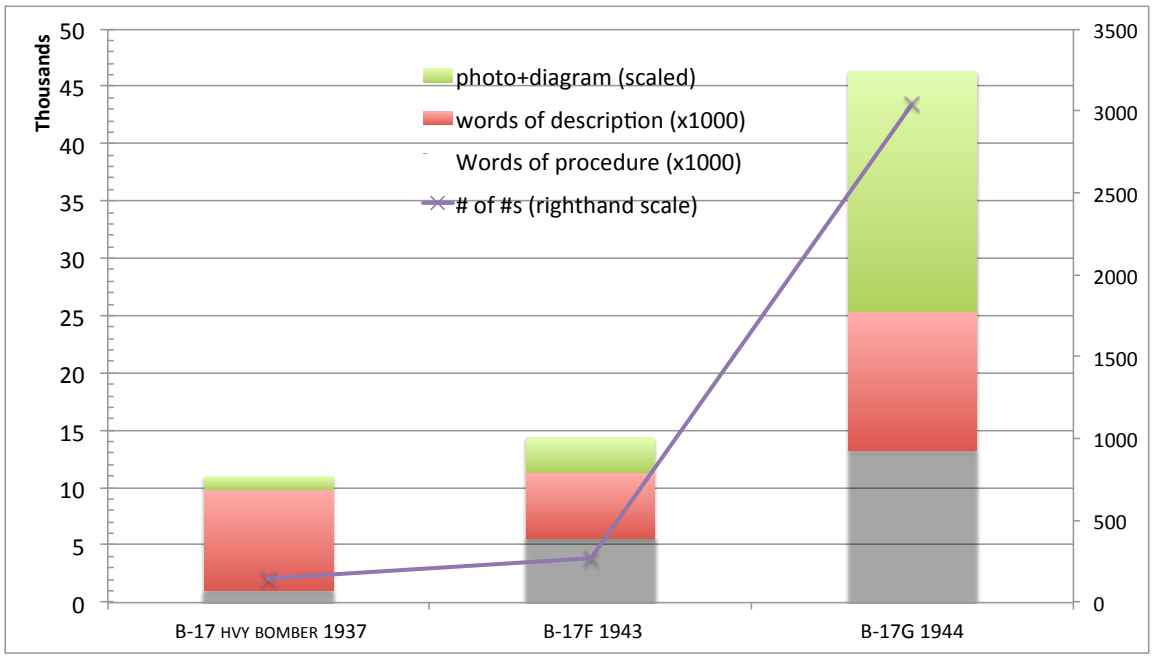
Delays in using SPF partly reflected different aviation cultures. Cultural explanations of behavior are hard to prove or disprove, because culture is hard to define, hard to measure, and can lead to circular arguments. Nonetheless, it is often useful for explaining large variations in behaviors of different organizations that have similar "hard" technologies. Successful military organizations make heavy use of culture, under terms like *morale* and *command authority*. Part of the cultural difference between the Navy and the US bomber force corresponded to a conflict which also bedeviled the adoption of Frederick Taylor's standardized manufacturing: the tension between personal expertise and personal discretion on one side, versus standardization and uniformity on the other side. Dif-

ferent air forces dealt with this very differently.

I will sketch the histories of seven air forces, each of which was exposed to different influences, and adopted SPF differently.[19] (Table 5-1) The big inhibitions against it were mostly cultural, as I will show. Only in certain cases were military needs and experiences strong enough to overcome cultural factors.

American procedural documentation in WW2: Illustrations

Figure 2 Three generations of manuals for the American B-17 bomber



American flight manuals grew larger and more quantitative, and shifted from pure description to procedural instructions for flying the aircraft. Each page of straight text was roughly 500 words. (Source: author's analysis)

Figure 3 Warning placards kept key instructions visible at all times.

(P-47 fighter, approx. 1944)

Figure 4 Cartoon from P-51 manual, 1944.
By 1943 most American manuals were much more "user friendly" than those of other nations, as well as more comprehensive.

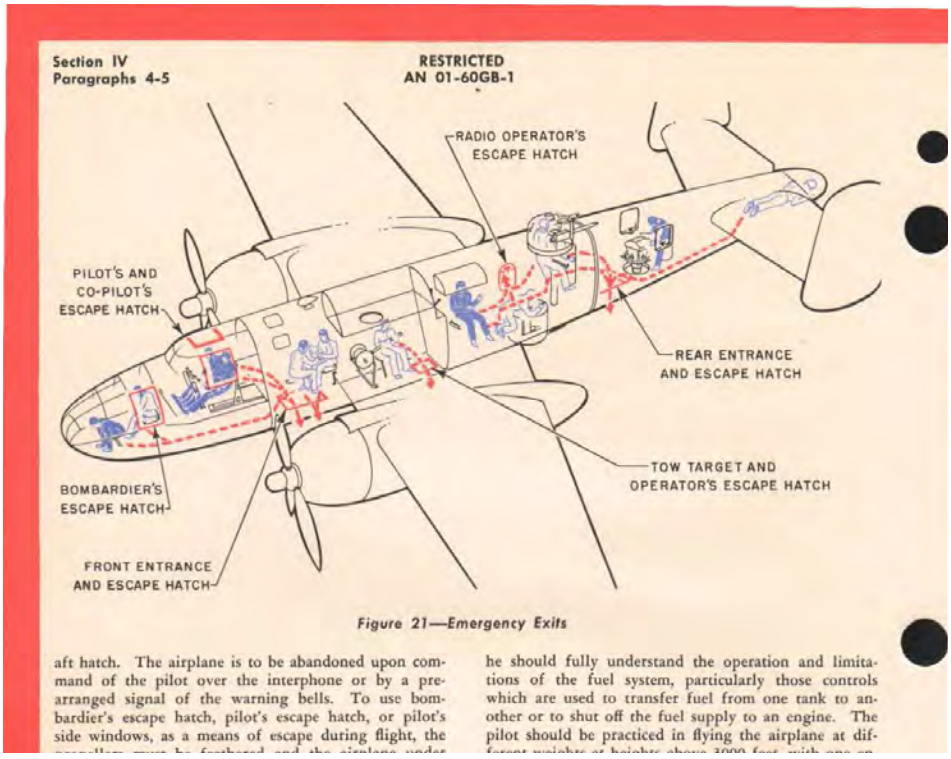


Figure 5 Example of color diagrams, 1944
From B-25 medium bomber manual

Figure 6 Cockpit of SNJ trainer. Checklist shown in inset.
This is an open-cockpit trainer. The instrument panel is simple, yet it includes a prominent artificial horizon. This aircraft is in a museum, and it's impossible to confirm that the checklist was present when the aircraft was built. (Photo: David Schultz Photography)

III. American Fighter Pilots in WW2

American fighter pilots learned to use checklists for takeoff and landing, but that was as far as they went with Standard Procedure Flying. Early in WW2, the mission of American fighter aircraft was defensive: to disrupt and destroy enemy bombers. Later in the war, it was to attack targets of opportunity, such as troop concentrations and airfields. And at all times, the biggest danger came from enemy fighters. In such combat, quasi-athletic abilities were the keys to success: fast reflexes, good eyesight, excellent subconscious flying skills, and personal courage. Fighter battles often developed into chaotic acrobatics, in which pilots were overloaded with information and had to operate on "instinct." Standard Procedure Flying had little role while a pilot could see an enemy aircraft.[20]

A frequent disciplinary issue with young pilots before they got to a war zone, and especially with fighter pilots, was illegal stunt flying. Newly commissioned pilots would play "chicken" with civilian cars, perform low-level acrobatics, and fly under telephone lines and bridges. Every air base had rules forbidding risky flying behavior. But pilots kept doing these stunts because it was fun, it was good training, and it gave them prestige among other young pilots. General Kenney, who went on to become commander of USAAF forces in the Pacific, describes in his memoir a tense meeting with a hot young Lieutenant (O-2 rank) named Richard Bong.[21] Bong had looped his twin-engined P-38 fighter plane around San Francisco Bay's famous Golden Gate Bridge, and flown down San Francisco's Market Street, while waving to young women in their offices. Kenney got a long report on Bong that included complaints from the mayor, the chief of police,

and a lady whose laundry had been ripped off her drying line, among many others.[22]

If caught, pilots were supposed to be disciplined. In Bong's case, "Washington was determined to stop low-altitude stunting and had put out some stringent instructions about how to handle the budding young aviators who broke the rules," and the report to Kenney recommended a General Court Martial. So the pilots' goal was to do something forbidden and dangerous - without being caught. A typical anecdote describes a new pilot who enjoyed buzzing a town near his airbase at night, when he and his plane could not be identified. He got away with it - until one night he failed to spot a tall factory chimney.[23] Charles Dryden of the famous Tuskegee Airmen, the first group of African American fighter pilots, saw his class's first fatality after two pilots flew their trainer under a bridge, and "somehow they didn't make it."[24] Even before he received his pilots' wings, Richard Curtis, who titled his autobiography *Dumb but Lucky*, managed to take out four telephone cables while flying down a twisty river, to get shot at by an angry sheep farmer, and to endanger a Major General (O-8) while doing acrobatics over the main runway -- and those are just the escapades where he got caught.[25] While he got in a lot of trouble, he managed to escape all the threatened courts martial.

The paradox is that the same traits which lead to this kind of forbidden behavior - giant egos, complete confidence in one's own abilities, propensity to take risks - are highly desirable qualities in fighter pilots. As fighter ace Donald S. Lopez wrote,[26]

> The deaths of some of our squadron mates in training had no noticeable effect on the rest of us. I believed, and I'm sure most of the others did also, that the ones killed had not been quite good enough, and that I would be able to handle any emergency or combat situation that I found myself in. …

So commanding officers *wanted* aggressive fighter pilots, and often looked the

other way at stunting. General Kenney, in fact, tore up the report condemning Lieutenant Bong, asking him "By the way, wasn't the air pretty rough down [at] second-story level?" and telling him "If you didn't want to fly down Market Street, I wouldn't have you in my Air Force, but you are not to do it any more…" Richard Bong (1920-1945) went on to become the highest-scoring fighter pilot in American history. Flying down city streets without hitting telephone wires was excellent training for strafing airfields, and a good way of selecting fighter pilots.

This approach to risk-taking was a continuation of flying culture going back to the 1920s and before. Rebecca Hancock Cameron wrote a comprehensive history of training in the USAAF from 1907 to 1945. In the 1930s when commercial aviation was shifting to Rules + Instruments Flying, military flying still used the Heroic Craft approach. "Air Corps officers still tended to be a daredevil lot who, much as in aviation's earliest days, faced down death in flying primitive aircraft. They relied more upon their own skill and confidence than upon knowledge of aerodynamics or instruments."[27] Brigadier General Noel Parish, who went through flight school in about 1933 and during WW2 was commanding officer of the Tuskegee Army Air Field, described what happened to his own graduating flight class of 96 men.

> "The figure that rather appalled me was that out of that 96, within a year, fifteen were dead. Crashes- mostly pilot error, and most of it was from high-spirited behavior. We, of course, had no radios in the planes, and people would take chances on weather....Doing stunts, flying under things, flying low, especially, and pulling up. Most of us had no strong desire to get up where it was terribly lonesome and fly around, ..., but to get down low where people could see us... …[I]t was a very risky life."

When the US fully entered the war in 1941, most new pilots finished their train-

ing in new squadrons still forming in the US. Donald Lopez's new 98th Fighter Group was ordered to take lethal risks in training. Lopez enumerated how pilots proved their ability and got away with egregious errors, and why it was part of the training philosophy.[28]

> The 98th CO [commanding officer] believed that you had to fly… on the edge of the performance envelope, to learn to be a good fighter pilot. When we peeled off to land... we had to execute a tight vertical bank, and were fined if we did not pull streamers with our wing tips.... It usually required about four Gs to generate them. In contrast, the 303rd squadron fined the pilots who pulled streamers on the landing break because too tight a turn could result in a high speed stall, followed by a spin with insufficient altitude to recover. This happened to one of our pilots, *but the fatal accident did not cause the 98th to change its policy*. Although we were not fined, it was considered poor technique to have to add power once you had chopped the throttle on the break [when landing].... ... the ability to make a tight 360-degree approach without touching the throttle was one of the first steps up the fighter pilot's ziggurat. [emphasis added]
>
> During that period *we could get away with things that would have brought a court-martial after the war.* We regularly flew just above the housetops, when returning to the base. When we found large herd of cattle being rounded up, we would dive on them causing them to scatter wildly.... "on-the-Deck" Beck insisted that we fly low enough to leave a wake when practicing low-altitude navigation over some of the Florida lakes. [emphasis added]
>
> It was also the practice in the 98th to attack any flight that was spotted after the formal part of a mission was completed. This included attacking aircraft from other bases.... This aggressive attitude, inculcated in us by the commander, led to a fine *espirit de corps* and pride in being part of the 98th.
>
> [after describing a wheels-up landing by a pilot] After the war, if you damaged an aircraft that way, you would have been grounded until you met an accident board. At the very least, you would have received an official reprimand. In this instance, though, the operations officer said to [the offender] "Well, do we land

> with our wheels up?" and [the pilot] replied "Yes, sir, I guess we do." That was the end of it. …
>
> Suddenly our two months of training was over. I realized that in addition to the formal goals of the course, we had learned, in varying degrees, the one vital skill that gave a pilot a fighting chance to survive in combat: the *ability to fly by instinct*. That was the real goal of the innumerable rat races and dogfights. At some time, near the midpoint of the program, *the student became one with the airplane*. The pilot, not his airplane, followed the plane ahead through any and all maneuvers without conscious attention to the controls. He could devote his mind to planning his next move or anticipating the other pilots, without worrying about flying the plane... [emphasis added]

Thus Air Force (and Navy) fighter culture encouraged risky behavior, often explicitly. Instinctive behavior, not that different than the barnstormers', was critical to survival. The 303 squadron's commander fined pilots for pulling high g's on landing, but the 98's commander fined them for *not* pulling g's. The craft aspects of flying fighters were highly cultivated: the "ability to fly by instinct." The officers accepted that fatal training accidents were part of the price for excellence in the survivors – just like the Heroic Craft flyers of WW1. Of course, there were some limits; one Navy instructor was court-martialed after buzzing a field so low that he decapitated a farmer.[29]

The overall USAAF accident rate in the continental US fell from 74 per 100,000 flying hours in 1942, to 54 in 1944 and 42 in 1945. The rate had fallen steadily from 467 in 1924 to 51 in 1940, then rose to 58 in 1941 due to the massive influx of novice pilots. The effect of massive training is evident in these numbers. Unfortunately we have no breakdown of fighters versus other aircraft types.[30]

IV. The Bombers Attack Germany

Next we turn to a part of the American USAAF that started with the same attitudes, but switched as the war continued. Some new bomber pilots also enjoyed dangerous and illegal maneuvers in training, such as low altitude flying.[31] Of course the consequences of slips in bombers were more serious: an entire crew would be killed. Even more important is that unlike fighters, heavy bombers needed to be parts of a regimented machine. Individualist flying in combat was bad for the mission and bad for survival. Flying down a twisting river was *not* good training for bomber pilots.

> *Modern commercial aviation is more like flying bombers than fighters. Commercial jets are considerably more complex than WW 2 bombers, and safe flying requires procedures and checklists. Commercial aircraft do not fly in formation, but they still require careful coordination, for instance to get multiple aircraft into and out of a busy hub airport in an hour. And "flying by the numbers" to meet schedules and conserve fuel is very important to the economics of commercial aviation.*

Standard Procedure Flying is especially valuable for flying that is complex and precise. The most complex and precise of the American air fleets were the heavy bombers that made daylight attacks on Germany and Japan, culminating in 1944 with the revolutionary B-29 with a crew of 11.

Huge missions lasting more than 12 hours and spanning 2,000 kilometers, generally over water (in the Pacific) or enemy territory (in Europe), were monumentally complex. Some involved well over 1,000 American aircraft, larger than any before or since. Crews, aircraft, and entire squadrons each had to act as parts of a giant machine. For this reason, precise and uniform flying was critical. It was needed to maximize fuel economy

and range, to avoid collisions, to keep the aircraft together for defense against enemy fighters, and to hit the right targets from an altitude of seven kilometers.

Two military problems added to the inherent risks of flying these bombers. First, the Americans flew under conditions that were forbidden in peacetime - airplanes were loaded past their "maximum" weight, and missions took off in bad weather as long as the weather over the target was forecast to be decent. Second, peacetime pilots battled only the elements and their own screw-ups, but wartime pilots had other men struggling to kill them using fighter planes and heavy artillery. The American bomber generals' response was to create highly choreographed missions with tightly coordinated schedules and elaborate "combat box" formations. Implementing these effectively required intensive use of Standard Procedure Flying.

World War 2 started directly for Americans with the Japanese bombing of Pearl Harbor in December, 1941. It took time for the US to ramp up aircraft manufacturing. Furthermore, new airplanes needed new pilots, and both the Army (USAAF) and Navy aviation required roughly twelve months to train individual pilots; it then took another six months to mold these pilots and their crews into effective machines. In late 1942, USAAF heavy bombing units began to arrive in England; over the rest of the war these units became increasingly procedure-based, calculation-based, and precise as the aircraft and the missions became more complex and strenuous. (The Air Force began bombing Japan only in 1944, as discussed later.) Table 5-2 summarizes key events of WW2 in the air.

Date	Event	Air Forces involved
1937	Japan invades China	Japanese Army + Navy (IJN)

1937-1940	All air forces begin deploying modern aircraft: metal, retractable gear, closed cockpits, etc.	All. US not at war until late 1941, but refitting and expansion begins as early as 1937.
Sept. 1939	WW2 in Europe begins	British RAF, German AF
July-Sept 1940	Heavy air fighting over Britain, the "Battle of Britain."	British RAF and German AF both have heavy losses.
December 1941	US enters war against Germany and Japan	Japanese IJN aircraft sink all US Navy battleships; Navy forced to rely on aircraft carriers
June 1942	Battle of Midway	US Navy defeats IJN
Late 1942	US AAF and British RAF begin bombing Europe	US Bomber forces accomplish little; take high losses
Early 1944	US attacks on Germany reach 500 aircraft per mission, with full fighter escort	German Air Force has precipitous losses; US bombers learn to make massive missions.
1945	B-29 bombers bomb Japan	US Bomber force shifts to mass destruction of cities.
August 1945	WW2 ends after 2 atomic bombs dropped on Japan	

Table 5-2 Air warfare timeline for WW2

Attacking Germany with heavy bombers flown from bases in Britain was assigned to a new organization, the Eighth Air Force, which eventually grew to a peak size of 200,000 soldiers and suffered about 60,000 casualties over the course of the war.[32] Harry Crosby (1919-2010), an Eighth Air Force B-17 navigator, arrived in the UK in May 1943 and remained in Europe throughout the war. His first combat mission had 24 aircraft, but by April 1945 his missions involved over 1000 bombers and a similar number of fighters. After the war Crosby became a professor of English, and eventually wrote a memoir, *A Wing and a Prayer*, which gives an eloquent picture of the conflict between craft and science in bombing Europe during the war. Crosby was in its 100th Bomb Group.

The leadership of the 100th in its first year was colorful and popular -- their role models went back to the barnstorming era. Two squadron commanders, both nicknamed "Bucky," exemplified this type, and "were the heart of the original 100th -- dashing, undisciplined, superb pilots, exactly what Hollywood expected them to be."[33] They were stylish, daring, but had "heart[s] as big as Texas." They wore white silk scarves and officer's caps cocked to the side of their heads and they chewed on toothpicks while they swapped stories about flying and women in the officer's club every night. And they broke rules, on the ground and in the air.[34] Unsurprisingly, they were role models on the 100th's base - and elsewhere. A story about one of them, Bucky Cleven, appeared in a leading American magazine, and turned him into a national hero. Younger officers looked up to them, talked and dressed like them, and emulated their flying style.[35]

Precision Flying

While many on base aspired to be like the Buckys, Crosby was reaching a different conclusion. He was promoted to become the navigator on a *lead crew*, which led an entire group of B-17s in combat. The other twenty aircraft in the group remained in tight formation behind the lead aircraft. A lead crew's performance was critical - any errors by a lead crew would throw off a whole formation, and could lead a group into disaster. Crosby and his pilot, Ev Blakely, could not afford to be fast-talking hot-shots; they chose to be technicians, performing the difficult lead job accurately, consistently, and using Standard Procedure Flying.

Blakely, Crosby wrote, "was a good pilot for a navigator." The lead position of their airplane meant that "[i]nstead of jockeying back and forth" as their following air-

planes did, "Ev, in the lead, could keep his needles and dials fixed." In the cockpit, Blakely, "beady-eyed," would sit "staring at his dials, his muscles tense as he fine-tuned his altimeter, power settings, and airspeed indicator." Blakely had neither the time nor the inclination to buzz bridges or play pranks, and that was just how Crosby liked it: "As a navigator, I didn't want a hot pilot, a rock" (slang for a hotshot). "I wanted a truck driver. I wanted a pilot who could keep the needles steady." Crosby began to jokingly call his pilot "Old Beady Eyes," and wrote later, "I could not have paid him a higher compliment."[36]

Blakely's serious attitude extended outside the combat missions. Every day with decent weather and no mission he took his crew 25,000 feet above the English countryside, practicing.[37] He had them tackle "formation control, navigation, and bombing," pretending they were followed by 20 other aircraft. "We conditioned ourselves to think of the other planes, gradual turns, exactly maintained airspeed and altitude, smooth, smooth, smooth…" Crosby wrote. It was "Practice, practice, practice. Smooth. Beautiful."

Some members of the crew appreciated this training more than others. Crosby knew he was not a fast or even proficient navigator yet and needed the practice, while the gunners, who had little to do on training missions, didn't see why they should go along. Of course the pilot, co-pilot, navigator and bombardier were officers, while the gunners were enlisted men.

