Canopies for RAF fighter aircraft in World War II – design and influences

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The pace of aviation development during the Second World War was a truly unique phenomenon. As with other major weapons systems of the era – such as submarines, warships, and tanks – the fate of entire nations rested on continued technical progress with these machines amongst the war’s major belligerents.

Aircraft were even more unique than other weapons in this regard as they represented the peak of the era’s technological capability. Attesting to this is the fact that 25% of the funds spent on research and development nationally were dedicated solely to aviation-related issues in the United States, for example [1]. The resulting progress in advancing the state-of-the-art for military aviation is well-covered in a large number of historical reviews as well as more popular works, particularly for the case of fighter aircraft [2-5].

Despite the staggering amount of books on the subject of WWII fighters, the changes to canopy design is one topic which garnered relatively little attention. This is somewhat surprising, considering that the impact of this one component on the ability of a fighter pilot to effectively fight and survive was immense. Attesting to this is the fact in nearly 80% of the air-to-air kills in the war the victim never even saw his attacker [6], or the respect that Polish pilots garnered for their ability to spot enemy planes before their English or American peers [7-8]. Truly, then, the ability for a WWII fighter pilot to successfully see and scan out his canopy was a matter of life or death. Further, expert pilots specifically aimed for the cockpit of their targets, as the pilot inside was far more vulnerable than any mechanical component of the plane. The balance between maximizing a pilot’s vision and his safety was therefore a key aspect of aircraft design during the war.

The following article adds some detail to this somewhat under-reported story by reviewing the more common designs used in the primary fighters employed by the Royal Air Force. It will be shown that the development of canopy designs, although less impressive than the major gains made in aircraft propulsion and armament during the era, still underwent a major evolution through WWII. The changes in these designs reflected technical and production improvements as well as an evolution in the understanding of air-to-air fighting. By the end of the war, new designs had become commonplace which not only represented a vast improvement over earlier versions, but which also set standards still in effect today.

First Generation WWII Fighters and Initial Designs

When the newest single-engine fighter planes first debuted in service with the RAF in the late 1930’s, their basic design and tactics were strongly influenced by the preconceptions military leaders had

SUMMARY
This paper discusses the changes in the design of canopies for British fighter aircraft in World War II. During the war, the state of the art for these aircraft types underwent a major evolution in terms of performance and armament. Somewhat underappreciated is the corresponding development of canopy designs, which proved to be a critical component in terms of pilot effectiveness and survivability. It will be shown that this development was influenced by the evolving perspective on the nature of the aerial warfare as well as improved construction methods. This resulted in not only massively improved designs at the end of the war, but also in establishing new concepts which are still in use today.
regarding the modern nature of air-to-air fighting. Amongst RAF leaders and their civilian peers in the Air Ministry, the orthodox thinking was that the speeds and limited range of the newest fighters, such as the Hawker Hurricane and Supermarine Spitfire, would make the type of ‘dogfighting’ which characterized WWI aviation impossible. The pre-war discussions of the RAF’s Air Fighting Committee, one of the leading organizations in developing new airplane types and fighting techniques, make this point repeatedly [9]. As a result, maximizing the pilot’s ability to see out of the cockpit was a fairly minor consideration compared to improved structural strength or better aerodynamic properties. With these latter considerations in mind, the common practice of the era was to employ an extensive array of supports resembling a birdcage in canopy designs, which provided adequate margins of strength and protection. Keeping weight to a minimum was also important, so the use of clear Perspex, which became readily available for mass-production in the mid 1930’s, also became common practice for the fighters which would see action in WWII. For better pilot protection, thicker glass panels were incorporated in key locations, normally directly in front of the pilot.

The canopy on the Hurricane, which was designed in 1935 and entered mass production in 1937, perhaps typifies the design philosophies of the era. This design had a large number of structural supports for strength, which inhibited the view of the pilot through his cockpit (Fig. 1). The entire cockpit was also blended into the fuselage in order to reduce drag. This severely compromised vision to the rear of the aircraft and forced the entire canopy to be located lower vertically, also inhibiting the ability of the pilot to scan the skies outside of the airplane. The pre-war versions of the Hurricane were sometimes fitted with an additional external windscreen directly in front of the pilot as well, which was intended to further improve protection at the cost of yet even more obscured vision. Later this was remedied somewhat by integrating a thicker glass panel directly into the center of the windscreen. The prioritization of strength over vision was further emphasized due to the results of high-speed combat testing in 1937, during which several canopies actually came off of the planes in flight [10].

The next, and more advanced, fighter which went into service with the RAF exhibited modest improvement over the Hurricane’s canopy. This aircraft was the Spitfire, designed by R. J. Mitchell and his team at Supermarine. In many regards the Spitfire was years ahead of the Hurricane, so the modest improvements in its canopy layout highlight that this component