Precise quantitative flying, such as Blakely and Crosby's, was essential to the American bomber force. As Crosby learned, "When we hit enemy territory, we had to have every group [and aircraft] right in place. If there was a straggling group, it got hit [by German fighters], and hit bad."[38] (Figure 7) Their 100th Group actually had a reputa-

tion as bad flyers. Crosby occasionally flew as lead navigator for other groups, and on one of these flights, a colonel pointed to the 100th's sloppy formation and told him, "That's why all the other groups like to fly with the 100th. The Luftwaffe [try to kill] them instead of us."[39]

Figure 7 Two B-17 groups, in combat box formation. Note irregular spacing; the aircraft at middle right (circled) is far out of position, making it vulnerable

The Colonel's revelation upset Crosby as much as another incident on the same mission, when he administered morphine to a mortally wounded crewman.

Quantitative flying was also critical during the "join up" procedure at the start of each mission, when hundreds of aircraft had to assemble into a single carefully structured formation. Each aircraft in a group took off in sequence at 30 second intervals, then had to climb to meet at a precise time and location, the *rejoin point*. In cloudy weather, normal much of the year in England, this required pilots to fly purely by instruments, sometimes for more than an hour, at "the exact airspeed and climb rate and followed the headings given him by the navigator, so that they would arrive precisely at the rejoin point at the briefed altitude." The only way to avoid collisions in the clouds was for every aircraft to fly the exact same flight path, separated by time and altitude.[40] Returning from missions in heavy cloud cover was also risky. (Figure 8)

Figure 8 B-17 collision over England, October 1944. Everyone on both aircraft was killed. Notice the poor visibility. Also notice that other aircraft remain on course despite the collision. Deviating risks another collision.

Such precision was a tremendous strain on pilots. As Crosby wrote,[41]

> For 120 minutes he [Blakely] can see nothing...All he can do is stare at his instruments. He must keep his airspeed at [exactly] 150 miles per hour. He must keep his turn and bank indicator at a single needle width...He must be sure all four engines are exactly synchronized, each showing the correct manifold pressure. He is probably watching fifteen instruments. ... At 10,000 feet, without permitting any change in anything, he has to put on his oxygen mask.

Timing errors could be very serious, even a five minute error on a 12 hour mission. Bomber and fighter groups flew at different speeds, and the fighters had much shorter range, so they had to rendezvous at predetermined times and locations. If either force was late, the bombers had to proceed without fighter cover. On some days multiple

bombing missions were mounted to keep the German defenders guessing and to spread out their forces. On several notable occasions one of these missions was was delayed, and the other bore the full brunt of German attacks.

Finally, and perhaps hardest of all, during the bombing run over the target, the pilots had to suppress their own instincts and fly straight and level, giving the gunners on the ground an easier target. Then-colonel (O-6) LeMay admonished his officers:

> Too many times, the command pilot, who is supposed to lead a mission, is the one who causes it to fail. Every time he sees a burst of flack, he takes the wheel and swerves the plane. That causes trouble for the whole group.
>
> If there is anything that is necessary on a bomb run it is that there be no evasive action. Too many command pilots have their own special ways of taking over on the bomb run. ... . The lead plane must fly straight and level. What you must do on the bomb run is to let the bombardiers and the Nordens [automated bomb-sight system] take over.[42]

Craft Flying

Returning to Crosby and the 100th, a rigorous and procedural approach did not necessarily denote that a pilot was a poor craft flyer. Their aircraft was badly damaged over the German city of Bremen, and an engine caught fire. Blakely dove 3000 feet at top speed, literally blowing the fire out. But the dive took them out of the tight bomber formation, which made them a target for German fighters as they struggled to return to England. At first they flew with another damaged B-17, but it physically disintegrated under enemy attacks. The gunners of Blakely's plane damaged, destroyed, and drove off fighter after fighter until finally they found themselves alone. With only two and a half of their four engines working, they flew so low that town policemen shot at them as they crossed

France. Yet Blakely managed to coax the airplane across the English Channel and make a successful crash landing on a tiny airfield. Their aircraft landed with 1,200 holes in it, and had to be scrapped. But 9 of their 10 man crew survived the mission.[43]

Not every aircraft in the 100th had been as lucky or had been flown by such good pilots. Of the 21 aircraft from the 100th Bomber Group on the Bremen mission, 7 were shot down, including the airplane flown by the famous Bucky Cleven. Headquarters offered to let the decimated group "stand down" while it recovered from the casualties, but the group's commander, in a characteristically macho decision, refused the offer.

Two days later, the Group was sent on a mission to attack the city of Munster. Only 13 crews were able to fly. With Blakely's aircraft destroyed and its crew recovering from the Bremen mission, the position of lead aircraft was taken by the remaining Bucky, Bucky Egan, who unwisely drafted an average crew that had not even been briefed for the mission. Out of the 13 aircraft in the 100th who left England for Munster, only one returned – a 92 percent loss rate.[44]

At this point, Crosby and Blakely had been in England only four months. They had arrived with 140 other flying officers. Of those 140, only 3 were left - the rest were dead, captured, missing, or injured and sent home. The Bremen and Munster missions were sufficiently disastrous that their commanding colonel (O-6 rank) was finally sent home “for medical reasons.” The 100th Group's craft flying, exemplified and encouraged by the Buckys, had almost wiped them out. The 100th got the nickname “Bloody 100th.”

The 100th’s troubles weren't over. The new commander sent to the Group was a Colonel (O-6 rank), an arrogant West Point graduate who "had never flown a [combat] mission." Not daunted by his own inexperience, on his very first mission he assigned

himself the position of command pilot for the formation. Crosby described him as "Air Force macho," and wrote later, "I began to wonder whether West Point taught its cadets the difference between bravery and bravado."

The mission was a fiasco. By the time their bombing run reached the target, they were too far off course to bomb it successfully. "With uncommendable brashness and derring-do," Crosby wrote, "the inexperienced colonel decided to go around again and make another pass at the target, same altitude, same speed, same direction.", German anti-aircraft fire made minor adjustments, "and blew the 100th out of the air" including the new commander and his crew.[45]

The generals apparently learned their lesson, and the new acting commanding officer of the 100th, Lt. Col. (O-5) Bennett, was very different. "The leaders of the 100th think they are making a movie, not fighting a war," he said. "We have to get serious." He did, getting rid of most of the surviving leadership, canceling leaves, making everyone fly practice missions whenever real ones were not scheduled (as pilot Ev Blakely had already been doing), and even forbidding alcohol sales on the base.[46]

No one was safe from criticism; Bennett even publicly pretended to chew out Crosby, a notoriously “by the book” officer. "He got rid of the deadbeats, the Hollywood fly-boys," Crosby wrote. "He promoted the good-guys. We now had the men to fight a war." Nobody would ever again be as popular as the two Buckys, but their era was over.

As Standard Procedure Flying took over, the 100th became less dangerous for its crews, and more effective for the American military. "The 100th stopped losing more planes than other groups," Crosby wrote. "Our bombing got better. Our gunners reported more kills. We felt better about ourselves." Crosby himself was promoted to work in-

creasingly with General Curtis Lemay, who was trying to push Standard Procedure Flying.

Two Cultures

In early 1944, Crosby, even then something of an intellectual, was sent to a two-week conference at Oxford University to discuss conflicts between the American and British forces. A common British complaint was that the Americans were "overpaid, oversexed, and over here."[47] Talk about American men dating British women led into discussions of Americans' general behavior. An Oxford professor proposed that the difference between the Americans and the British was a clash between Romanticism, an early 19th century cultural movement that emphasized individuality, and neo-Classicism, a cultural change that emphasized discipline and societal roles. As a Canadian explained, the Americans "all want to be rugged individualists. You hate discipline… None of you can march [on the drill field]." Someone else asked "And why do so many of you wear high-heeled boots? Are you all cowboys?"

In response, the American fighter pilots in the conference were happy to admit to lack of discipline: "The two American fighter pilots, both of them wearing boots, laughed. One of them said 'You hit us. Maybe that's why we all wanted to be fighter pilots instead of getting stuck flying formation in big ones [bombers]'."

Crosby's suite-mate, British officer A. N. Wingate, arrived at the conference late. To his consternation, Crosby discovered that Wingate was, in fact, a woman. In the evenings they would go over Crosby's notes of the daily discussion. Crosby told her about the 100th and the way in which the leaders actually cultivated "'raunch" (sloppi-

ness). The two Buckys, he said, "were the very soul of Romanticism. They hated discipline," and discipline in the 100th was referred to as "chickenshit." "Like the two Buckys, our pilots all wanted to be dashing individualists."

Crosby explained his contrary view to Wingate. "Discipline should be important. Formations should be good. Cooperation between the [crew members] and among the groups, wings, and air divisions, they are how we will win this war." Crosby was, he acknowledged, "a neo-Classicist surrounded by Romantics," or in his earlier vocabulary, "a navigator in a pilot's air force," and in our terms a scientist surrounded by craftsmen. Most of the 100th's reaction was different, though. "When [the Buckys] were still around, the men were happier. With them gone, the heart of the 100th has stopped beating."[48]

Perhaps the heart had died, but the brain of the 100th improved - the perfectionist "neo-Classicist" Bennett was followed by like-minded officers, and the Group became a more effective fighting force for the remainder of the war. Standard procedure flying was pushed on the entire Wing by Curtis LeMay, who took it with him to the Pacific as discussed below.

The 8th Air Force further reduced individualism through the *lead crew* system. During most of the flight one navigator was effectively directing an entire combat Wing of 54 aircraft, made up of 3 Groups of 18 aircraft each. By the end of the war, the lead bombardier in each Group was the only one who decided where to bomb. The other 17 bombardiers simply watched the lead aircraft, and when its bombs started to fall, they released theirs.[49] Making this system work effectively required careful procedures at each step of the mission, for example to ensure that each aircraft reached and then maintained its proper location within the three dimensional "combat box" formations.

An anecdote by German pilot Norbert Hannig emphasizes the contrast between bomber and fighter flying. Even in Germany, where there was no use of Standard Procedure Flying, the two cultures were incompatible. As a fighter instructor late in the war, Hannig was assigned three superior officers as his trainees. To him, even their takeoffs were defective.

> [T]heir years as bomber pilots had ingrained in them the habit of lifting off gently and maintaining a straight course until a slow turn to either port or starboard. By contrast a fighter pilot would retract his undercarriage and flaps almost before his wheels had left the ground, pour on the coal and be ready for any eventuality the moment he was in the air.
>
> To them it was second nature to carry out all control movements carefully and in a coordinated manner. We, on the other hand, worked quickly and instinctively, often jerking the throttle and stick about, twisting and turning, zooming and diving as the situation demanded. If they couldn't develop such reflect actions…. they would be dead men on their first [combat operation].[50]
>
> ...Their formation flying and station keeping were impeccable -- their practice dogfights a catastrophe.

Hannig got rid of them by challenging them to dogfights stacked in their favor. When he convincingly destroyed them each time, they thanked him for the demonstration, and withdrew from the program. Fighter and bomber flying styles were completely different all over the world, and in the USAAF the differences contributed to adopting Standard Procedure Flying in bombers.

V. Optimizing the B-29 program in Japan [incomplete]

After WW2, the US Army Air Force (USAAF) split off from the US Army, and

became the US Air Force (USAF), a coequal service to the Army and Navy. The big-bomber commanders took over leadership of the USAF, and several of the officers Crosby admired in the 100th Group ended up as major generals (O-8). The entire Air Force, and especially the strategic bomber force carrying nuclear weapons, thereafter followed the Standard Procedure Flying paradigm. Even the post-WW2 fighter force switched to it.

That the strategic bomber generals became the leaders of the USAF was not coincidence. During the war USAAF leadership had forcefully advocated strategic bombing of Europe and Japan, even claiming that strategic bombing alone would force Germany's surrender, with no need to invade the European continent.[51] Henry Arnold, commander of the air forces, chose only "bomber men" as his top subordinates.[52] They fought hard and mostly successfully for manpower and money to build up strategic bomber fleets. They also maintained their pre-war doctrine of " high-altitude daylight precision bombing," even though the British RAF had quickly switched to night bombing to hold down casualties.

The background to these claims was the USAAF leaders' desire for independent status as a co-equal service to the Army and Navy. If they could end WW2 by strategic bombing, their claim would be politically unstoppable. "[T]he battle over Germany became the one to which the Air Force would point and claim as the hard-fought proof of strategic bombardment. Furthermore, it was the trump card the service had long waited to play in its bid for independence."[53]

In 1943, however, the US bombing of Europe was visibly ineffective. Therefore the USAAF put considerable effort into long-range escort fighters and operational improvements including enforcing Standard Procedure Flying and better bombing methods.

One of the key leaders of the operational push was General Curtis LeMay, who in 1939 was a lowly Captain (O-3) in the nascent B-17 bomber force. He was very successful in his push to remove discretion and craft from bomber pilots in the Eighth Air Force, as discussed in the previous section.

In one of innumerable ironies of the total warfare from 1939 to 1945, even after LeMay's changes, American strategic bombing in Europe by men like Crosby did *not* have the full intended effects, and in some ways was a failure.[54] But on the other hand, it had decisive effect on the war with Japan.

In mid 1944, LeMay was sent to Asia to deal with the thus-far ineffective B-29 program for bombing Japan. The B-29 was a "super-bomber," on paper far more capable than the B-17. It was designed from the start for long-range high-altitude daylight bombing of heavily defended targets, and it included such new technologies as pressurized crew compartments and remotely-controlled defensive guns. But it had been rushed into production, and suffered from severe technical problems, especially engine fires. In addition, there was little doctrine and no experience about how to use B-29s effectively. Finally, it was being deployed from India at the end of an extremely long logistics pipeline, which limited the force to a few dozen aircraft sorties per month, attacking targets on the Chinese mainland rather than in Japan.

The B-29 program cost was huge, at $3 billion, compared with $2 billion for the vast Manhattan Project (the atomic bomb).[55] If B-29s failed to hurt Japan significantly, the USAAF leadership, which had fought so hard for that budget, would lose credibility post-war, and independence from the Army would be in jeopardy. LeMay turned this incipient fiasco around. From January 1945 when B-29s were first able to take off from

newly captured Pacific islands, to August 1945, his 21st Air Force destroyed most of the Japanese economy and shortened the war dramatically.[56] The United States Air Force was saved; it was created as a separate service in 1947.

One technique that LeMay used to make the B-29s effective was a radical shift from daylight high-altitude bombing of specific factories, to nighttime medium-level fire-bombing of major cities. He even had most of the defensive armament and armor plating of the B-29s removed, to increase their payloads. In military and economic terms LeMay was extremely successful. The still-controversial bombing of Tokyo on the night of March 9, 1945 created a firestorm that burned out 15 square miles and may have killed 100,000 civilians, more than the later atomic bomb attack on Hiroshima.

LeMay made another change that was probably equally important, but has been neglected by historians: he vigorously pushed more scientific flying by his bombers, especially more use of quantitative methods, i.e. "flying by the numbers." The bombing force that burned Tokyo consisted of 334 B-29s, of which 325 (97 percent) reached the target. Three months earlier, a 110-aircraft attack on Tokyo had only 24 aircraft that bombed the primary target. (22 percent)

A special *Combat Crew Manual* produced by LeMay explicitly laid out the knowledge developed by the B-29 force up to December 1944 that was not contained in the original manuals.[57] It contained more than 200 pages of knowledge accumulated from the six months of B-29 experience through November 1944. For example, there are four pages of detailed procedure discussion for the pilots alone. For flight engineers, the manual gives detailed instructions on adjusting engine cowls at different stages of flight, to keep the engines from catching fire.

LeMay's manual claims, and has the data to demonstrate, that overall effectiveness per aircraft went up by about 10-fold over the six month period. (Figure 9) It breaks this down into three factors: five-fold improvement in bombing accuracy; doubling of the bomb load per aircraft; and 35 percent increase in flight hours per aircraft. The manual gives examples of changes, such as:

- Better use of optimal engine settings by the flight engineers, allowing lower fuel reserves;
- Removing paint and standardizing weight procedures, increasing the payload;
- Training of lead crews, which increased bombing and navigation accuracy.

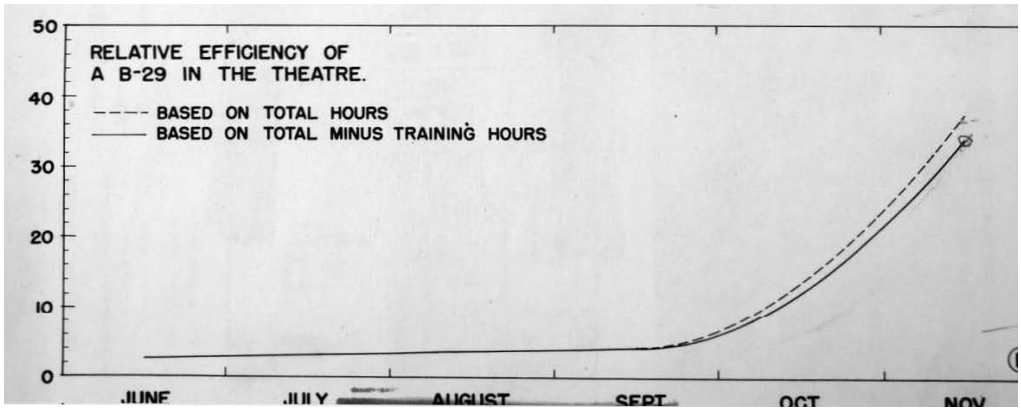


Figure 9 Effects of increased use of procedures under Gen. LeMay, 1944

In-the-field training and Standard Procedure Flying were complements rather than substitutes. The complex procedures were not instinctive, and had to be practiced by each crew on their own aircraft.

Fuel management was a particular emphasis. Takeoff weight was a limiting constraint on missions, and B-29s were loaded well past the point where they could survive an engine failure during takeoff. So the less fuel the aircraft carried, the more bombs

could be carried. The 21st Air Force developed a variety of procedures to reduce fuel loads. First, headquarters staff carefully forecast fuel requirements for each mission, taking into account the destination and predicted weather. Second, flight engineers carefully tracked actual fuel consumption during the flight, and predicted whether there would be enough to return home. When there was too little, the aircraft would divert to one of several airbases in China that were not in Japanese control. Later in the war, they could also land at Iwo Jima which was on the way home.

Third, the 21st Air Force developed and trained in a rigorous method of fuel economizing referred to as "cruise control." It was entirely "flying by numbers." Alex Green, previously a doctoral student at Caltech, worked on the project.[58] A heavily instrumented B-29 tested fuel consumption under a variety of conditions (load, pressure altitude, temperature, air speed, and others). Green took the resulting two-inch thick book of data and reduced them to two charts that could be used by flight engineers to estimate both optimal and actual fuel consumption for different situations. It was also implemented in an analog, hand-operated, computer for calculations in flight. (Figure 10)

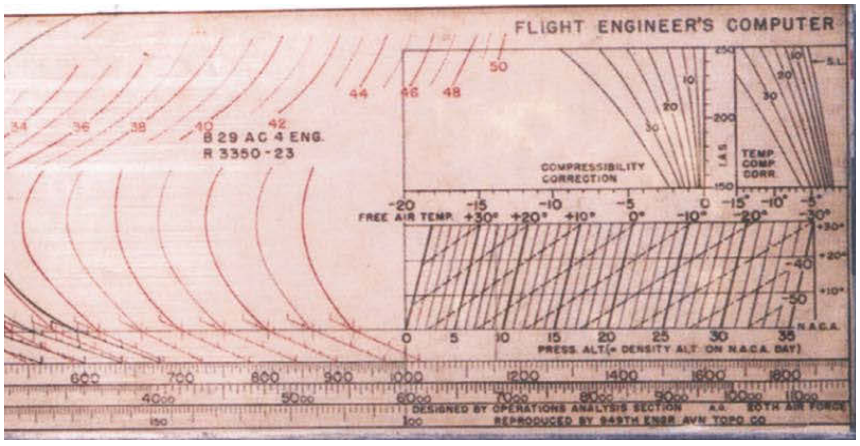


Figure 10 Hand computer for B-29 fuel consumption calculations (partial view)

VI. US Army in Vietnam: back to 1942 flying

The US Air Force adopted and rigorously implemented Standard Procedure Flying, while other air forces were much slower. After the spinoff of the USAAF into an independent service, the US Army was without its own aircraft. By the Vietnam War in the 1960s, the Army had developed its own organic aviation wing, primarily of helicopters. Michael Novosel flew B-29 bombers in WW 2, and in the 1950s advanced to O-5 rank while flying helicopters in the US Air Force. He left the Air Force, but in the 1960s while working as a commercial pilot he wanted to fly in the Vietnam War. The Air Force did not have an opening for him, so he joined the Army at a much lower rank, and was assigned to fly helicopters.

The Army had extensive training for helicopters, but did not send Novosel to be trained. Instead, they gave him a "proficiency test." By the 1960s aviation organizations had standard procedure for checking pilot proficiency in a particular aircraft type: usually a prescribed flight routine with a check pilot, plus a written examination on the aircraft's systems. Novosel's Army evaluator took him up for a check ride, but it did not follow the usual format.

> I made a normal takeoff and left the traffic pattern. We soon were flying over a paved road when he cut the throttle. He wanted to see my forced landing procedure, so I autorotated straight ahead and landed on the road. He said, "Okay, I've got it," and he flew us back to the heliport at Wolters. The entire episode lasted a mere half hour. That check ride was the basis for the people at Fort Wolters to designate me a *bona fide* army aviator. *My old air force associates* [in the 1950s] **w***ould have been aghast at such footloose procedures*. We hadn't even filed a flight plan.

> I knew then that flying for the army was going to be a new experience. I'd have to set aside all the strictures and regulations so common in the air force**.** *I thought of my early days in the Army Air Forces of World War II and realized that I was returning to military flying such as I knew as a young second lieutenant.*[59] [emphasis added]

Thus Novosel draws a sharp contrast between flying as it was done in the USAAF in 1942, and as it was done later in the war and post-war. The Army in 1965 was at the level of the USAAF in 1942.

The Army made a good bet on Novosel – he flew 2600 "dustoff" (medical evacuation) missions in Vietnam. These missions required extreme craft ability. They were called out on a few minutes notice, with little time to plan and little information about the exact locations of friendly and enemy troops. Many evacuations were conducted on bad terrain, under fire, and sometimes at night. Pilots learned to fly the same way they had in the 1930s - by apprenticing (being copilot) to an expert. This is described vividly in the autobiography *Chickenhawk*, by another dustoff pilot in Vietnam.[60] Novosel's son became a pilot in the same unit, and when he was shot down his father went out to rescue him. The son returned the favor a month later. Novosel even flew one "heroic craft" mission so extreme that he won the Medal of Honor for it.

VII. Navy Pilots Are Different

Definition of an optimist: a naval aviator with a savings account.[61]

As discussed earlier, at the end of WW2 the Navy and Air Forces had similar flight manuals, with corresponding procedures, checklists, and quantitative flying rules. Yet by most accounts, Navy pilots were less advanced and less compliant in Standard Procedure Flying than those in the Air Force – a difference that persisted long after the

war. Even the simple checklist was not ingrained. A Navy magazine for aviators contained an article in 1950 titled *Throw away those good-luck charms and use the check-off list*.[62] The examples included pilots forgetting to lower their landing gear, and a non-fatal version of the B-17 prototype crash – the "elevator control locks had not been removed prior to take-off."

The difference in flying methods between the Navy and the Air Force persisted for more than a decade, covering the Korean War and the first 15 years of the Cold War. Thanks to the survival of detailed manuals from WW2 to the present, and a variety of academic papers, we can trace the Navy's transition in unusual detail. The underlying impetus was that jet aircraft had much less margin for variation than prop aircraft, and when the Navy shifted to jets the accident rates became unsustainable. The rate of major accidents reached 70% for at least one fighter aircraft.

Winning Naval Battles

Why was there a discrepancy between Navy and Air Force flying styles immediately after WW2, despite both services having similar training and manuals? The reasons have never been formally analyzed, but several factors may have been important. Size and complexity of most naval aircraft in 1945 were similar to or slightly higher than Air Force fighters, and were far lower than their heavy bombers. In addition naval air attacks, with the exception of some attacks on the Japanese home islands in 1945, were smaller and less tightly coordinated than Air Force heavy bomber attacks. Thus the Navy's post-war leaders had less reason to believe in the importance of tight coordination or flying by the book, and in Standard Procedure Flying as a necessary condition for success.[63]

The most famous naval aviation battle in history was the Battle of Midway in June 1942, between three American carriers and four Japanese carriers. The Americans won the battle not by the mass and precision of Curtis LeMay's Air Force bombing of 1944-45, but seemingly by inspired improvisation. The American carriers and nearby Midway Island launched a total of 15 squadrons of attack aircraft totaling almost 200 aircraft against the Japanese carriers: seven squadrons of dive bombers, six of torpedo bombers, two of B-17 heavy bombers.[64] The squadrons were launched over several hours, without coordination and without accurate information about the location of Japanese ships. Of the 15 American squadrons, two were sent in the wrong direction and never found any enemies. The six squadrons of torpedo bomber squadrons were annihilated, losing 41 out of the 51 aircraft that attacked, without scoring a single hit. The three bomber squadrons on Midway island also attacked without any hits. In total, in the first few hours of American attacks 11 squadrons of bombers and torpedo planes, supported by several fighter squadrons, achieved no hits.

Fortunately for the Americans, the US Navy won at the 11th hour, mainly because of two squadrons of dive bombers from the carrier *USS Enterprise.* They were low on fuel after searching fruitlessly for the enemy, but just before turning for home their leader, Commander (O-5 rank) Wade McClusky, noticed a single Japanese destroyer acting strangely. From that clue, he located the Japanese carriers. By chance, he arrived just as the last of the American torpedo planes was being shot down by Japanese fighters, who were therefore at low altitude and completely unaware of McCluskey's arrival. (Japanese fighters had no effective radios and the carriers had no radar.) By chance, a third squadron from the *USS Lexington* arrived overhead at the same time from a different di-

rection. Between them, the 50 aircraft in the 3 squadrons destroyed three carriers in five minutes.[65]

Figure 11 Aircraft being moved on carrier deck after returning from a bombing mission, October 1943.
Note spinning prop on left, wooden decks, and bomb still in place.

The Americans won a resounding victory in the Battle of Midway, losing one carrier to four for the Japanese. They won even though their attacks were marred by poor coordination (squadrons from different carriers took off at different times), poor communication (McClusky did not know where the enemy was even after other squadrons had found them), and poor weapons (American torpedoes in 1942 were almost all duds). About half of McCluskey's aircraft did run out of fuel while returning to the *Enterprise,* but in retrospect his decision to continue searching when he was low on fuel was correct.[66] Raw courage played a tremendous role. Five out of six of the torpedo squadron leaders were killed, and a similar proportion of the other aircraft. In Torpedo Squadron 8 every one of its 15 aircraft was shot down while attacking, with only one survivor eventually rescued. But their suicidal attacks had a major role in the victory.

The Navy continued from success to success after the Battle of Midway, so it had much less internal pressure to change.[67] Sitting in an armchair 70 years later, we realize that with better quantitative flying (principally engine adjustments) fewer aircraft would have run out of fuel. But in military terms, that was almost irrelevant, because those aircraft had already made their attacks. American aircraft and crews could be replaced quickly; Japanese crews and aircraft carriers could not. Thus the Navy perceived little reason to become more formal and procedural in flying. (Figure 11[68])

Navy Culture

The argument that different experiences in 1942 and 1943 pushed the USAAF and US Navy in different directions is speculative. Whether or not strategic issues were important, there was clearly a notable "personality" difference between Air Force and Navy pilots that contributed to different approaches to flying. Professor Robert Rubel, retired Navy Captain (O-6 rank) and pilot, summarized it as follows:

> Naval aviators always viewed themselves as daredevils. The difficulties of taking off from and landing on ships were unequaled in the land aviation domain, and naval aviators therefore considered themselves exceptionally skilled—and expendable. … Naval aviators always … shared, and still do, the Navy's culture of independence and self-reliance. The simplicity and relative inexpensiveness of early naval aircraft allowed this culture to thrive; flight instruction was personal, and aviators had few detailed procedures or rules to follow in mastering their aircraft. "Seat of the pants" flying and individuality in technique were the orders of the day.[69]

In short, most of Standard Procedure Flying was not part of naval practice.

Around 1950 jets reached naval aviation, and in consequence accident rates rose to unsustainable levels that gradually pushed the Navy toward Standard Procedure

Flying. Jets inherently have very different operating characteristics than propeller aircraft, notably higher speeds and much lower endurance (flight time), and therefore much lower margins for sloppy execution. New jet models arrived with novel problems in design, in procedures, and in training. These problems were gradually uncovered and solved, which "required a trial-and-error process that resulted in the fielding and rapid obsolescence of a series of different jets, each reflecting solutions to the defects discovered in earlier models." [70] The very high rate of change in aircraft technology is reflected in the rapid rate of aircraft development: the Navy had 22 new types of fighters alone between 1945 and 1959, compared with only five new types in the following half century. But hardware changes alone did not overcome the cultural bias in the Navy toward a more artistic flying style. According to Prof. Rubel,

> The Navy has always placed considerable responsibility and authority in the hands of the individual officer. An imperative of war at sea, this delegated style of command and control has both enhanced and afflicted U.S. naval aviation. Throughout its history, outstanding decision making by relatively junior officers has made the difference in battle, such as when, during the Battle of Midway [McCluskey decided to follow the clue to enemy location]…. Faced in the 1940s and '50s with new technology that demanded new types of procedural discipline and centralized management, the culture was slow to adapt, and many naval aviators lost their lives as a result. [71]

One pilot characterized Navy advanced flight training in the 1950s as Darwinian:

> What the flying did not include in those days was a fully-fledged standardization program and a mature Naval Aviation Safety program. The result, predictably obvious by today's standards, was a horrific accident rate. You see, the folks who led us back then were all wily, steely-eyed veterans of World War II and Korea and knew no fear. They trained us the same way they had been trained—by launching us into the hostile sky largely unsupervised with the hope that the

> more promising among us would return alive. Surprisingly, some of us did. It was a training system Charles Darwin would have been proud of.[72]

The Navy at the same time was moving toward night and all-weather capability for its aircraft, which meant radar and often a second aviator, and required considerable new training and development. Night flying knowledge developed at the end of WW2 had lapsed, and when night operations were restarted in the early 1950s, accidents were common.[73] A large "composite squadron" called VC-4 was responsible for all night aircraft activity on the East Coast. Some of the pilots sent to it had little flight experience. Gerald O'Rourke, a member of VC-4 recalled:

> …for the kids newly arrived at VC-4 from the all-prop training command and a short night/radar course in props…, sporting only about four hundred hours of total flight time, the simultaneous introduction to night, weather, and jets, all done in an informal, casual manner, presented a real exercise in personal survival. This demanding environment…exacted a very deadly toll in fatal accidents.[74]
>
> ….
>
> As a matter of custom and tradition, nightfighters were supposed to be a bunch of crazy, suicidal bastards.[75]
>
> ….
>
> All naval aviators are routinely exposed to, or involved in, aircraft accidents. That's accepted as almost a hazard of the trade. In carrier work, where dangers abound, accidents tend to be more frequent. In the night carrier operations of those days, accidents were so frequent that they were considered commonplace and unexceptional. Whenever a det [detachment of four to six aircraft sent out to operate from a carrier for a few months] departed [from VC-4], the aircraft they flew off were more or less written off. No one expected that all of them would ever come back. . . . Unfortunately, the same negativism tended to extend to the pilots as well, whose safe return wasn't much better than the aircraft. Between

> pilots lost, the pilots maimed, and the pilots who decided to throw in their wings [resign], precious few dets ever returned with the same resources they took with them.[76]

Fundamentally, night landings were still done using Rules + Instruments, with a large dose of craft ability. Although night *takeoffs* can be done by carefully following procedures, night *landings* can be learned only through experience, the ability quickly deteriorates when it is not used, and even experienced aviators find them stressful. Heart rates during night landing are sometimes higher than during combat.[77] A modern naval aviator stated that he eventually came to enjoy carrier landings in daylight, but never at night.[78]

In 1953 a famous fighter pilot from WW2, Jimmy Flatley, wrote an alarming critique of Naval aviation's safety record.[79] During FY 1953, 23 percent of the Navy's 14,000 aircraft were in an accident, and 5 percent of them were destroyed. 423 aviators were killed, and the overall accident rate was 51.2 per 100,000 flight hours. In 1954 these numbers rose to 535 deaths and 54 accidents per 100,000 hours. This is a Mean Time Between Failure of only 1850 flying hours, and a pilot serving a 20 year career in the Navy had approximately a 25 percent chance of being killed in an accident.[80]

Although Flatley's report captured the Navy's attention, the problems were not solved quickly. Professor Rubel concluded that it took the Navy until 1988 to complete its transition to jets. 1988 was the year its accident rate declined to the level of the Air Force: [81]

> The logic behind this reasoning is that whereas a multitude of factors—technical, organizational, and cultural—constitute the capability to operate swept-wing jets, the mishap rate offers an overall indicator of how successful an organization is in adopting a new technology. Using this criterion, the Navy's transition pro-

> cess lasted until the late 1980s…. This article argues that tactical jet aircraft design and technology presented Navy aircrews, maintenance personnel, and leaders with several major challenges that were in fact not substantially overcome until the introduction of the F/A-18 Hornet in 1983. These challenges included such technical problems as engine reliability and response times, swept-wing flight characteristics, and man/machine interface issues. The Air Force also encountered these challenges [from jets], but the Navy's operating environment and, indeed, its organizational culture kept it from achieving a fully successful transition until well after the Air Force did.

Rubel cites the Navy's F-8 Crusader supersonic jet fighter, introduced in 1957, which killed 186 pilots over its 18 year service life. Its accident rate in 1957 was 243.9 accidents per 100,000 flight hours, which works out to a mean flight time between accidents of 409 hours – less than two years for many jet pilots.[82]

> The F-8 was always known as a difficult airplane to master. In all, 1,261 Crusaders were built. By the time it was withdrawn from the fleet, 1,106 had been involved in mishaps. Only a handful of them were lost to enemy fire in Vietnam. While the F-8 statistics might have been worse than those for most other models, they make the magnitude of the problem clear: whether from engine failure, pilot error, weather, or bad luck, the vast majority (88 percent!) of Crusaders ever built ended up as smoking holes in the ground, splashes in the water, or fireballs hurtling across a flight deck. This was naval aviation from 1947 through about 1988.[83]

The Crusader entered service about 10 years after the first naval jets, and four years after Flatley's report. Its very high accident rate was partly due to fixable design flaws – even today, most commercial and military aircraft have higher accident rates in their first few years of service. But many accidents were due to pilots' techniques. Adm. Gillcrist flew Crusaders for many years, and personally witnessed numerous accidents. In one, Gillcrist and other pilots were re-qualifying to land on carriers. Since it had been more than six

months since their last landing, they needed to make eight day and six night landings – almost as many as were needed for initial qualification. Fellow pilot Richardson used a shortcut to make his landings, in which he took his eyes off the landing system lights at the last moment and looked directly at the carrier deck. This technique, called "spotting the deck," is instinctive and works well for simulated carrier deck landings on runways, but is dangerous on ships because of the chance of descending short, which is called a "ramp strike." On this particular night, Richardson's aircraft landed short, hit the edge of the deck, split in half, and created a fireball. His seat ejected but propelled him into a ship structure, while the wreckage of his aircraft knocked two deck crew into the water.[84] All three men were killed. Figure 12 shows a similar accident, in daylight.[85]

Figure 12 F7-U jet fighter-bomber ramp strike on an aircraft carrier, 1955.

The Navy had not implemented standard procedure flying in practice, and that created an unsustainable situation.

> In the early years of the jet transition, naval aviation remained wedded to its individualistic culture. Structured programs of training, detailed reference

> manuals, and disciplined evaluations of pilot performance did not exist in any coherent way across naval aviation. But jets, with their higher speeds, challenging handling characteristics, and ever more complex systems, required just that. The horrible accident rates eventually drove the Navy to do something…. [86]

NATOPS Implements Standard Procedure Flying

The Navy eventually tamed its accident record. Some changes were outside our scope, such as angled decks and other British innovations in carrier design.[87] But critical changes finally made Standard Procedure Flying part of Navy culture. The story is told by Vice Admiral Robert F. Dunn, in his article about naval aviation from 1958 to 1963, *Six Amazing Years: RAGs, NATOPS, and More*.[88] The new knowledge was embodied in NATOPS manuals, which stands for Naval Aviation Training and Operations Procedures Standardization.

> Vice Admiral Robert Pirie, USN, Deputy Chief of Naval Operations (Air Warfare) … made the basic decision that there must *be one best way* to, say, make an approach in an A-4, [or] recover from a Cutlass post-stall gyration…. He put a team together to find, for each situation, that best way.… Naval Aviators who were actually flying the aircraft in the fleet, lieutenants and lieutenant commanders, wrote the books…. Agreement had to be reached from squadron to squadron and fleet to fleet and up the chain of command before any NATOPS manual was approved. …The end result was *a manual that stipulated the best method of performing every function in a given aircraft*…
>
> …
>
> … Of course, manuals for every aircraft type did not spring up the day the instruction was signed; it took a great deal of work and coordination to bring out each one. … within the year manuals for forty-seven aircraft had been issued. It was as if everyone had thought, "It's about time!" Gone were arguments with newly arrived operations officers about the "right way." Down went the mishap

> rate. Almost everyone pronounced NATOPS to be "good," though diehards continued to grumble about lost opportunities for initiative.[89] [emphasis added]

The NATOPS manuals started out as distinct from aircraft Flight Manuals, but by about 1964 they were consolidated. The early one or two page "cockpit checklists" grew to separate pocket-sized reference guides of 50 to 100 pages. The NATOPS knowledge development process added a considerable amount of depth to the procedures and quantitative information about each aircraft, and we can measure the change. For example the 1962 Navy manual for the A-4 aircraft totaled 165 pages (without classified performance supplement), while the 1970 NATOPS manual for the same aircraft was about 586 pages. The checklists expanded even more, and became booklets that fit into the pilots' flight suit.

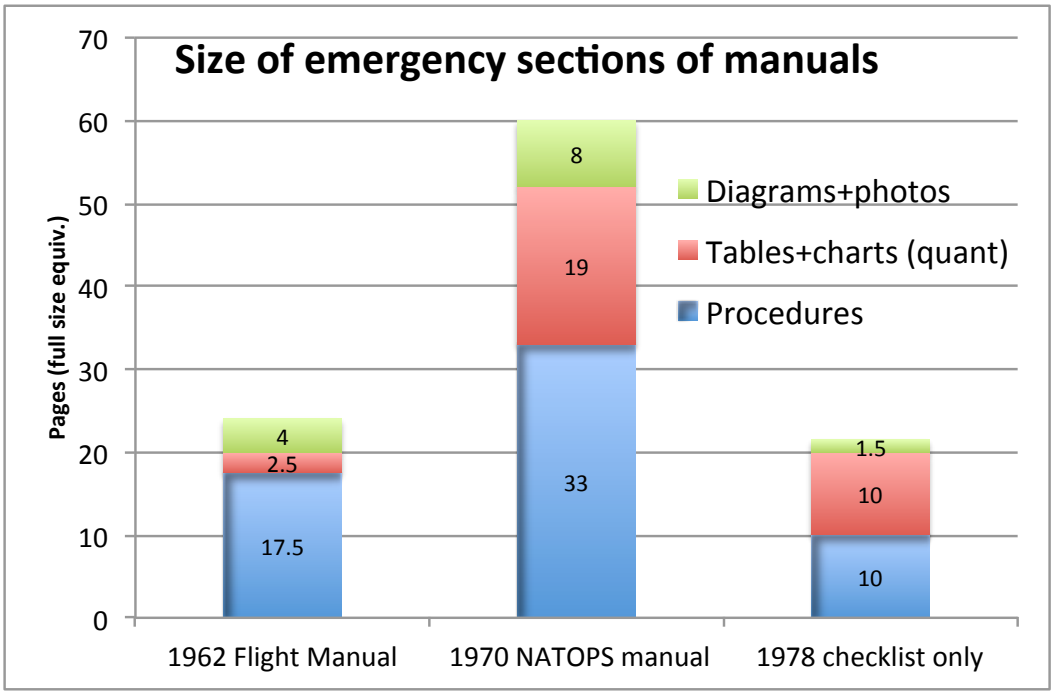
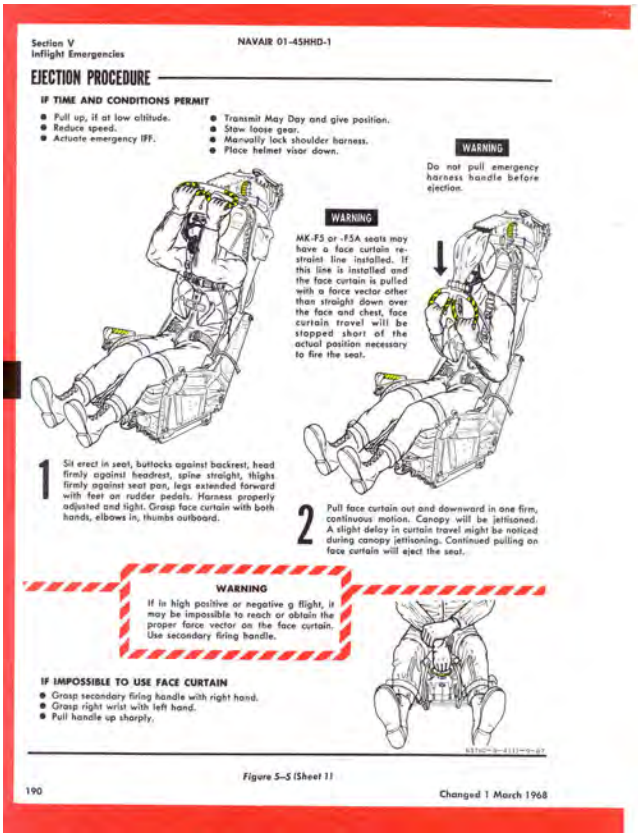


Figure 13 Comparison of Emergency sections of A-4 manuals, before and with NATOPS

Figure 13 compares the EMERGENCY PROCEDURES sections of each manual

for a single aircraft, before and after NATOPS was introduced. The 1970 NATOPS manual has twice as many pages of emergency procedures as its 1962 non-NATOPS counterpart, and 250% as many pages in total (24 versus 60).[90] It has extensive quantitative flying data (tables and charts), covering 19 pages. In addition, the on-board NATOPS Pocket Checklist (from 1978) has an " Emergency Procedures" section of 45 pages, including 20 pages of quantitative data.[91] These 20 pages include more than 10 pages of detailed nomograms (diagrams used for analog computation) covering takeoff and landing weights, distances, and speeds. For example one nomogram calculates V_1 speed (referred to as "takeoff refusal speed") as a function of aircraft gross weight, airfield length, pressure altitude, air temperature, headwinds, and runway slope.


Section V
Inflight Emergencies

NAVAIR 01-45HHD-1

EJECTION PROCEDURE

IF TIME AND CONDITIONS PERMIT

- Pull up, if at low altitude.
- Reduce speed.
- Actuate emergency IFF.
- Transmit May Day and give position.
- Stow loose gear.
- Manually lock shoulder harness.
- Place helmet visor down.

WARNING

Do not pull emergency harness handle before ejection.

WARNING

MK-F5 or -F5A seats may have a face curtain restraint line installed. If this line is installed and the face curtain is pulled with a force vector other than straight down over the face and chest, face curtain travel will be stopped short of the actual position necessary to fire the seat.

1 Sit erect in seat, buttocks against backrest, head firmly against headrest, spine straight, thighs firmly against seat pan, legs extended forward with feet on rudder pedals. Harness properly adjusted and tight. Grasp face curtain with both hands, elbows in, thumbs outboard.

2 Pull face curtain out and downward in one firm, continuous motion. Canopy will be jettisoned. A slight delay in curtain travel might be noticed during canopy jettisoning. Continued pulling on face curtain will eject the seat.

WARNING

If in high positive or negative g flight, it may be impossible to reach or obtain the proper force vector on the face curtain. Use secondary firing handle.

IF IMPOSSIBLE TO USE FACE CURTAIN

- Grasp secondary firing handle with right hand.
- Grasp right wrist with left hand.
- Pull handle up sharply.

Figure 5-5 (Sheet 1)

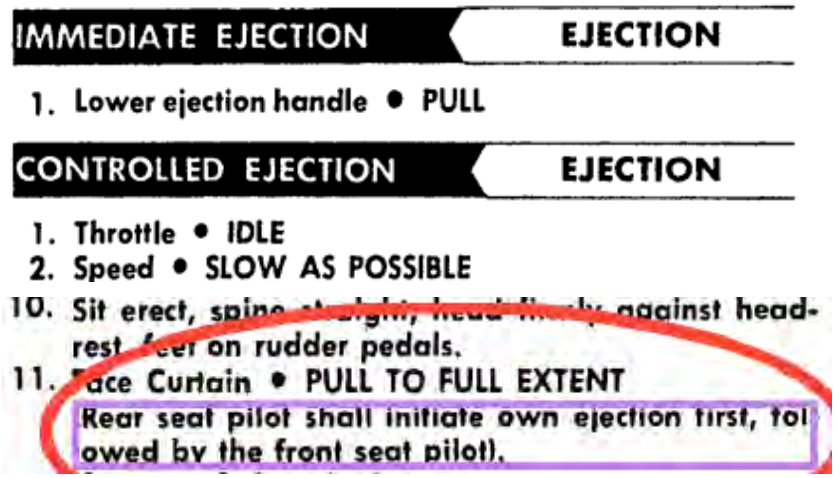
190

Changed 1 March 1968

Figure 14 Page from emergency section of F-8 Crusader manual, 1968

The main NATOPS manual has 23 pages devoted to ejecting from the aircraft, including 5 pages of diagrams showing how ejection system's complex sequence of automatic activities and 15 pages of graphs showing "terrain clearance for safe ejection" under different flight conditions. Figure 14 is an example of such a page, from a different aircraft. At the opposite extreme, the pocket checklist

discussion of ejection is reduced to a single page, consisting of two procedures. The first procedure has a single action of four words. (Figure 15) The second one has eleven steps, plus six more to try if the first eleven don't work. Two procedures are needed since the longer controlled ejection procedure leads to less injury to pilots, but the short immediate ejection procedure is a few seconds faster.


IMMEDIATE EJECTION EJECTION

1. Lower ejection handle • PULL

CONTROLLED EJECTION EJECTION

1. Throttle • IDLE
2. Speed • SLOW AS POSSIBLE

10. Sit erect, spine [illegible] against head-rest, feet on rudder pedals.
11. Face Curtain • PULL TO FULL EXTENT

Rear seat pilot shall initiate own ejection first, followed by the front seat pilot).

Figure 15 Two ejection procedures for TA-4 aircraft (1978) The first is is shorter, the other is safer if you have time.

Creating and commanding use of the NATOPS system did not suddenly overcome resistance to standard procedure flying. Prof. Rubel describes some of the resistance.[92]

> However the "ready room" culture was resistant to change. … A major element of the resistance to change was the fact that adaptation to the new technology … made irrelevant certain skill sets that had been associated with being a "good" aviator. The issue was not so much the difficulty of learning new skills as reluctance to abandon old ones that were associated with professional virtue. The naval aviation culture that had grown up from 1911 to 1947 was intense, parochial, and value-centric. Moreover, likely because of the acrimonious relationship that developed between the two services in the late 1940s, there was a reluctance to view anything the Air Force did as appropriate for naval aviation.

An August 1961 article in a Navy magazine titled *'The One Best Way', New Stan-*

dards for Naval Air addressed the fear that standardization will limit pilots' flexibility:[93]

> Some people view the idea of everyone in Naval Aviation doing everything 'the one best way' with some misgivings. *They fear that general use of standardized procedures*, while it may reduce the accident rate, *will result in a reduction of a pilot's ability to 'think on his feet' and deal flexibly with emergencies and combat situations.* Experience in other fields has proved that fear unfounded. [emphasis added]
>
> The Aviation Training Division, which has Chief of Naval Operations responsibility for the NATOPS program, answers the argument this way: "This program is only a continuation of the standardization which all pilots are taught in the training Command. As we know, the Training Command has one of the most effective organizations of its type in the world today and its safety record is outstanding. Standardization has been a major key to success.
>
> "The new NATOPS program was developed by the users for the users. It will be modified, as we go along, by the same individuals. Tricks of the trade will be passed around quickly for expert evaluation and, if sound, for use by all hands. The end result will be increased operational readiness through increased safety, brought about by improved pilot techniques."

Both the language ("one best way") and the arguments about standardization parallel 1920s debates about Taylorism in manufacturing. Some experienced pilots viewed it as a reduction in their autonomy, flexibility, and ability to use the flight expertise they had built up over a decade or more. The counterargument, as with Taylor, was that if a best way to do a particular activity existed, everyone should use it. After all, no single pilot would ever experience all the possible emergencies that were covered. Unlike Frederick Taylor, fortunately, the US Navy had the wisdom to use the "front-line managers" such as squadron commanders as the first-level source of these procedures. When disagreements existed, for example whether to use speed brakes when landing, the NATOPS development system would test the alternatives and get consensus on the final answer.

NATOPS had another major difference from Taylor's system. The system included explicit mechanisms for learning and change, both top-down and bottom-up. "Frequent and regular NATOPS conferences under the auspices of the air type commanders helped to keep the manuals current and useful."[94] The front "promulgation letter" in each NATOPS manual today still emphasizes *both* the value of standardization, and the value of flexibility. It reads in part:

> [NATOPS-led] standardization, based on professional knowledge and experience, provides the basis for development of an efficient and sound operational procedure. The standardization program *is not planned to stifle individual initiative*, but rather *to aid the Commanding Officer* in increasing the unit's combat potential without reducing command prestige or responsibility.
>
> 2. This manual standardizes ground and flight procedures … In order to remain effective, *NATOPS must be dynamic and stimulate rather than suppress individual thinking. Since aviation is a continuing, progressive profession, it is both desirable and necessary that new ideas and new techniques be expeditiously evaluated and incorporated if proven to be sound.* To this end, Commanding Officers of aviation units are authorized to modify procedures contained herein,..., for the purpose of assessing new ideas prior to initiating recommendations for permanent changes. …[emphasis added]
>
> 3. Checklists and other pertinent extracts from this publication necessary to normal operations and training should be made and carried for use in naval aircraft.[95]

As manuals were updated, individually changed pages were sent out to all users to insert in the loose-leaf binders. The rate of change was high even when an aircraft type was nearing the end of its service life. For example a rewritten pocket checklist was issued in April 1972 for the models TA-4F and TA-4J. It was revised every 24 months thereafter.[96] By 1978 it had grown from 124 to 145 pages (14% growth), and of those

pages, only 50 had not been changed (34% of the 1978 version). For example, four items were added to the 22 item checklist for the aircraft's *forward fuselage preflight inspection*. New item 12A was to make sure that a particular nut was securely tightened. A new procedure was also added for an obscure situation: "STUCK SPOILER ON LANDING ROLL."

These very specific updates were generally to fix problems that had caused an accident. For example in December 2008 a naval aircraft crashed near my house. The pilot was conducting carrier qualification landings on the *USS Lincoln*, 100 miles off-shore of San Diego, when the right engine of his F/A-18 gave an oil pressure warning. He shut down the engine and was diverted to Miramar Marine Corps Air Station near my house.[97] Although there was still fuel on board, the pilot did not transfer it properly to the left tank, and the left engine ran out of fuel shortly before the aircraft would have landed. Twenty seconds later the aircraft crashed into two houses, killing four people on the ground. The pilot ejected at the last second, and was not hurt.

The subsequent accident investigation established the sequence of events that ended so badly. It started with some maintenance errors weeks earlier. But failure to read and follow emergency procedures was a factor in the last few minutes. The accident report stated that "The [squadron officer on the carrier] should have read the entire Single Engine Approach and Landing Procedure to the [pilot], including all warnings, cautions, and notes." Instead, neither the pilot nor the officers advising him by radio read the relevant sections of the checklist.[98]

The accident review board's recommendations included changes to the NATOPS procedures for the aircraft, to other NATOPS documents, and even to the F/A-18 simula-

tor used for training, which incorrectly simulated the fuel management problems the pilot had encountered. Several of the squadron's officers were relieved of duty.

NATOPS was not the only major change that affected Navy flying and safety. Until 1958, pilots went directly from their flight training into operational squadrons, where they were taught how to fly the specific aircraft type of that squadron. In contrast, during WW2 pilots were sent to type-specific land-based training units. As a result, "he was combat ready when he reported to his squadron."[99] This practice was dropped after the war, but with jets the complexities and the radical differences between jets and prop-powered flight training aircraft led to a difficult situation for new pilots – as with the comment about "Darwinian training" above.

Therefore in 1958 the Chief of Naval Operations reorganized carrier aviation and "provided for a permanent replacement Air Group to be established on each coast and made responsible for the indoctrination of key maintenance personnel, the tactical training of aviators, and conducting special programs required for the introduction of new models of combat aircraft."[100] These became RAGs (Replacement Air Groups) and were eventually expanded to two sites for each aircraft type in the inventory. The effect was immediate. In 1959, the first full year of operation, four percent of A-4 pilots who had gone through the RAG had accidents with pilot-related causes, compared with 11 percent of conventionally trained pilots.[101]

When NATOPS arrived a few years later, it was integrated with training. The NATOPS program includes annual checks of every pilot, testing them on their knowledge of the material relevant to their aircraft. Training and standard procedure flying are com-

plements, meaning that each enhances the value of the other.

To summarize, although the US Navy taught Standard Procedure Flying in WW2 training, its pilots used it considerably less than their USAAF air force counterparts did. A loose approach to procedures and flight discipline led to heavy losses from accidents when the Navy shifted to jets in the 1950s. In the early 1960s, the Navy took Standard Procedure Flying to a more advanced level with its NATOPS program.

VIII. British Air Force

At least on paper, all the American air forces adopted Standard Procedure Flying by the end of the war in 1945. Other nations were far behind. The British Royal Air Force (RAF) had a rudimentary start on Standard Procedure Flying by 1940, including use of procedures, but progressed only modestly over the next five years. This is surprising since the RAF and USAAF were in close physical proximity in England and collaborated to an extent. The RAF even sent thousands of trainees to the US for several stages of flight training, and had access to, but did not use, USAAF manuals for some of its aircraft.

The Flying Club

Like the US Army in 1934, when it was briefly and disastrously given the job of flying all airmail in the US, the pre-war RAF flew simple aircraft and still used the Heroic Craft approach to aviation – instrument flying was almost unknown. One officer commented that "Such was the style of the Service [RAF] at the time that it was known as the 'Best Flying Club in the World,' but measured against today's standards [it was] *utterly amateurish and grossly incompetent*."[emphasis added][102] And indeed, "utterly amateurish and grossly incompetent" attitudes and practices are described in numerous memoirs about the period. Air Vice-Marshal (O-8 rank) A.G. Dudgeon, writing in 1985, described his career as "above all fun."[103] He admitted that he was lucky; of his pilot class, 85% were killed "along the way." Dudgeon mentions in passing that a year after they graduated from the RAF's elite flying college, "Mad Wally," the best pilot in their class, killed

himself while performing a spin almost to the ground. His purpose was to scare another pilot, and the stunt went fine, except that he delayed the pullout a little too long. A few weeks later another classmate and close friend began his first night flying practice in an operational aircraft by attempting a fancy maneuver. He lost orientation and flew into the ground. A historian who was also a retired military pilot summarized the training and flying of the period as follows: "While we have all read spirited, even amusing, accounts of what great fun all this was, we should bear in mind that these were written by the guys who got away with it – which certainly excludes the more than 200 who had died in 1938 alone."[104]

This craft approach to flying collided with the RAF's technological discontinuity in aircraft design in the run-up to WW2. In 1936, most of its aircraft were still biplanes made of wood, fabric, and wire. They were obsolete, and Britain began to develop modern aircraft which introduced multiple complexities for pilots:

- Single wing, mainly metal construction rather than biplanes with fabric and wood construction;
- Hydraulic systems, which allowed retractable landing gear, flaps, and adjustable engine cooling;
- Closed cockpits and oxygen supplies;
- Variable pitch propellers and superchargers;
- Electrical systems, with radios and lights;
- Artificial horizons.

Figure 16 compares the cockpit of a 1941 Hurricane fighter, with a biplane fighter of the 1930s, the Gloster Gladiator. The Gladiator does not even include an artificial hori-

zon, as RAF (like most air forces until the late 1930s) were thinking mainly in terms of clear weather flying. This omission was fatal for some pilots, as discussed later.

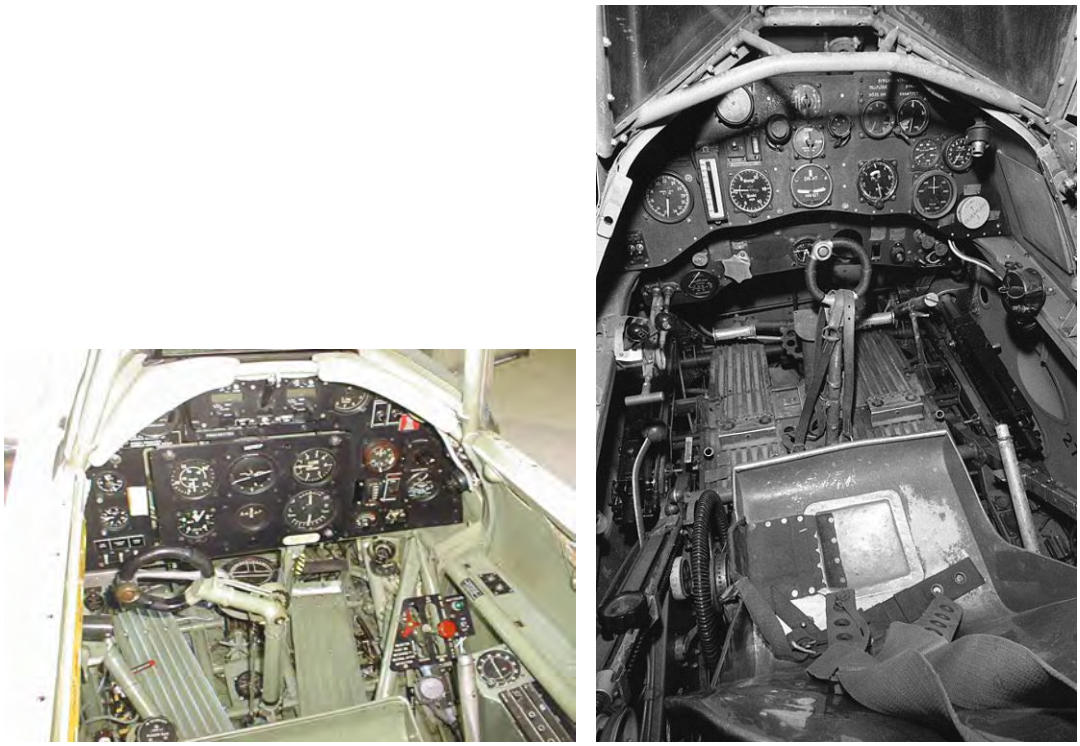


Figure 16 Cockpit of WW2 fighter compared with pre-war biplane fighter Hawker Hurricane versus Gloster Gladiator [105]

Heavy aerial fighting began in May 1940 when Germany invaded France, and by then most British front-line squadrons had been re-equipped with these modern aircraft. But pilots flying aircraft with so many changes should in principle have had more than one hundred hours of flight time "in type" before entering combat.

Raold Dahl (1916-1990), later the author of drily humorous children's books, was a new RAF pilot in the Middle East in 1941. He was given only two days to teach himself how to fly a Hurricane fighter – without any manual or instruction. It was the first time he had flown anything but biplanes -- see Figure 16 for an indication of the magnitude of the

transition. "Somehow I managed to get the thing off the ground and back down again without smashing it up, but for me it was like riding a bucking horse. *I was just beginning to learn where most of the knobs were located and what they were used for* when my two days were up" and he had to fly solo from Egypt to Greece.[106] Dahl made it across the Mediterranean, and went into combat the next day with a total of seven hours in a Hurricane, and without even a wingman. But he managed to shoot down a German aircraft and to survive the next two weeks of fighting against overwhelming numbers. Another pilot in his squadron was probably the leading scorer in the RAF - but he did not survive the two weeks. Memoirs are indeed "written by the guys who got away with it."

A.G. Dudgeon's memoir provides another example of the "amateurishness and incompetence" of the RAF just before the start of WW2. His squadron in India was upgraded in 1939 from cloth and wood Hart biplanes (maximum speed 161 knots, maximum takeoff weight MTOW 2100 kg) to the twin-engine Bristol Blenheim bomber, a new first-line aircraft (maximum speed 231 knots, MTOW 6500 kg). A single Blenheim was delivered to the squadron, in which the squadron commander took a flight with the delivery pilot. There was space for crew but no dual controls, so only one person could fly at a time. The squadron commander then took Dudgeon for a flight the same way. Documentation consisted only of handwritten notes by someone who had flown Blenheims –which gave the pilots their first explanation of an artificial horizon.[107] The third step in the squadron's conversion program was for Dudgeon to train the rest of the squadron's pilots in the same way he was trained – with "no instructors on the new techniques, no books on the arts needed, and no one with sound experience on the machine who could tell us what to do." Amazingly, nobody was killed and no aircraft were lost in

the next few weeks. This method of training is from the Heroic Flying era – get in, fly, and learn by doing or crashing. But with these higher performance aircraft, crashes were much more likely to be fatal, as well as more financially expensive, than they had been twenty years before.

Dudgeon's squadron was then dispatched on a 3000 mile, multi-day trip to Singapore. Some of the pilots had only 2 hours flight time in the Blenheim when they started off.[108] A senior officer flew his aircraft into a monsoon storm cloud. The artificial horizon probably lost its orientation in the violent storm. But their handwritten flying notes had not warned about this possibility, and he and his crew were killed. Another pilot accidentally raised his landing gear while taxiing. A third pilot with engine trouble did a forced landing on a grass field – which turned out to be a pond. In all only about half the aircraft arrived in Singapore. This was a colossal waste of new state-of-the-art aircraft, one month before Britain declared war on Germany.

The First RAF Pilot's Manuals

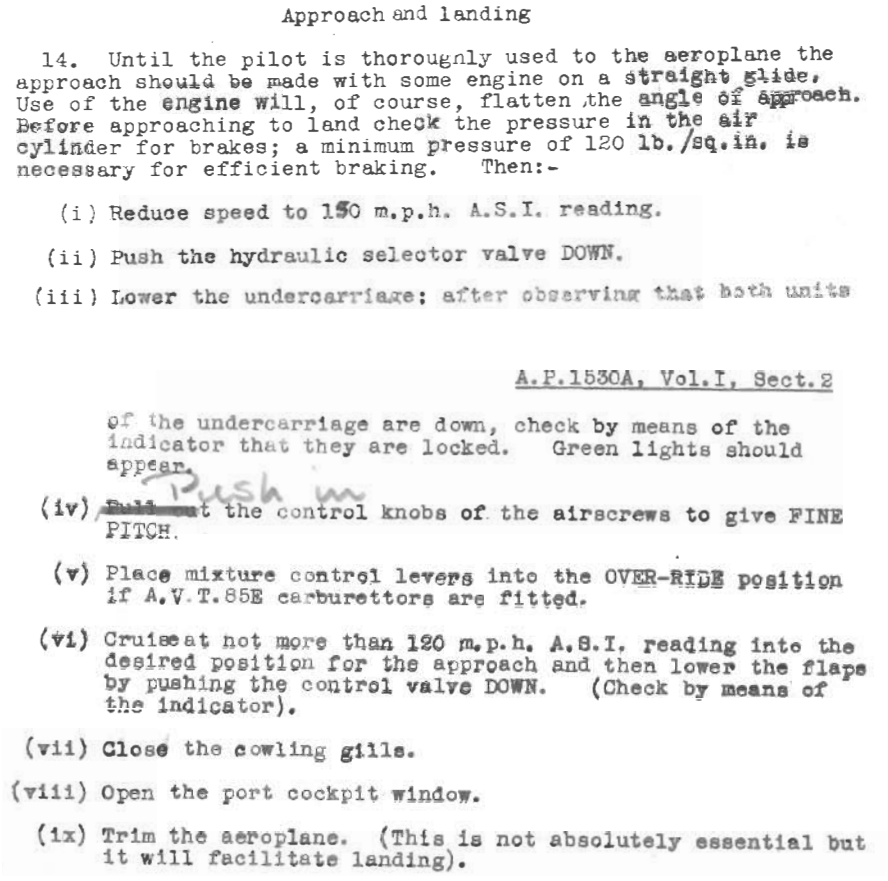
Rising accident levels from 1935 onward led to various proposals to increase safety, and one proposal that made its way successfully through various committees was:

> the introduction of what [a senior officer] called 'Users Manuals'. The outcome was the establishment of a … unit … tasked with assessing the characteristics of new [aircraft] types as they entered service, and producing written advice on the best way to fly them and pointing out the likely pitfalls. By late 1939 the first editions of *Pilot's Notes* had begun to appear.[109]

Such manuals are a prerequisite for Standard Procedure Flying. Previously, the RAF had had a single very general manual on flying regulations, plus manuals that discussed maintenance of particular aircraft, but it did not have *any* written type-specific

advice about how to actually fly. There were no formal procedures, no checklists, and apparently no standardized numbers even for critical activities like landing.

What was in these new RAF manuals, called *Pilot's Notes*? They mixed descriptions of controls with simple procedures. Figure 17 is the pre-landing procedure from a 1939 Pilot's Notes for a Blenheim twin-engine bomber.[110] The writing, at least to the modern eye, is formal and pedantic. But the procedure is reasonable and easy to understand, aside from the reversed instructions about how to set prop pitch in item (iv). A former RAF pilot described a heavy bomber's manual as "[t]he RAF's Lancaster manual consists of fairly tedious lists and diagrams whereas the equivalent American version for the B-17 contains more 'cartoony' graphics which may have helped the reader to get a feel for operating a B-17 more quickly."[111]



Approach and landing

14. Until the pilot is thoroughly used to the aeroplane the approach should be made with some engine on a straight glide. Use of the engine will, of course, flatten the angle of approach. Before approaching to land check the pressure in the air cylinder for brakes; a minimum pressure of 120 lb./sq.in. is necessary for efficient braking. Then:-

(i) Reduce speed to 150 m.p.h. A.S.I. reading.

(ii) Push the hydraulic selector valve DOWN.

(iii) Lower the undercarriage; after observing that both units

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of the undercarriage are down, check by means of the indicator that they are locked. Green lights should appear.

(iv) Push in the control knobs of the airscrews to give FINE PITCH.

(v) Place mixture control levers into the OVER-RIDE position if A.V.T.85E carburettors are fitted.

(vi) Cruise at not more than 120 m.p.h. A.S.I. reading into the desired position for the approach and then lower the flaps by pushing the control valve DOWN. (Check by means of the indicator).

(vii) Close the cowling gills.

(viii) Open the port cockpit window.

(ix) Trim the aeroplane. (This is not absolutely essential but it will facilitate landing).

Figure 17 Landing procedure from first British manual for Blenheim Aircraft, 1939.

Penciled correction in the original

The 1939 discussion of how to recover from a spin in a Hurricane fighter was a gem of bad technical writing.[112] Spins are accidental departures from controlled flight. (Chapter 3) If an aircraft gets into a spin without enough altitude to recover, the only solution is to bail out – otherwise the pilot is doomed. Here is the advice on spins, quoted at length to illustrate tedious, frightening, confusing, and almost useless technical writing:

> 22. Spinning.- Spinning of Hurricanes is prohibited (A.M.O.A.15/1938). The following extract from an Experimental Establishment report is included in order that a recovery may be made from an inadvertent spin.
>
> "The aeroplane is easy to spin, more noticeably so at the extended aft centre of gravity. [which probably means 'when the aircraft's center of gravity is far back'] …
>
> …[several paragraphs of data on height loss in spins, concluding with]
>
> "… The average total height lost from initiation of the spin to attainment of level flight is about 3,800 feet for a three turn spin….
>
> "It appears that the aeroplane emerges from a spin in a stalled state which persists for a considerable portion of the resultant dive if backwards pressure is exerted on the control column. If however the control column is pushed forward in recovery so that no effort is made to flatten out from the dive until a reasonable airspeed is reached, the stalled condition is avoided but the height lost is prohibitive. [In other words, "damned if you do; damned if you don't."] It will be seen, therefore, that if recovery is made according to Flying Training Manual Part I., the loss of height during the recovery is normal considering the [Hurricane's high] wing loading. On the other hand there is fear of flicking into a spin in the other direction because the aeroplane emerges from the spin in a stalled state.
>
> The instructions laid down in the Flying Training Manual Part I., Chapter III, paragraph 134, are applicable to the Hurricane, but should be amplified in

light of the foregoing remarks.

We must pity new pilots who reported to an operational squadron for the first time and were handed this. They were expected to have the "Flying Training Manual Part I." readily accessible, and understand how to "amplify" its instructions. Such a newcomer would learn more from a face-to-face discussion with an experienced Hurricane pilot. But even an experienced pilot wouldn't have much experience with spins, since spins were forbidden according to "A.M.O.A.15/1938". And the rapid expansion of the RAF meant that it had far too few experienced leaders in any case. At the end of 1938, it had less than half its authorized number of O-3 level officers.[113]

The British manuals were not just written differently; they were much shorter and less detailed than American manuals. Since both air forces flew some of the same aircraft, and wrote their manuals independently, we can quantify the differences. The British manual for the B-17 heavy bomber was 48 pages. The USAAF manual for the same aircraft in October 1943 was more than twice as long.

Table 5-3 compares two 1944 manuals for the P-51 aircraft, called the Mustang by the British. The American manual was about 2.9 times larger than its British counterpart, adjusting for the much larger size of its pages. It had only 68 percent as much textual description, but 6 times as much visual description (diagrams plus photos, many of them heavily annotated). The American manual had 30% more procedures, and on average they were considerably more detailed: 40% more steps per procedure, and 80% more words per procedure. TheAmerican manual was also much more quantitative. Within the main manual it had 50 percent more numbers, some of them expressed in graphs rather than tables. The long appendix had about 20 pages of additional detailed data tables. [114]

	US P-51D	***RAF Mustang III***	***US/ RAF***
Date of last revision	*April 1944*	*June 1944*	
Gross number of pages	*78 (includes 22 pages of detailed tables)*	*48*	*1.6*
Numb. of pages times words per page	*660*78*	*370*48*	*2.9*
Number of photos + diagrams	*11+19*	*4+1*	*6.0*
Words of description	*4,300*	*6,300*	*0.68*
Number of numbers + graph equivalents	*740 (not including approx 6000 words in appendix)*	*500*	*1.5*
Words of procedures	*7,100*	*3,000*	*2.4*
Number of distinct procedures	*31*	*24*	*1.3*
Avg. # steps per procedure	*4.9*	*3.4*	*1.4*
Words per procedure	*230*	*125*	*1.8*

Table 5-3 Comparison of American and British manuals for P-51 Mustang Aircraft

Just as for the American fighter pilots, simply writing user manuals did not solve the problems of risky and incompetent flying. In the first half of 1941 – more than a year after WW2 started for the British – the RAF was losing 170 aircraft per month in operational accidents – far more than were being lost in training. On average 12 men per month were lost while showing off –a problem that was not unique to the British, but was indicative of weak flying standards and discipline. The rate of major accidents in 1941 was 340 per 100,000 flying hours -- which is roughly 1.7 major accidents per pilot per year.[115]

RAF Checklists

Strangely, the RAF did not use formal in-cockpit written checklists of the American kind until the 1950s. By 1940 some Pilot's Notes did have something called "drill of

vital actions before takeoff," illustrated in Figure 18.[116] Pilots were admonished that "Some of this may already have been done, but must invariably be checked before every take-off." Some bomber manuals show versions of these simple "drills" in 1939. By 1944, manuals included a similar drill before landing, and a 1946 Spitfire manual referred to them as a "check list."[117]

In order to make these "cockpit drills" easier to remember, trainees were taught crude mnemonics for different aircraft, such as "TMP Fuel, Flaps" in Figure 18. These lists were intended to be *memorized*, not carried in the cockpit.[118] But memory aids are no substitute for written checklists. Memorized lists are much more error prone than in-cockpit lists, and doubly so for pilots who are inexperienced, tired, distracted, in a hurry, nervous, or wounded – most of which probably applied to 20 year old fighter pilots like Raold Dahl taking off to intercept incoming German bombers.

FINAL PREPARATION FOR TAKE-OFF - DRILL OF VITAL ACTIONS

7. On reaching the take-off position, stop across wind, facing the aerodrome circuit, and carry out the Drill of Vital Actions. Some of this may already have been done, but must invariably be checked before every take-off. A convenient catch-phrase is applied to this drill "T.M.P. and Flaps".

(i) -	T - Trimming tabs	-	Elevator about one division nose down from neutral. Rudder about central or, if preferred fully to starboard.
(ii) -	M - Mixture control	-	Back to NORMAL
(iii) -	P - Pitch control	-	FULLY FINE (lever fully forward)
	and Flaps	-	UP (These must never be down when taking-off, as they would be at 85°).

Figure 18 Drill of Vital Actions, from Spitfire Pilot's Notes, 1940[119]

"Boy" Wellum (1921-) describes working purely from memory for his first familiarization flight in a high-performance Spitfire fighter in 1940. He "[took] my time doing the cockpit checks and try to remember what I've been told" about the differences be-

tween the Spitfire and his training aircraft. Even vital differences that would cause a crash, such as adjusting the prop pitch before takeoff, were in procedures but not written down in a cockpit-accessible list. A few weeks later, while landing after his first operational flight, Wellum was focused on landing before he ran out of fuel, and almost forgot to adjust the prop pitch.[120] In 1940 Douglas Bader, who later became a famous ace despite being a double amputee from a pre-war flying accident, crashed his Hurricane on takeoff. It was only a few months after he had transitioned from a training aircraft into the much more complex fighter, and he had forgotten to set the prop pitch control before takeoff.[121] Such episodes were accepted as a matter of course; Bader was barely admonished.

Lack of true checklists undoubtedly contributed to high accident rates. During training in 1939, Wellum watched a classmate take off on his first night solo flight. All he could see were his friend's navigation lights, which seem to be going up too fast. Then, still at full throttle, the aircraft flew into the ground. Two days later, the Flight Commander called all the trainees together, and silently wrote on the board "COCKPIT DRILL." The friend had forgotten to "uncage his gyros" before taking off, rendering his artificial horizon useless and making it impossible to stay oriented on a dark night. This was portrayed as a personal failure by the dead trainee, not as a flaw in procedures or checklists.[122]

Bombers, which were considerably more complex than fighters, also lacked onboard checklists. One reminiscence was that as late as 1949, "squadron pilots laughed about the American system of having checklists." The flight engineers on the Lancaster bomber did have their own complex procedures, such as external preflight checks and for starting engines, which were detailed in *Flight Engineer's Notes*. There is no evidence

whether these were available while on the aircraft. Some crew members also wrote their own procedures to summarize the official ones – in effect creating a checklist.[123]

Quantitative flying was gradually introduced over the course of WW2. Manuals in 1939 had a few rules of thumb, such as the following for the two-engine Blenheim bomber. "Most economical cruising.- For most economical cruising the engines should be throttled down to the lowest speed necessary for the occasion; … less than 1,600 r.p.m." Since there are different ways to run an engine at 1600 rpm, this is not very useful advice. Somewhat better is the advice on climbing: "At full throttle the best climbing speed is about 150 m.p.h …"[124] By 1944 the equivalent manual had several pages of useful quantitative information, such as the recommended speeds for climbing and cruising at different altitudes. Three small graphs with tradeoffs among speed, fuel consumption, and altitude were also provided. But even by 1945 the information provided was a fraction of the information provided for the American equivalent aircraft.

The British RAF finally switched to the American checklist concept in the mid 1950s. Initially, checklists were provided as part of the normal operating sequence of the Pilot's Notes. For example, the 1953 procedure for starting engines in the Canberra jet included *Checks before starting*, and was followed by *Checks after starting*, then *Checks before taxiing*. The take-off procedure included *Checks before take-off*.[125] By 1956 a completely separate *Pilot's Check List* was provided, as a nine-page spiral bound pad designed to fit in a pilot's thigh pocket, imitating the USAAF practice.

Even when the RAF converged to Standard Procedure Flying, it chose to provide much less detailed documentation, and fewer and shorter procedures, than the US. This pattern went all the way back to WW2, when the RAF flew many of the same aircraft as

the USAAF. Clearly, the two air forces had different philosophies about what their pilots should know and do. The reasons for this difference are unclear, but it continued for decades. For the F-4 Phantom fighter in 1969, the USAF section on *Emergency Procedures* was 50 pages long and had about 90 subheadings, such as "Inverted Spins."[126] But the RAF version for the same aircraft in 1969 was only 9 pages long and had 17 subheadings. The US Navy February 1973 F-4J manual has an emergency procedures section 55 pages long, with about 100 topics.

IX. German Air Force

Many other air forces fought in WW2, but none was advanced in Standard Procedure Flying. The Axis countries had two major air forces: the German Luftwaffe, and the Imperial Japanese Navy. Neither made significant use of Standard Procedure Flying. They had few procedures, no checklists, and little written documentation for quantitative flying. Ironically, in 1936 the commander of the Luftwaffe, General Walther Wever, was killed when he was piloting his own aircraft and forgot to remove the external gust locks – the putative spur to the USAF's invention of aviation checklists.

The new American technology was not classified, and the checklist portion of it could have been copied easily. *Life* magazine ran an article on the B-17 checklist in 1942, and shot-down American aircraft carried checklists in various formats. The lack of interest by Axis air forces is notable, since both air forces attempted to train a large number of pilots very rapidly -- a situation that cried out for standard procedure flying. The Luftwaffe did make small moves in its direction at the end of the war, but it did not catch on.

I will tell the story for the Luftwaffe out of sequence. In 1945 German aviation was terminated by Germany's conquerors, and only in the mid-1950s was West Germany allowed to recreate an air force. Starting in 1956, some former pilots of the Luftwaffe were sent to the United States to be trained in modern jet flying. These old/new pilots reacted adversely to the rigid standard procedure flying taught by the US Air Force. So the first part of the story is the 1950s experiences of the German pilots, and what it says about how they flew during WW2.

I then turn to a recently written analysis of how pilots were treated during the war.

The Luftwaffe was heavily dominated by individualistic fighter pilots, and like its adversaries with similar fighter cultures, accidents were common and accepted. Standardization was not considered, and discipline of pilots' antics was not a priority.

Finally we will look at the last few years of the war and the disastrous situation of German pilots defending against Allied bombers. High casualty rates, many from non-combat causes, created a vicious circle with poor training. Thousands of novice pilots were killed in accidents, many of which would have been avoided with better training. Of course the outcome of the air war would not have changed. But it might have taken the Allied air forces months longer to establish air superiority over Europe.

Relearning to Fly in the 1950s

When the West German military was reconstituted in the 1950s as a counter to the Soviet Union's Iron Curtain and to fears of a Soviet invasion, for leadership it naturally looked to the few surviving apolitical mid ranking pilots from 1945. Two of the pilots sent to Arizona for jet training were Major (O-4) Günther Rall (1918-2009), with 275 kills (aircraft shot down), and Oberst (O-6) Johannes Steinhoff (1913-1994) with 176 kills. The training experience of this group and those who followed them to America was described in a paper by Dr. Wolfgang Schmidt, whose title translates to *From the "Command Output" to "briefing": The Americanization of the air force during the construction phase of the German Air Force*.[127]

The Germans had strong reservations about the Standard Procedure Flying system. They drew a contrast between the "joy of flying" approach of their time in the Luftwaffe, and the "dogma," "corset," and even "slavery" of the USAF approach. After

one jet training session, Steinhoff was castigated by a lowly American lieutenant (O-2 rank), "Mister Steinhoff, you might be a hero but your instrument flying is lousy!" -- even though six of Steinhoff's 176 kills had been made from jets, a technology which the Germans invented! Dr. Schmidt describes the skeptical German reaction to the 1950s American training methods.

> In spite of the [English] language training, the German pilots had difficulty to adapt to the American concept of training, which stressed systematic memorization, repetition, and *precise implementation of standard procedures*. This was in stark contrast to the experiences of the German veterans. The longer the war had lasted, the shorter and less professional the German pilot training had become. In the end, *improvisation dominated*, and the ideological image of the fanatical fighter had increasingly overtaken professional capabilities and skills. Little thought was given to the pilot students' lives. [During the war,] *quantity came before quality*.[128] [emphasis added]
>
> ……
>
> The German World War 2 aviators were skeptical of [the American] heavily regulated procedures. Many were first of all disappointed about this not being "spontaneous and fun flying". Being guided by "check lists" and bound by "procedures" … was perceived to be exaggerated and confining. ...this way of flying was bound to "kill any enthusiasm for aviation, and we had to summon our entire energy to get through this check list ballyhoo that oftentimes appeared to make no sense."[129]
>
> ….
>
> Even before building up the air force [in the 1950s, German] experts had to admit that "the aviation training program, which may seem extremely extensive to us, […] really does ensure that only adequately experienced pilots get into the formations, where relatively low accident rates confirm that the training requirement are in order." The problem was more the shattered self-image of the German war pilots, who often had shot down many aircraft and received many

> awards. While this had confirmed their aviation experience, it now seemed to "be seen as null and void". … It took avowedly some time until the war heroes of yore not only accepted the "advantages of this system that at first glance appeared rigid and stupefying", but even got to appreciate its "foolproofness" for the sake of safety: "When you know your procedures by heart, and the acronyms to call them, you hardly can make mistakes, even under stress."[130]

Schmidt explains these criticisms by looking at the Luftwaffe's military ideology in WW2. This came from:

> typically German military-ideological ideas and mentalities that were longstanding, deep-rooted and radicalized in the national-socialistic [Nazi] war: Even with all the sophisticated technology, *it was the morally firm and mentally agile man that decides a battle*, or so it was thought. A report on the experience of the first refresher training for German marine pilots at the US Naval Station in Pensacola incidentally reflects incidentally very similar conditioning as well. The author of the report praises the overall very thorough training and the strict safety standards a lot; on the other hand, however, he has the impression that "this treatment [of the safety of man and machine] *cannot be healthy for a fierce and soldierly mind*." For a lack of alternatives, though, it was necessary to adapt to the American corset, whether they liked it or not.[131] [emphasis added]

Pilot Günther Rall gives a balanced evaluation, writing many years after his retraining. Here is his colorful comparison of checklists with Catholic religious rituals.

> Then, on 19 Sept 1956, I am at last once again strapped into a proper aircraft: a North American T-6.... And on my knees, for the first time in my flying career, I have a check-list. On this the Americans have set down, step by step, every action that has to be taken to get the T-6 into the air and then back down again. The list is arranged in handy sections and *anyone who doesn't carry out all the moves and checks in exactly the right sequence is automatically flunked*, despite the fact that he might be a hundred times more efficient by doing things in his own individual way. [emphasis added]
>
> ... Procedures and checks do for US pilot training what the rosary and litany do

> for the devout Catholic -- more in fact: if employed with sufficient ardor, both will get you into heaven, but only the former will return you to earth afterwards. It takes some little while before I learn to appreciate the benefits of this system *that at first sight seems so rigid and stupid*. Anyone who knows his procedures and has the acronyms in his head to call them up, can hardly go wrong even in the most nerve-wracking of situations. [emphasis added][132]

German Pilot Culture

For the Luftwaffe, World War 2 started in 1939 with Germany's invasion of Poland. Rall's describes his transition in 1939 from training aircraft to the Messerschmitt Me 109, a front-line fighter. He already had almost 200 hours of flight time, but the transition was still harrowing. Rall was operating without any checklist, not even a simple memorized one such as the British used. In retrospect, the situation cried out for checklists and standardized procedures:

> Its spindly narrow-track undercarriage is actually much too weak to cope with the enormous torque, rate of yaw, and turbulence of the airscrew. Take-off accidents are therefore commonplace, not just in the training schools, but also among front-line units... And once in the air the pilot still has his hands more than full: the undercarriage must be retracted...before a certain airspeed is reached, engine and propeller have to be set manually to cruise, the flaps cranked up by a large hand-wheel....and the now tail-heavy bird....trimmed for level flight..... [A few moments later].... frantically carrying out in reverse order everything that they had somehow successfully managed to do at take-off.
>
> It is advisable under such circumstances not to mix up, let alone forget, any of the actions described above, for the Messerschmitt is no docile carthorse, but a highly-strung thoroughbred. If the propeller pitch is not reduced in time, any attempt to go round again will end in a crash beyond the airfield perimeter. If the undercarriage has not been lowered, because the pilot has never before needed to lower an undercarriage in his life, he'll at least get down on the field, but in a resounding belly-landing .... But even then the Messerschmitt still has a few more

> tricks up its sleeve. If the stick is not held firmly back after touchdown, or if the pilot tramps a little too heavily on the brakes, a somersault is almost inevitable. .. …
>
> The Messerschmitt has no second seat to accommodate an instructor who might be able to prevent the trainee from committing any of these sins. The budding fighter pilot is therefore entirely on his own as he climbs into the narrow cockpit and lets himself be strapped in. He is all ears as the instructor imparts the last few words of good advice in that special tone of studied casualness which every student -- fully aware of the dangers that lie ahead -- understands only too well also contains more than a hint of subtle warning.[133]

This was basically the training method of the obsolete Heroic Craft period (WW1 to 1930), with a few rules provided by an instructor who remains on the ground.

A more detailed analysis of the culture and attitudes of Luftwaffe pilots *during* the war is provided by Ernst Stilla in his doctoral dissertation, which analyzes the "Human Resources" side of the Luftwaffe's defeat in its defensive battle against Allied bombers. It has never been published in English, and is worth quoting at length. In a short section titled "Flugdisziplin und Teamgeist" (Flight discipline and team spirit) Stilla paints a devastating picture of the promotion and reward system of the Luftwaffe.[134] Pilots were viewed as special compared with the infantry, and their primary requirements were "courage, special agility, excellent instincts," which entitled them to more freedom than the infantry.

> The Air Force leadership and the unit commanders played to these requirements so as to further the characteristics that were specific to fighter pilots, and therefore not only loosened the disciplinary brake, but also oriented the promotion system to individualism.
>
> [This] led to a relatively low aviation discipline within the entire Air Force, which in turn resulted in regular complaints by the Air Force leadership. … [Field Mar-

> shall O-11 rank Erhard] Milch complained about declining aviation discipline and mentioned the loss rates during transfer [long-distance change of base] flights, on the order of 20% damaged or destroyed [in Fall 1942]. [In comparison,] the overall American losses during transport flights from the US across the Atlantic Ocean [were 1.2%][135].
>
> The Air Force Leadership Staff mainly blamed the pilots' carelessness, who would laugh about accidents they survived, without any embarrassment. In the case of the Air Force, this was not simply the result of the intensifying war… [Famous pilot Werner] Mölders noted as early as 1935 in his diary that there were very many accidents due to lack of discipline, and[General Adolf] Galland's biographers noted that accidents were a daily occurrence in 1938…[136]

One of the difficulties faced by the Air Force leadership attempting to discipline pilots was that their leader and Hitler's second-in-command, Herman Göring, took a lax attitude, even bragging about his own accidents during World War 1.

> As a result of Göring's stance, accidents caused by boldness and daring were not at all evaluated according to their damage. Instead, they were attributed to the boisterous natural character of the fighter pilot and met with much understanding. When crash-happy pilots could expect that much sympathy from the highest leadership circles, the effect of the most martial warnings remained small. The executive staff itself deemed Göring's warnings and threats not very promising, so that Göring's last resort was simply to set up a commission to identify the cause of accidents.
>
> In a partial report of the commission, the author, Major Grote, back from a business trip to three different training squadrons, started the report with references to the discipline and self-image of fighter pilots: "The pilot students, including the cadets, don't care enough. They know that they get everything easily. [Unclear sentence]. The old airs and graces of the fighter pilot have not been done away with." The conclusion of the executive staff from the final results of the investigation almost looks like a declaration of bankruptcy: "We finally need to put an end to the obfuscation of [safety] breaches and of the causes of breaches, and to the search for excuses."[137]

Senior officers were not exempt from careless accidents. General Wever died in 1936 due to a careless failure to check the gust locks of his aircraft. One of Gunther Rall's commanding officers crashed the same way in 1942.[138] Apparently, nothing came of Major Grotte's recommendations.

This analysis of Stilla's is quite the opposite of accounts of German army discipline. It is corroborated by a post-war analysis by a senior Luftwaffe general, of "the problem of inadequate flight discipline." It led to very high accident rates, so high that according to him Goering called them "the plague."

> The personnel and material losses attributable to the factors listed [below] were so high that they represented a serious threat to the maintenance of operational readiness in the units. From this standpoint, lack of flight discipline was responsible for a genuine crisis.
>
> In spite of warnings, briefing sessions, fines, and more drastic punishments ranging from court sentences to the death penalty, with subsequent dishonorable burial of the victims, it took a very long time before any noticeable improvement occurred.[139]

The most common problems listed included:

- Inadequate mission preparation, or not following the approved route;
- Deliberately flying through bad weather zones despite lack of instrument training;
- Inadequate preflight checks by pilots;
- "showing off with acrobatics, although this was expressly forbidden."

In other cases, superior officers ("supervisors") were indirectly responsible, by:

- Inadequately checking pilot certification and flight orders before flights;
- Ordering missions that exceeded student ability, and

- Requiring tired crews to fly additional missions.

The Luftwaffe was further structurally hampered by bad promotion policies at the level of squadron and group commanders. The "dashing fighter pilot" approach was actively encouraged by a system that emphasized personal kills over leadership.[140]

> In the end however, the decisive [harmful] element of the army's promotion policy, ... proved to be two factors that started with the Spain mission: focusing on the individual's kills … and accentuating the fighter pilot as a fierce individual, in line with how he was perceived as "knight of the skies" by both the Air Force and civilian society. "As their number of kills soared, so did their officer career. Within only a few months, they had advanced to the level of squadron commodores, with the corresponding promotions. He who did not kill could not assert himself as unit leader for long. (…) The front units were exclusively led by "aces", whose main focus and ambition consisted, and had to consist, in leading the squadron's kill list, and in the squadron's kills, in turn, being ahead of those of other fighter squadrons."

> The results of such a staffing policy were twofold…. This meant that [the air force] promoted officers who were not up to the leadership tasks, neither in terms of character nor in terms of intellect, and who were unable, as described above, to clean up the disciplinary conditions, rather worsening them.

Another result of promoting the individualists was a lack of teamwork in attacking the American bombers. As Harry Crosby saw from inside the B-17 formations, German fighters needed multiple attacks by multiple aircraft, to break up the heavily armed formations. But the promotion policies put the lone wolves in charge.

> Because promotions were based on shooting down and shooting out, respectively, and not the number of missions, or in the case of leading officers on their tactical decisions, some had a narrow view of the total [situation]. Squadron and group leaders, who actually should have been supposed to keep the unit

> together, to lead them to the correct attack position and to gather them after a first wave [of attacks] and start a new attack, ended up being assessed according to the point system, just like their subordinates. The tactical leadership was often neglected because of the "kill pressure" that accordingly also applied to the unit leader: "This not only led to the captains, commanders and even commodores being evaluated like section leaders or flight leaders in the best of cases; it also resulted in most of them behaving as such in the air."
>
> Integration of young pilots into the unit and preparing them for the front suffered from this, too. A large part of the unit leaders remained focused on their own success and neglected to support young pilots. Because serious pressure from higher levels was lacking, integration of young pilots continued to rely on the individual character disposition of the respective unit leader.[141]

The WW2 German concept of how to fly was partly based on the Rules + Instruments paradigm, but even went back to the Heroic Craft era, with its emphasis on the pilot's tacit ability, developed by individual flying. Although most aircraft were equipped with artificial horizons, most pilots were not well-trained in instrument flying.[142] German pilots were therefore stuck on the ground by poor weather while enemy aircraft flew overhead. General Steinhoff described it as follows.

> The German tactical air force did not keep pace with the parallel development of the Allied bomber force. It was primarily a fair-weather air force in 1940, and it remained such throughout the war. ... [T]he German Air Force in 1940 did not possess the capacity to carry out sustained night flying operations, at least not flying under IFR (Instrument Flight Rules) only. Later on during the war, when the Allied bomber forces began to penetrate the borders of the German homeland in daylight operations, the Luftwaffe, because of the lack of all-weather training, was unable to deploy its fighter-intercepter force since the frequently prevailing heavy and thick cloud cover prevented the interceptors from getting to the required attack altitude against the Allied bomber fleets.[143]

The Luftwaffe did develop a small but effective specialized night-fighter force,

but the daylight force continued to be troubled by bad weather. "Very frequently fighting took place over long distances above cloud cover, and the completely disoriented fighters had to go below the deck and attempt to land wherever they could. Together with insufficient navigational aids, this resulted in many additional losses and a wide scattering of our aircraft."[144]

If we think of the craft mentality of Saint-Exupéry and his contemporaries discussed in Chapter 3, the undisciplined and dangerous behavior of German fighter pilots is easier to understand. General Steinhoff recalls a pilot under him in 1940 who

> was a brilliant guy, very intelligent, very quick and aggressive, but he spent too much time looking for the girls, and his mind was not always on operations. He actually had to be taken off flight status on more than one occasion because he was so exhausted from his nights on the town, if you know what I mean…. He was an individual, not a team player. He had seven victories when I fired him, not because he was not good, but because he was shot down four times while getting those victories…. and many men did not want to fly with him as their wingman. ... He was a true character and *was the epitome of the First World War fighter pilot*, but we were not fighting the First World War.[145] [emphasis added]

Steinhoff had this pilot transferred to North Africa, where the style of combat was very different and there was no French night life. The pilot reached 158 victories before he was killed.

Another Luftwaffe pilot describes flying around an automotive race track at an altitude of a few feet to see if his plane could handle the curvature. "Looking back on our antics today, when a pilot's prowess is rated in terms of the safe and responsible handling of his machine at all times and in all situations, I can only shake my head in disbelief at what we got up to–and got away with–back in those less regulated days."[146]

There are some indications of local moves toward Standard Procedure Flying very late in the war. In January1945 the manual for a prototype fighter aircraft included a series of nine short procedures, from starting engines through takeoff, level flight, landing, and shutting down the engine.[147] There are even four procedures for "special flight situations" such as bailing out. These take up the last 11 pages of the very short (16 page) manual. This is a major change from earlier manuals which followed a purely descriptive format, going through the controls and instruments one by one.

Losing the air war

Finally, what was the effect of this behavior? The Luftwaffe started WW2 (in 1939 for Germany) with well trained pilots, some of whom had combat experience in the Spanish Civil War. But by late 1943 the Luftwaffe had lost most of its original pilots. In the first six months of 1943, Germany lost 1,100 fighter pilots, which was about 60% of the number at the start of the year. It lost another 15 percent in each of July and August.[148] New pilots and new aircraft were arriving every month, but unlike new aircraft, new pilots are inferior to what they replace.

The high pilot losses had two disastrous effects. First, even if they had been well trained, newer pilots were inexperienced and inevitably had more accidents and combat casualties than the pilots they replaced. Second, the Luftwaffe increased its training rate partly by shortening the training period. Shortages of fuel due to bombing and Soviet recapture of oil fields also forced reductions in flight training hours. Figure 19 shows the dramatic reduction in training hours for Germany, from over 240 hours including about 80 hours of training in front-line aircraft, to less than half that by the last year of the war.

Over the same years the training hours for the Americans and British were growing, with the American USAAF eventually averaging over 400 hours of flight training before pilots reached operational units.

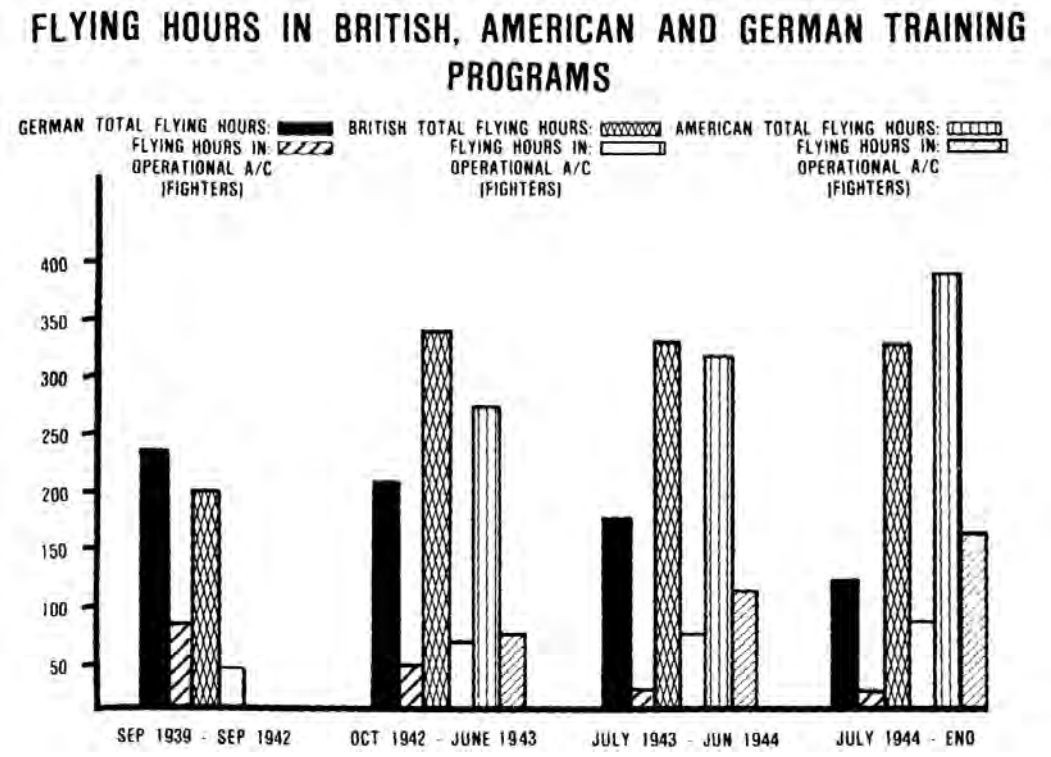

Figure 19 Flight hours in training for different air forces. [149]

The Luftwaffe trained enough pilots to make up for losses, but it never got significantly ahead of them and therefore pilots did not live long enough to build experience. In 1942 Germany trained 1660 new pilots; in 1943 it doubled that to 3276.[150] The effects of more new pilots with fewer flying hours showed up in falling pilot quality and higher casualties. General Steinhoff recalled that:

> Toward the end of 1944 the situation of the German fighter forces was such that, while we still had a limited cadre of experienced pilots, the majority of the fighter pilots were very young and inexperienced. Between late 1944 and early 1945, the average young pilot flew only two missions before he was killed—that is what

> the statistics say. On the other hand, the aircraft situation was excellent. We were virtually drowning in aircraft. For instance, during October of 1944 alone, 4,300 fighter aircraft were built. However, the fuel situation was hopeless; for training purposes almost no fuel was released any more.[151]

Similarly, Günther Rall (1924-2009) wrote that in late 1943:

> To compensate for the growing losses against the western allies' bomber streams, the training time of young fighter pilots is shortened. Now pilots are going into action with scarcely more than 50 hours of flying time on powered aircraft in their logbooks, and with only a handful of those hours having been completed on the types they will fly operationally. Most of them will be killed before their tenth mission.[152]

One measure of pilot ability is the rate of non-combat aircraft losses. This rate reflects training, airmanship, and flying style. It is not a perfect measure of pilots' ability but it provides at least a relative metric. Over the period 1941 to 1943 non-combat losses were a high 77 percent of the level of combat losses: 11,452 versus 14,829. Looking just at non-combat losses, from 1940 through mid 1942 the Luftwaffe's non-combat aircraft loss rate was 3.5 percent per month.[153] This is poor. But starting in the second half of 1942 these losses worsened dramatically. (Figure 20) In the first half of 1944, they reached 52 percent of the base level per six months, almost 9 percent per month and more than 100 percent per year. These are *non*-combat losses. These figures signal the great loss in experience and competence of pilots in the last three years of the war.

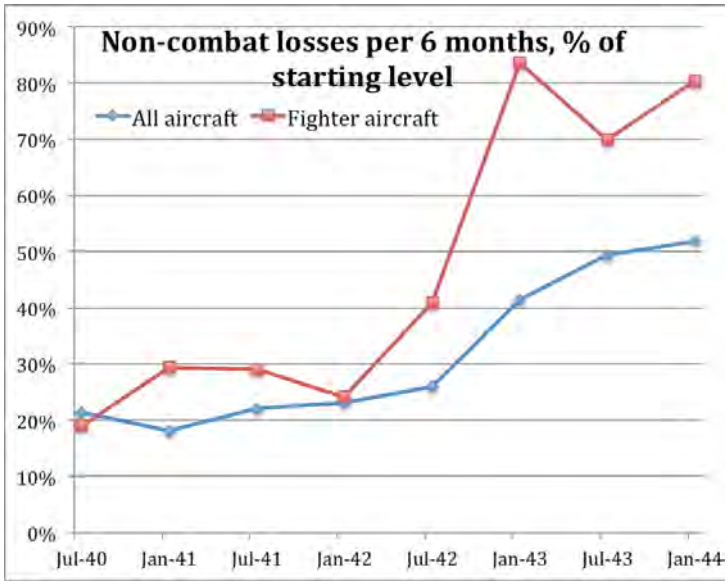

Figure 20 German non-combat aircraft losses per 6 months (calc. from Murray, 1983)

A detailed analysis of losses in February 1944 showed how many accidents were being caused by poor training, aggravated by lack of experience. In that month, total losses were 1791 aircraft, of which only 26 percent (472) were due to enemy action.[154] (Figure 21) This was out of a total strength of about 6400 aircraft. So in a single month, 20 percent of the Luftwaffe's strength was lost to accidents.

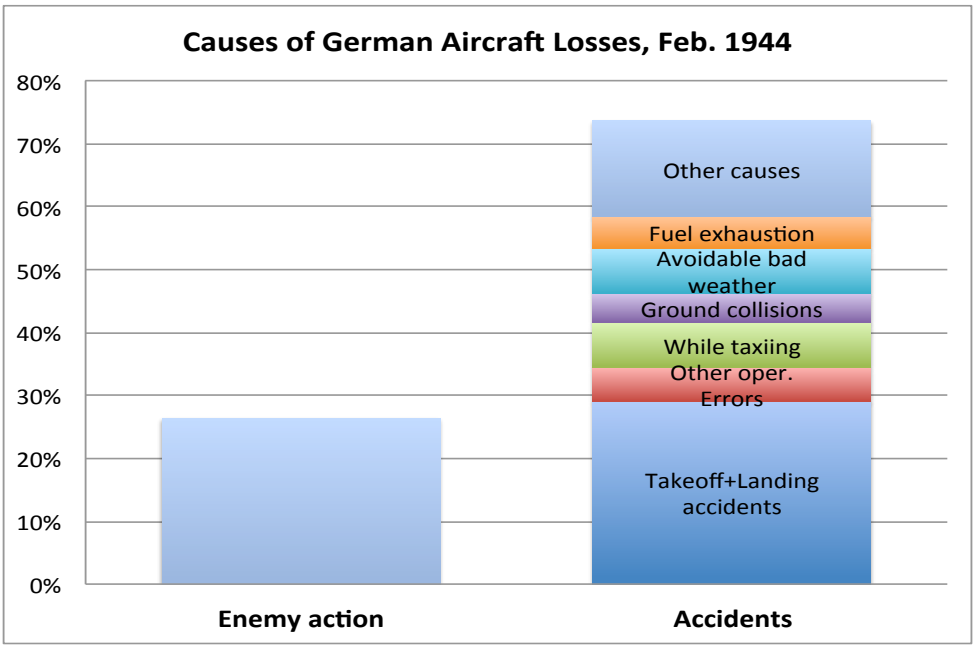

Figure 21 Causes of aircraft losses in Feb. 1944

Figure 20 also shows that from the second half of 1942 onward the non-combat loss rate for fighters was considerably worse than for total aircraft. It exceeded 70 percent per six months(12 percent per month) from 1943 onward. Since fighter aircraft are high performance and require more ability from pilots, this also signals a major decrease in pilot quality. From 1941 to 1943, the ratio of non-combat losses for fighter aircraft was 86 percent: 3902 lost in non-combat accidents and 4547 lost in combat. Damaged aircraft, which consumed scarce spare parts and skilled labor to repair, were probably in a similar ratio.

Losing 100 fighters also meant losing about 55 pilots.[155] This suggests that about 2100 fighter pilots were killed in non-combat accidents from 1941 through 1943. The average number of active pilots on duty in 1943 was also 2100.[156] So cutting non-combat losses in half would have greatly increased the number and average experience of fighter pilots.

So by 1943 the Luftwaffe was struggling not just with undisciplined pilots but with undertrained pilots and high losses of aircraft and pilots in accidents. This would have been a good situation to adopt Standard Procedure Flying. But as we saw from the experience in 1955, the concepts were alien. One historian linked this to the pursuit of craft excellence.

> No, the Luftwaffe never introduced check-lists. This was mainly due to a completely different training philosophy which placed less stress than the US one on churning out a very large number front-line ready pilots in record time. Instead, a number of physical and psychological tests were used in order to produce an elite, made up of the best of each intake. The Japanese Naval Air Service took this to even more extreme lengths, with baleful consequences. This is not to say that features like check lists could not have been integrated into this system - it just

> didn't occur to anyone because the priorities lay elsewhere.[157]

The symmetry here is ironic. In 1943 Harry Crosby in B-17s and Johannes Steinhoff in Me 109s were trying to kill each other 30,000 feet above Europe. The cultures of pilots on both sides in 1943 encouraged individualism, Romanticism, and personal craft excellence. The reality of hundreds of aircraft on each side, filled with inexperienced and justifiably frightened crews, groping through bad weather, was that Standard Procedure Flying was superior for accomplishing their missions of attack and defense. Bomber pilots should not act like fighter pilots, and even the Luftwaffe's fighter pilots should have moved past the Craft era and toward operational science. General LeMay and the bomber-centric leadership of the USAF realized this, and had the ability to enforce it on their bomber pilots.[158] When the German generals eventually tried to rein in their pilots, they were held back by the mid-level leaders under them and the opium addicted politician, Göring, over them.

X. Conclusion

In all air forces, there was initial resistance to the new approach to flying. By 1960 all Western militaries were flying high-performance jets, and that forced the laggards to some version of Standard Procedure Flying.[159] On the civilian side, American commercial aviation dominated after WW2, using ex-military pilots, and it used SPF also.

The status of each in 1945, and the approximate time when they fully adopted Standard Procedure Flying, was shown in Table 5-1. These outcomes are the result of two somewhat conflicting patterns. First were the the conditions that made Standard Procedure Flying more valuable. These had the most value in reducing casualties and increasing mission effectiveness in flying situations with:

- Many inexperienced pilots. This was an issue for everyone, but for the Allies it was more pressing early in the war, while the Luftwaffe had severe problems from 1943 onward.
- High aircraft complexity. All air forces were frantically shifting into more complex aircraft just before and at the beginning of the war. Heavy bombers were another step up in complexity. Jets, which came into wide use only in the 1950s, were still more complex.
- Difficult flight maneuvers. B-29s were heavily loaded on takeoff and low on fuel when landing. They also had to deal with the previously unknown jet stream and with long flights over water. Naval jets were unforgiving at all times and especially when landing on aircraft carriers. Vietnam helicopters were difficult when taking off or landing near enemy troops, and at night/bad weather.

- Many aircraft on a mission, and a high degree of coordination required. Highest for European bombers especially toward the end of the war. (B-17s)
- High mission complexity. This over the course of the war for the Allies. Higher for European bombers. Low for Luftwaffe, mostly by choice. Low for most American naval flying.

All of the air forces would have benefitted from Standard Procedure Flying throughout the entire war, but in different degrees. It made sense that the American heavy bombers experienced the most pressure to implement SPF, even if they had not initially been doing poorly in their battles. They had high aircraft and mission complexity, mission coordination (in Europe) and flight difficulty (B-29s). It also made some sense that the US Navy chose not to pursue SPF until its shift to jets. The British suffered from lack of SPF early in the war with inexperienced pilots flying novel aircraft, but by 1943 this was not so acute as its pilots had gained experience.[160] The Luftwaffe had a strong need to use it due to pilot inexperience; in a logical world they would have adopted it by 1943.

But technology adoption does not proceed by logic or necessity alone. A second set of factors dictated whether and to what extent SPF was actually implemented. Most pilots started with a latent preference for flying according to individual preferences and "style." The fighter forces then further selected for this personality. In the various case studies, the following factors played a role in adoption, or not, of SPF.

- Attractiveness of the Hollywood role model of dashing individualist fighter pilot.
- The selection process in choosing and assigning pilots. Assignment refers to sending newly trained pilots to different specialized training (bombers, fighters) and from there to specific aircraft classes and units (heavy bombers, medium bombers, reconnaissance, fighter-bombers, regular fighters, night

fighters, and so forth). To an extent, new pilots could self-select toward different types of flying. Training then weeded out those who did not fit well. Thus fighter and bomber pilots really did have different personalities - it was not just a stereotype.

- The contrasting cultures of bombers and fighters, which interacted with the flying requirements for each.
- Crew size. Fighters were almost all single-seat (one pilot, no other crew). Light bombers such as Navy dive bombers had several seats but only one officer, the pilot. Only American medium and heavy bombers had co-pilots, although flight engineers played similar roles in the RAF.
- Mid-level leadership. Each air force promoted pilots to leadership positions based on its view of desirable characteristics. The Luftwaffe promoted and rewarded squadron commanders based on individual performance, not their leadership ability. In the US 8th Air Force, getting rid of leaders who were not willing to follow standard procedures was an important part of its transition.
- Senior leadership. They chose which mid-level leaders to promote, and which to re-assign due to poor performance. They also enforced, or not, the restrictions that every air force had on dangerous flying.

A number of these factors had to line up in order to overcome resistance to the Standard Procedure Flying paradigm. This occurred thoroughly only in the two cases discussed above, both in USAAF strategic bomber forces. (Other USAAF strategic bombers, such as those operating from Southern Europe, were not studied.) Several other air forces did make some use of checklists in training, and probably during operations as well.

Postwar, USAF fighter aircraft shifted over to the new system presumably by their post-war leaders, who were all promoted bomber generals. In the 1950s the West Germans were thoroughly inculcated in the new system by their American trainers. In con-

trast, the US Navy ignored the Air Force experience until they were faced with high jet accident rates. Then, they seemingly re-invented a comprehensive version (NATOPS) of Standard Procedure Flying, perhaps with some use of lessons from the Air Force.

As for the last two air forces discussed, the Royal Air Force and the US Army helicopter forces, I have not studied either enough to know when and to what extent they shifted. The US Army's helicopter forces might be particularly interesting, since it apparently still uses a lot of craft skills. The RAF would also bear examination. It underwent the same transition to more dangerous jets that the US Navy experienced. Did that transition play the same role?

Several other national air forces faced the same choices as those discussed in this paper. Perhaps most notable was the Red (Soviet Union) Air Force. It was decimated in 1941 by the initial German invasion. But by 1945 it was very powerful. How was this achieved?

Another potentially important case is the Imperial Japanese Navy's aviation arm. It appears that it followed a trajectory similar to the Luftwaffe: Very well trained and experienced pilots initially, who were mostly killed by 1943. The rate of training new pilots was much too low, and shortages of fuel and other resources meant that new pilots were poorly trained. But the ideology of the Japanese military probably also prevented them from recognizing the value of Standard Procedure Flying.[161] In addition, since their combat was mainly over water, it would have been much harder for them to recover American documents embodying it.

Finally, the US Marine Corps had its own aviation units. Organizationally it was part of the Navy's aviation system, flying the same aircraft and using the same manuals.

But there may have been differences in the Marine Corps pilots' actual flying methods.

Index

Endnotes

[1] Many people have helped me with this research. In many cases, they may not recognize what I did with their ideas. All responsibility for errors and omissions is mine. My thanks to all of the following. Permission to use photographs: as noted. General commentary: Prof. David Mindell; Peter Bohn. US Air Force: Col. Raymond O'Mara, Larry Wilson at Smithsonian Museum. US Navy: Karl Zingheim; Vice Admiral Robert F. Dunn. RAF: Peter Thomas. Luftwaffe: Prof. Klaus Schmider, Dr. Ernst Stilla for sharing his doctoral research, Ms. Carola Betzold for her translation work. Research assistant: Daniel Lakis. Librarians at the Smithsonian Air & Space Museum, USS Midway museum.

[2] Women flew only in non-combat roles such as aircraft delivery, except in the Soviet Union..

[3] Curtis Rist, "Physics Proves It: Everyone Should Shoot Granny-Style," *Discover Maga-*

zine, August 2008.

[4] Full implementation of quantitative flying in Standard Procedure Flying does require formal aircraft testing, with instrumentation, test pilots, and computing to translate the raw test results into the tables in the back of flight manuals. By 1944 the German Luftwaffe could not have done much formal testing, due to shortages of fuel among other problems. But the other two parts of SPF, checklists and standard procedures, require little more than pen, paper and a bunch of experienced pilots.

[5] Rules+Instruments Flying taught pilots to fly through clouds, which had previously been impossible even for experts.

[6] As things turned out, American "precision" bombing was not precise, and caused roughly as much death and destruction in German cities as the British night bombing. Parts of this story are discussed in Section IV.

[7] For example: Carlyle "Jai" Rampersad and Sally E. Rampersad, "Can medicine really learn anything from aviation? Or are patients and their disease processes too complex?," Seminars in Anesthesia, Perioperative Medicine and Pain (2007) 26, pp 158-166; Brigette M. Hales MSc and Peter J. Pronovost MD, PhD, "The checklist—a tool for error management and performance improvement," Journal of Critical Care (2006) 21, pp 231–235; Bradford D Winters *et al*, "Clinical review: Checklists – translating evidence into practice, " *Critical Care*, vol 13 number 6, 210, 2009 (doi:10.1186/cc7792); Peter Pronovost and Eric Vohr, *Safe Patients, Smart Hospitals: How One Doctor's Checklist Can Help Us Change Health Care from the Inside Out*, Hudson Street Press, 2010.

[8] Ingrid M. Nembhard, Jeffrey A. Alexander, Timothy J. Hoff, and Rangaraj Ramanujam, "Why Does the Quality of Health Care Continue to Lag? Insights from Management Research," *Academy of Management Perspectives*, February 2009, pp 24-42.

[9] Based on my search for and study of surviving manuals. I have just located a second 1937 Navy manual with checklists, for the Douglas TBD-1 Torpedo bomber.

[10] *Handbook of operation and flight instructions for the model B-17 bombardment airplane manufactured by Boeing Aircraft Company*, Technical order 01-20EA-1 JULY 5, 1937 Revised 5-20-40. Published by authority of the Chief of the Air Corps by the Materiel Division Field Service Section, Wright Field, Dayton, Ohio. Wright Field is where the Type 299 crash occurred in 1935.

[11] *Pilot's Flight Operating Instructions for Army Models B-17 F and G and British Model Fortress II*, AN0l-20EF-l, August 1 1943, pages 26-34. The oldest physically separate checklist I have located is from May 1943, "Pilot's Check List B-24D, B-24E and PB4Y-1 Airplanes," April 15 1943.

[12] *Approved B-17F and G Checklist,* PIF 2-10-1, Revised 3-1-44. An April 1943 checklist for the B-24D is even more elaborate.

[13] *A-Train, Memoirs of a Tuskegee Airman* by Charles W. Dryden, 1997, p 52.

[14] R Bruce Porter and Eric M Hammel, *Ace!: A Marine Night-Fighter Pilot in World War II*, Pacifica Military History, 1998, p 42.

[15] *Pilot Training Manual for the Mitchell Bomber,* Headquarters, AAF, Office Of Flying Safety, November 1944. These "pilot training manuals" were distinct from the *Pilot's Flight Operating Instructions*, and were more anecdotal and much less formal instructions for pilots in training on a particular aircraft.

[16] Training film TF1-3394 *How to Fly the B-17 Part 2 Flight Operations*. This film literally talked through each checklist at multiple points of the training flight.

[17] Navy aircraft manuals were initially written by the different manufacturers and in different styles, while the USAAF's were more standardized. Air Force bombers were also more complex, making exact comparisons difficult.

[18] Compare *Pilot's Flight Operating Instructions for Navy Model PBY-5A*, 5 June 1944 revised 10 January 1945, AN 01-5MA-1, with the checklist card for the same aircraft, *Pilot's Check List, Army OA-10A and Navy PBY-5A Airplanes, R-1830-92 Engines*, 30 July 1944, Smithsonian Institution Archives. The Check List is two small pages, while the procedure section is 22 full-sized two-column pages, and includes multiple diagrams, warnings, side notes, and other miscellaneous information.

[19] The Soviet Air Force probably played a major role in WW2, but it is not as well documented as the others here. Similarly for the Imperial Japanese Navy air force. I have not found evidence that either of them used any part of Standard Procedure Flying.

[20] The Army Air Force did have training manuals with discussions of a few combat techniques such as deflection shooting. But flight leaders had to know what to do without hauling out a manual! Less experienced pilots were the "wingmen," whose job was to stay glued to their leader.

[21] Different air forces use different titles for their ranks. In this chapter each rank is listed with its equivalent US standard rank code, which for the USAAF includes O-1 (second lieutenant), O-3 (captain), O-6 (colonel), and O-9 (3 star general).

[22] Kenney, George C. *General Kenney Reports. A Personal History of the Pacific War*, New York, Duell, Sloan and Pearce, 1949, pp 3-5. Available from http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA442853

[23] Chimney collision incident.

[24] Charles W. Dryden, *A-Train: Memoirs of a Tuskegee Airman*, University of Alabama Press, 1997, p 86.

[25] Curtis, Richard K., *Dumb but Lucky!: Confessions of a P-51 Fighter Pilot in World War II*, Ballantine Books, 2005, pp 66-71.

[26] Donald S. Lopez, *Into the Teeth of the Tiger*, Bantam, 1986, p 46.

[27] Rebecca Hancock Cameron, *Training to Fly*, US Government Printing Office, 1999, p 272. Available from scribd.com.

[28] Donald S. Lopez, *Into the Teeth of the Tiger*, Bantam, 1986, pp 41-46.

[29] R Bruce Porter and Eric M Hammel, *Ace!: A Marine Night-Fighter Pilot in World War*

II, Pacifica Military History, 1998, p 40.

[30] These are fiscal years, e.g. 1942 is October 1941 to September 1942. Office of Flying Safety, Table 212 -- Aircraft Accidents -- Number and Rate: Fiscal Years 1921 to 1945, *Army Air Forces Statistical Digest, World War II*, n.d.

[31] Susan Sheehan, *Missing Plane,* Putnam Adult, 1987, describes the training, wartime service, crash, and crash recovery forty years later, of a B-24 bomber pilot. He was one of the "hot shots" in training, and he got caught and punished when he flew into a flock of ducks 30 feet over the Rio Grande River. Also available as a *New Yorker* article.

[32] The ratio of casualties to force size is misleading. Because combat crews were sent home after accomplishing a fixed number of missions, usually 25, the number of men who served in the Eighth was much higher than 200,000. Among the combat crews, though, the casualty rate was about 50 percent until near the end of the war.

[33] Harry H. Crosby, *A Wing and a Prayer*, 1993, Caption, illustrations after p 208.

[34] *Masters of the Air: America's Bomber Boys Who Fought the Air War Against Nazi Germany* by Donald L. Miller, page 8.

[35] Harry H. Crosby, *A Wing and a Prayer*, 1993, p 148. Although writing decades after the events, Crosby researched his book carefully, including numerous interviews with surviving members of his unit. Other historians have confirmed his account, including many of his anecdotes.

[36] Harry H. Crosby, *A Wing and a Prayer*, 1993, p 73.

[37] Harry H. Crosby, *A Wing and a Prayer*, 1993, p 70ff. In contrast their adversaries, the German Luftwaffe, were always short of fuel for training and by 1944 were rigidly limiting non-combat flights. See Section IX.

[38] Harry H. Crosby, *A Wing and a Prayer*, 1993, p 70.

[39] Harry H. Crosby, *A Wing and a Prayer*, 1993, p 199.

[40] This paragraph and next from Raymond P. O'Mara, *The Socio-Technical Construction of Precision Bombing: A Study of Shared Control and Cognition by Humans, Machines, and Doctrine During World War II*, PhD Dissertation, MIT, June 2011, pp 120-122.

[41] Crosby, p. 46, also quoted in O'Mara 2011, p 121.

[42] Crosby, 1993 p 75. LeMay's leadership in Europe is described in many books.

[43] footnote to Crosby or Jablonski

[44] For the Eight Air Force as a whole, about half of the crewmen who were shot down bailed out successfully, including both Buckys. Most of the survivors became German prisoners, while some managed to escape to England. A small proportion died in captivity or at the hands of the local population when they landed.

[45] Crosby 1993, pp 240-241.

[46] Crosby, 1993, pp 241-246.

[47] "...overpaid, over-decorated, over-sexed -- and over here." Robert E. Sherwood, "Joe Legion, Private First Class; Mr. Sherwood gives a close-up of the man who will help liquidate Hitler," *NY Times*, May 28, 1944, p SM5.

[48] Crosby, 1993 p 230. Crosby himself loosened up; he and Wingate had an affair that lasted until he went home on leave to see his wife.

[49] Raymond P. O'Mara, Chapter 5 in *The Socio-Technical Construction of Precision Bombing: A Study of Shared Control and Cognition by Humans, Machines, and Doctrine During World War II*, PhD Dissertation, MIT, June 2011. My thanks to Col. O'Mara for discussing his research with me. Most of his material is covered in another portion of the full book.

[50] Norbert Hannig, *Luftwaffe Fighter Ace: From the Eastern Front to the Defense of the Homeland*, Stackpole Books, 2009.

[51] Such as General Frederick L. Anderson, commander of the 8th Air Force bombers. "The VIII Bomber Command is destroying and will continue to destroy the economic resources of Germany to such an extent that I personally believe no invasion of the Continent or Germany proper will ever have to take place,...." Stephen L. McFarland and Wesley Phillips Newton, *To Command the Sky: the battle for air superiority over Germany, 1942-1944,* Paperback edition, Smithsonian Institution Press, 1991, p 109

[52] Stephen L. McFarland and Wesley Phillips Newton, *To Command the Sky: the battle for air superiority over Germany, 1942-1944,* Paperback edition, Smithsonian Institution Press, 1991, p 3.

[53] Many historians have discussed the military politics of forming an independent air force. The quote is from Matthew K. Rodman, *A war of their own : bombers over the Southwest Pacific,* Air University Press, 2005. Another discussion is Stephen L. McFarland and Wesley Phillips Newton, 1991, pp 3-9.

[54] Historians agree that the strategic bombing did not have its intended effects of destroying German morale or industrial capacity. It may nonetheless have been militarily effective due to two indirect effects. First, once attacks began on Germany itself, the Nazi leadership diverted a huge share of resources to defense against the bombers. Second, it brought the Luftwaffe fighters into the sky, where they were gradually annihilated. The result was that from D-Day onward the Allies had air superiority over every battlefield. See, for example, the Introduction to Stephen L. McFarland and Wesley Phillips Newton, *To Command the Sky: the battle for air superiority over Germany, 1942-1944.* Also Williamson Murray, *Strategy for Defeat: The Luftwaffe 1933-1945*, Air University Press, January 1983.

[55] Wesley Frank Craven and James Lea Cate, editors, "The Pacific: Matterhorn To Nagasaki," *The Army Air Forces In World War II,* vol. 5, p 7.

[56] Since the actual surrender of Japan was precipitated by the only nuclear bombs ever used in combat, the conventional bombing might seem superfluous. Everything about the final two months of the war, Japan's seemingly abrupt surrender, and the role of atomic bombs is controversial and will remain so. In any case, the following facts are agreed on.

Before Hiroshima was bombed on August 8, 1945, LeMay's bombers had already fire-bombed 64 Japanese cities, and their productive capacity, leveling a total of 178 square miles. Tragically but as expected, this conventional bombing killed far more Japanese civilians than the two atomic bombs.

[57] Anonymous, *Combat Crew Manual*, XX Bomber Command, December 1944. Available from http://www.scribd.com/document_downloads/direct/37160919

[58] Alex E. S. Green "A Physicist with the Air Force in World War II," *Physics Today* 54(8), 2001 pp 40-44; doi: 10.1063/1.1404848

[59] *Dustoff: The Memoir of an Army Aviator* Michael J. Novosel, Presidio Press, Novato, CA, 1999, page xx. Novosel had finished his Air Force pilot training in late 1941.

[60] Robert Mason, *Chickenhawk,* 1983, various editions.

[61] Robert C. Rubel, "The U.S. Navy's Transition To Jets," *Naval War College Review*, Spring 2010, Vol. 63, No. 2, p 49.

[62] "Throw away those good-luck charms and use the check-off list," *Naval Aviation News*, August 1950, p 13. http://www.history.navy.mil/nan/backissues/1950s/1950/aug50.pdf

[63] A third US air force was the US Marines. The reputation of Marine pilots was that they were looser than Navy pilots.

[64] Numerous sources. A concise summary is NAVAL HISTORY & HERITAGE COMMAND, *Battle of Midway, 3-6 June 1942 Composition of U. S. Forces*, http://www.history.navy.mil/faqs/faq81-5.htm. One squadron consisted of four B-26s, which are normally used as medium bombers but in this battle carried torpedoes and made low-level attacks.

[65] Numerous books have been written on this battle, including several in the last 10 years. With hindsight, the victory was more complex, but the received story at the time affected Naval culture. The US had broken the Japanese codes, and it also had radar technology to spot incoming attacks. Without radar, the Japanese were unaware of McCluskey's approaching squadrons.

[66] Earl Gallaher, *Report of Action, June 4-6, 1942*, Enterprise Air Group's Scouting Squadron Six June 20, 1942. Downloaded from http://www.cv6.org/ship/logs/action19420604-vs6.htm.
Richard H. Best, *Report of Action, June 4-6, 1942*.Enterprise Air Group's Bombing Squadron Six, June 10, 1942. Downloaded from http://www.history.navy.mil/docs/wwii/mid10.htm. It appears that most of the 17 lost aircraft from these two squadrons ran out of fuel, but some were shot down and not all the crews were rescued, so the breakdown between fuel exhaustion and combat damage will never be known.

[67] There were at least two exceptions, where the Naval Air Force was not a clear victor. First was the aerial component of fighting around Guadalcanal, when a tiny force of mainly Marine fighters was pitted against a larger force of Japanese bombers. Both sides were using land bases rather than aircraft carriers. The Marines had the handicap of a terrible supply situation, but they were defending their own base while the Japanese were handicapped by operating near the limit of their range. In any case the Marine "catch-as-

catch can" style of fighting was ultimately successful. Second, the last major challenge to Naval aviation was the *kamikaze* attacks on the US fleet off Okinawa in April 1945. Approximately 2,000 *kamikaze*s sank or damaged 125 ships, including damage to many aircraft carriers. In this situation, the Navy eventually adopted a systematic and coordinated defense in depth. But it does not seemed to have led to a change in flying styles.

[68] Photo from National Archives at College Park, NAIL Control Number: NWDNS-80-G-473547. Caption says "Flight deck crews spot SBD's which have just returned from Jap island attack., 10/1943." However the middle aircraft has its bomb loaded, suggesting that they are about to leave.

[69] Robert C. Rubel, "The U.S. Navy's Transition to Jets," *Naval War College Review*, Spring 2010, Vol. 63, No. 2.p 56.

[70] Robert C. Rubel, "The U.S. Navy's Transition to Jets," *Naval War College Review*, Spring 2010, Vol. 63, No. 2.

[71] Robert C. Rubel, "The U.S. Navy's Transition to Jets," *Naval War College Review*, Spring 2010, Vol. 63, No. 2.p 56.

[72] Col. William T. Hewes, USMC (Ret.), "The High Dive," *Naval Aviation Museum Foundation* 31, no. 1 (Spring 2010), p. 96, quoted in "Six Amazing Years: RAGs, NATOPS, and More" Vice Admiral Robert F. Dunn, U.S. Navy (Retired) *Naval War College Review*, Summer 2011, Vol. 64, No. 3.

[73] Until at least 1942, the US Navy was behind commercial aviation in both instrument and night flight. See "Night is my Ally" by Vice Admiral William I. Martin, in *Carrier Warfare in the Pacific* by E.T. Wooldridge, p 146-147. He describes how in summer 1941, two reserve pilots who had previously flown with the airlines were sent around the Pacific fleet to teach instrument flight techniques using gyro instruments, presumably meaning artificial horizons. Previously, the Navy had only used the needle-ball-airspeed method, on the grounds that gyro instruments were "unreliable." In 1942 Martin wrote "the first [US Navy?] instruction book" on gyro instrument flying. He then led development of night carrier techniques; by 1945 an entire carrier was devoted to night operations.

[74] Gerald G. O'Rourke, "We Get Ours at Night," in *Into the Jet Age : Conflict and Change in Naval Aviation, 1945 – 1975*, E/T. Wooldridge editor, 1995, p 26.

[75] O'Rourke 1995 p 29.

[76] O'Rourke 1995 p 32. Also cited in Rubel.

[77] "As I lowered the wheels handle and raised the wing incidence handle, my heart started beating faster. It was always this way: No matter what else happened during a flight, recovery on the carrier was always the most exciting part." Paul T. Gillcrist, *Feet Wet: Reflections of a Carrier Pilot*, Pocket Books, 1990, p 230. On pages 327-340 Gillcrist describes a combat mission in Vietnam. Four pages describe the combat; the rest of the chapter describes his night landing.

[78] Personal communication, captain of USS Stennis, 2007.

[79] Ewing, Steve, *Reaper Leader: The Life of Jimmy Flatley*, US Naval Institute Press, 2002, p 298.

[80] For example in 1958 Paul Gillcrist attended Navy Test Pilot School, and the incoming class was told to purchase life insurance and update their wills. 20 years later only 70 percent of them were still alive. Paul T. Gillcrist, *Feet Wet: Reflections of a Carrier Pilot*, Pocket Books, 1990, p 138. [need better source]

[81] Robert C. Rubel, "The U.S. Navy's Transition to Jets," *Naval War College Review*, Spring 2010, Vol. 63, No. 2.

[82] John "Crash" Miottel, *Callsign "Crash",* http://www.miottelcollection.com/index.php?pageid=18063

[83] Robert C. Rubel, "The U.S. Navy's Transition to Jets," *Naval War College Review*, Spring 2010, Vol. 63, No. 2. The 88 percent number appears to assume that all 1106 accidents destroyed the aircraft. An unofficial incident-by-incident list of F-8 ejections lists about 900, the vast majority in non-combat incidents. Each ejection corresponds to a lost aircraft, so the number of destroyed aircraft was is at least 70 percent of the fleet, in any case. http://ejection-history.org.uk/Aircraft_by_Type/F_8_Crusader/PART_ONE_CRUSADER.htm

[84] Paul T. Gillcrist, *Feet Wet: Reflections of a Carrier Pilot*, Pocket Books, 1990, p. 213ff.

[85] https://commons.wikimedia.org/wiki/File:F7U-3_CVA-19_ramp_strike_1955.jpg

[86] Rubel 2010, p 56.

[87] See for example Thomas C. Hone, Norman Friedman, and Mark D. Mandeles, "The Development of the Angled-Deck Aircraft Carrier: Innovation and Adaptation," *Naval War College Review,* Spring 2011, Vol. 64, No. 2, pp 63-78.

[88] Robert F. Dunn, "Six Amazing Years: RAGs, NATOPS, and More," *Naval War College Review*, Summer 2011, Vol. 64, No. 3.

[89] Robert F. Dunn, "Six Amazing Years: RAGs, NATOPS, and More," *Naval War College Review*, Summer 2011, Vol. 64, No. 3, p 106.

[90] *NATOPS Flight Manual Navy Model A-4E/F Aircraft*, NAVAIR 01-40AVC-1, November 1970; *Flight Handbook Navy Model A4D-l • A4D-2 Aircraft*, NAVWEPS 01-40AVA-1, April 1961, Revised January 1962. The 1970 manual is for model E, and the 1961 manual is for model D.

[91] *NATOPS Pilot's Pocket Checklist, TA-4F/J Aircraft*, NAVAIR 01-40AVD-1B, 1 April 1972. Change dates 1 April 1974, 1 May 1976, 15 Nov 1976, 1 May 1978. The checklist totals 145 half-size pages. The original 1972 version of the checklist totaled approximately 100 pages. It is for the training version of the A-4F.

[92] Robert C. Rubel, "The U.S. Navy's Transition to Jets," *Naval War College Review*, Spring 2010, Vol. 63, No. 2, p 58.

[93] Anonymous, "'The One Best Way', New Standards for Naval Air*" Naval Aviation News*, August 1961, pp 6-7. Also quoted in Rubel, 2010.

[94] Robert F. Dunn, "Six Amazing Years: RAGs, NATOPS, and More," *Naval War College Review*, Summer 2011, Vol. 64, No. 3, p 107.

[95] A variety of NATOPS manuals after 2000 contain this letter on page 1.

[96] *NATOPS Pilot's Pocket Checklist, TA-4F/J Aircraft*, NAVAIR 01-40AVD-1B, 1 April 1972. Change dates 1 April 1974, 1 May 1976, 15 Nov 1976, 1 May 1978. Downloaded from www.scribd.com.

[97] The pilot was in the Marine Corps. My wife noticed him going past because noisy jets traveling West at low altitude were unprecedented. He also flew over two schools.

[98] I obtained the accident report by FOIA request, and this section was heavily redacted. It is posted at http://art2science.org/2010/09/24/official-report-of-fa-18-crash/#more-313. The report is referred to as: *Command Investigation Into The Circumstances Surrounding The F/A-18 Aircraft Mishap Involving Buno 164017 That Occurred On 08 December 2008 In University City, San Diego*, *CA* various dates. A newspaper article on the crash is Steve Liewer and Rick Rogers, "A chain of wrong decisions," *San Diego Union-Tribune*, March 4, 2009. The Marine Corps gave a public briefing, but the charts from that briefing are not publicly available.

[99] Robert F. Dunn, "Six Amazing Years: RAGs, NATOPS, and More," *Naval War College Review*, Summer 2011, Vol. 64, No. 3 p 100.

[100] Roy Grossnick, *United States Naval Aviation, 1910–1995* (as republished in Roy A. Grossnick, *Dictionary of American Naval Aviation Squadrons* [Washington, D.C.: Naval Historical Center, 1997], vol. 2, CD-ROM). Quoted in Dunn 2011, page 101.

[101] *Approach*, August 1959. Referring to the A4D (later A-4D) Skyhawk. Quoted in Dunn, 2011, p 104.

[102] Attributed to Group Captain (O-6) Hamish Mahaddie, by Rupert Parkhouse "Taking The 'Battle' Into Battle," *Royal Air Force Historical Society Journal* volume 20, 1999. The "best flying club in the world" epithet was a common description of the RAF in the 1930s.

[103] Anthony G. Dudgeon, *The Luck of the Devil: An Autobiography 1934-41,* Airlife Publishing Ltd, 1985.

[104] Jeff Jefford, "Accidents – Investigation, Institutions And Attitudes 1919-1945" in *Royal Air Force Historical Society Journal 37*, 2006, p 44

[105] Sources of photos. John Deakin, "Pelican's Perch #73: Hurricane (Part 1)," September 14, 2003, www.avweb.com. Gladiator is from https://commons.wikimedia.org/wiki/File:Gloster_Gladiator_Cockpit.jpg. Photo by Towpilot. This Gladiator was used by the Swedish Air Force, and it may have some different instruments.

[106] Dahl, Roald, *Going Solo,* Penguin Books, 1986, p 119ff. Emphasis added. Dahl's training and very limited experience had been in Gladiator fighter biplanes. The rest of Dahl's squadron had presumably received better training, but Dahl had been recuperating from injuries for six months and unable to fly. Cockpit photos of the Gladiator are mixed as to whether it had an artificial horizon, but it was somewhat more complex than the Tiger

Moth.

[107] The episode is described in Anthony G. Dudgeon, *The Luck of the Devil: An Autobiography 1934-41,* Airlife Publishing Ltd, 1985, pp 117-123. The Blenheim I manual did exist, but for some reason it was not available to them. Anonymous, *Pilot's Notes Blenheim I Aeroplane Two Mercury VIII Engines,* Air Publication 1530A, April 1939, courtesy of WWW.FLIGHT-MANUALS-ON-CD.COM.

[108] This episode is discussed in Anthony G. Dudgeon, *The Luck of the Devil: An Autobiography 1934-41,* Airlife Publishing Ltd, 1985, pp 122-123. Also in Peter Thomas, *Sweet Bird of Youth,* manuscript, 2011. My thanks to Peter Thomas for assistance.

[109] Wing Commander Jeff Jefford, "Accidents – Investigation, Institutions And Attitudes 1919-1945" in *Royal Air Force Historical Society Journal v. 37*, 2006, p 46.

[110] Anonymous, *Pilot's Notes Blenheim I Aeroplane Two Mercury VII Engines*, Air Publication 1530 A, April 1939, courtesy of WWW.FLIGHT-MANUALS-ON-CD.COM.

[111] Anonymous, "Discussion," *Royal Air Force Historical Society Journal* volume 37, 2006, p. 69.

[112] Anonymous, *Hurricane I Aeroplane Merlin II Engine*, Air Publication 1564A, volume I, March-1939, Section 22.

[113] Wing Commander Jeff Jefford, "Accidents – Investigation, Institutions And Attitudes 1919-1945" in *Royal Air Force Historical Society Journal 37*, 2006, p 44.

[114] *Pilot's Flight Operating Instructions, Army Model P-51D-5 and British Model Mustang IV,* AN 01-60JE-1, April 5, 1944. *Pilot's Notes for Mustang III*, Air Publication 2025G-PN, June 1944. Retrieved from http://www.ww2aircraft.net/forum/attachments/other-mechanical-systems-tech/33641d1157971192-mustang-manuals-mustiii.pdf. All numbers are approximate.

[115] Wing Commander Jeff Jefford, "Accidents – Investigation, Institutions And Attitudes 1919-1945" in *Royal Air Force Historical Society Journal v. 37*, 2006, pp 38-39. The 1.7 calculation is my own, for a pilot who flies 500 hours in a year.

[116] Anonymous, *Spitfire version 2 manual*, Air Publication 156 B, July 1940. Longer lists appear in *Pilot's Notes, Spitfire VA, VB and VC Aircraft, Merlin 45, 45M, 46, 50, 50A, 50M, 55 or 55M Engine and Seafire IB, IIC and III Aircraft*, Air Publication 1565E and Air Publication 2280 A,B &C, no date, amendments Feb. 1943 and Feb. 1944, reproduced by Air Data Publications, Cheshire, U.K.

[117] Anonymous, *Pilot's Notes for Spitfire XIV & XIX, Griffon 65 or 66 Engine, Air Publication 1565T&w – P.N.* 2nd edition, Air Ministry, April 1946.

[118] There is some evidence that flight engineers in 4-engine bombers may have had more drills than just pre-takeoff and pre-landing. Personal communication with Larry Wright, October 27, 2012.

[119] Anonymous, *Pilot's Notes, Spitfire IIA and IIB Aeroplanes, Merlin XII Engine*, Air Publication 1565B, Air Ministry, July 1940.

[120] Geoffrey Wellum, *First Light*, 2002 Penguin Books, page 102, 125. Since this memoir was written in 1971, the specifics of some of his recollections may not be accurate, but other stories from novice pilots in that era are similar. In 2011 the BBC produced a TV series based on Wellum's experiences.

[121] *Reach for the Sky: The Story of Douglas Bader, Legless Ace of the Battle of Britain*, Paul Brickhill, 1954, page 162.

[122] Geoffrey Wellum, *First Light*, 2002, page 73.

[123] Examples of handwritten notes: see *Gaining An R.A.F Pilots Brevet In WWII*, PPRuNe Forums, entries by "Cliffnemo" on Oct. 13, 2010 and Oct. 22, 2010.

[124] *Pilot's Notes, Blenheim I Aeroplane, Two Mercury VIII Engines*, Air Publication 1530 A, April 1939. Courtesy of WWW.FLIGHT-MANUALS-ON-CD.COM.

[125] Anonymous, *Pilot's Notes Canberra B.2*, A.P. 4326B-P.N. 2nd Edition, 1953. Available from http://www.avialogs.com/component/phocadownload/category/1488-contribs?download=15356:0002512canberrab2.pdf

[126] RAF manual is *Phantom FGR Mk 2 Aircrew Manual - Book 1* AP101B-0902-15A October 1969, revision 23 March 1990. USAF manual is *Flight Manual USAF Series F-4C, F-4D, and F-4E Aircraft*, T.O. 1F-4C-1, McDonnell Douglas,1 October 1970. Navy version is a different aircraft and year: *NATOPS Flight Manual RF-4B Aircraft*, NAVWEPS 01-245FDC-1, 15 December 1965, updated to 15 April 1966.

[127] Wolfgang Schmidt, 'Von der ''Befehlsausgabe'' zum ''Briefing'': die Amerikanisierung der Luftwaffe während der Aufbauphase der Bundeswehr', *Militärgeschichte* 3 (2001). Reprinted in *Die Luftwaffe 1950 bis 1970*

Konzeption, Aufbau, Integration, editors Bernd Lemke, Dieter Krüger, Heinz Rebhan • Wolfgang Schmidt, R. Oldenbourg, Verlag Munich 2006. Translations provided by Carola Betzold.

[128] Schmidt 2006 p 672. He cites Das Deutsche Reich und der Zweite Weltkrieg, 5/1, p. 911-913 (Beitrag Kroener). Cf. Boog, Die deutsche Luftwaffenführung, p. 26-30; Rall, Mein Flugbuch, p. 212; Bundesarchiv-Militärarchiv 11188, Erfahrungsbericht von Fregattenkapitän Thomsen, März 1958. In diesem Sinne auch Späte, Flieger, p. 45.

[129] Schmidt 2006, p xx. He cites Sie holten sich ihre "Wings" in den Staaten [They got their "wings" in the States]; Bundesarchiv-Militärarchiv, BL 1/3502, Erfahrungsbericht von Hptm Ortmann, Aug. 1956.

[130] Schmidt 2006 p 674. He cites: Sie holten sich ihre "Wings" in den Staaten, p. 4. Cf. Rall, Pilot in den Aufbaujahren, p. 584.; Die außergewöhnlichen Männer [The extraordinary men], 2, p. 13; Rall, Mein Flugbuch, p. 246; Steinhoff, Aufbau einer taktischen Luftwaffe [Building up a Tactical Air Force], p. 911.

[131] Schmidt 2006, p 679. He cites Braun, *Die fliegerische Ausbildung*, p. 128; Tietz, *Der schwere aber schöne Weg*, pp. 104-108.

[132] Gunther Rall, *My Logbook - Reminiscences 1938-2006*, 2006 pp 244-245. The Ger-

man version of this book is *Mein Flugbuch. Erinnerungen 1938-2004*. By Günther Rall. Ed. Kurt Braatz, Wang, Germany: Verlag NeunundzwanzigSechs, 2004

[133] Rall, *My Logbook*, 2006 pp 34-35.

[134] Ernst Stilla, *Die Luftwaffe im Kampf um die Luftherrschaft: Entscheidende Einflussgrößen bei der Niederlage der Luftwaffe im Abwehrkampf im Westen und über Deutschland im Zweiten Weltkrieg unter besonderer Berücksichtigung der Faktoren „Luftrüstung", „Forschung und Entwicklung" und „Human Ressourcen,"* PhD thesis, Rheinische Friedrichs-Wilhelms-Universität, Bonn, 2005. Section "Flugdisziplin und Teamgeist" pp 243- 249. Translation by Carola Betzold: *The Air Force in the battle for air supremacy: Major influences in the defeat of the Luftwaffe in the defensive battle in West Germany in the Second World War, with particular emphasis on the factors of "air defense", "research and development" and "human resources."*

[135] The actual German text says American losses were 0.5% during a certain period. Perhaps surprisingly, Milch was rather accurate. The number is for all American transport flights, to both England and the Pacific, over the entire war was 1.2%. The 1942 number was 1.9%; by 1945 it was down to 0.6%. The average distance of these flights was over 10,000 km. By comparison, the distance from Berlin to Moscow is only 1,600 km. The comparison of the American and German losses is indeed extraordinary.Crew losses enroute from 1943 to 1945 were 400 in all theaters, 149 in the European theater. Source: " Table 206 -- ATC Ferrying Operations: Jan 1942 to Aug 1945," *Army Air Forces Statistical Digest, World War II*, n.d. "Table 63 -- Crew Losses Enroute From US in Overseas Theaters, By Theater and By Type of Crew: 1943 to 1945."

[136] Except as noted, all long quotations are from Stilla, 2005.

[137] Except as noted, all long quotations are from Stilla, 2005.

[138] Rall, *My Logbook*, 2006 p 113. The officer was "Kommodore Herbert Ihlefeld" which probably translates to O-7 rank, Brigadier General in the USAF system. He forgot only the rudder lock, and was flying a low performance aircraft, which may explain why he was hospitalized rather than killed.

[139] Kreipe, Werner, and Rudolf Koester. *Technical Training within the German Luftwaffe,* edited by Karl Gundelach. Maxwell Air Force Base, Air Force Historical Research Agency, 1955, pp 288-289. http://www.afhra.af.mil/studies/numberedusafhistoricalstudies151-200.asp. This report was originally in German. One of the authors, Kreipe, ended the war at the rank General der Flieger(O-9). He observed at close hand much of what he discussed.

[140] Except as noted, all long quotations are from Stilla, 2005.

[141] Stilla, 2005. This is echoed by Klaus Schmider, in "The Last of the First: Veterans of the Jagdwaffe Tell their Story," *The Journal of Military History*, Volume 73, Number 1, January 2009, pp. 231-249. Schmider writes that the promotion of a high-scoring fighter pilot into a leadership role was "a classic example, perhaps, of the wartime Luftwaffe's policy of giving accelerated promotion to those officers who had shown themselves to be

gifted dogfighters, rather than inspiring leaders or good administrators." p 243.

[142] See for example Chapter 2, "Training to Destroy," in Stephen L. McFarland and Wesley Phillips Newton, *To Command the Sky: the battle for air superiority over Germany, 1942-1944,* 1991.

[143] "The German Fighter Battle Against the American Bombers" by Lieutenant General Johannes Steinhoff, Inspector General, German Air Force, Translated and edited by Lieutenant Colonel William Geffen. In *Command & Commanders in Modern Military History, Proceedings of the Second Military History Symposium,* USAF Academy, 1968. Published by the Office of Air Force History, Headquarters USAF. Available at http://www.au.af.mil/au/awc/awcgate/cbo-afa/cbo10.htm

[144] Steinhoff, 1968.

[145] The pilot in question was Hans-Joachim Marseille. Colin Heaton, "Interview With World War II Luftwaffe Eagle Johannes Steinhoff," *World War II* magazine, Feb. 2000. Published Online: June 12, 2006. http://www.historynet.com/interview-with-world-war-ii-luftwaffe-eagle-johannes-steinhoff.htm

[146] Wolfgang Fischer, *Luftwaffe Fighter Pilot*, edited and translated by John Weal, Grub Street, 2010.

[147] *8-152 H-0 2 Bedienungsvorschrift-F1, Teil 1, Bedienungskarte für den Flugzeugführer*, Ausgabe Januar 1945. Translation: 8-152 H-0 Operating instructions Fl, Part 1 Instruction chart for the pilot, Edition January 1945. The Ta152 H was intended to be a successor to the Fw 190, but it never went into full production before the war ended.

[148] Williamson Murray, *Strategy for Defeat: The Luftwaffe 1933-1945*, Air University Press, January 1983, p 182 footnote 184.

[149] Murray 1983, Table 90, page 314.

[150] Murray 1983 p 254.

[151] Lieutenant General Johannes Steinhoff, "The German Fighter Battle Against the American Bombers," in *Command and Commanders in Modern Warfare: The Proceedings of the Second Military History Symposium U.S. Air Force Academy 2-3 May 1968*, available at http://archive.org. Translated and edited by Lieutenant Colonel William Geffen.

[152] Gunther Rall, *My Logbook - Reminiscences 1938-2006*, 2006, p 188.

[153] For example in January 1942, total strength was about 5100 aircraft including front line aircraft, trainers, and obsolete aircraft that were still in service, such as the Ju-87 (Stuka). Over the next 6 months, about 1800 were destroyed due to combat-related causes and 1500 were lost from other causes (accidents). The rate of new aircraft production was higher than the 3300 aircraft destroyed, and in July 1942 strength was about 5900 aircraft. Source: Murray Tables 57 and 65. His numbers are not entirely consistent, probably due to aggregation of monthly data to longer periods, and missing data for a few months. The discrepancies are small.

[154] Kreipe, Werner, and Rudolf Koester. *Technical Training within the German Luftwaffe,*

edited by Karl Gundelach. Maxwell Air Force Base, Air Force Historical Research Agency, 1955.

[155] Calculated based on fighter pilot losses from January 1943 to May 1944, Tables 38 and 44, in Murray 1983. The exact number is 55.8 percent. All data on fighter pilots is more reliable than other pilots because other aircraft had multi-person crews.

[156] Active duty number from Murray 1983 page 227. This estimate is approximate since the ratio of pilot to aircraft losses is unlikely to be the same for combat versus non-combat losses.

[157] Personal communication from Klaus Schmider, 9 October 2010.

[158] The Eighth Air Force and other American air groups rotated the experienced pilots home after about six months of combat if they had not been shot down, allowing the generals to alter the culture of the newcomers.

[159] I have not investigated the timetable for the Soviet/Russian air force. China may use a completely different approach. By approximately 2004, a manual for the Russian Su-27 fighter contained procedures, checklists, and complex graphs. Anonymous, *Aircraft Su-27[Sk], Leadership On The Flight Operations*, no date but stamped 24.02.2004. Partial English translation. Ironically, a full English-language original manual for the Mig-29 exists for the German Air Force, which inherited Mig-29 aircraft when East and West Germany merged. This manual is in English, dated 1994/2001, and follows the "Air Force" format described earlier. All manuals mentioned are courtesy of WWW.FLIGHT-MANUALS-ON-CD.COM LTD.

[160] The British also bombed Germany with heavy bombers. But they shifted to night bombing relatively early, and it was both harder and less necessary to coordinate night bombing.

[161] For example, by some accounts the IJN made little effort to recover pilots who had been forced down at sea. This was claimed, by some American historians at least, to be due to the attitude that pilots who had been shot down were demonstrably unfit warriors, just like its Army officers who lost battles and then committed ritual suicide.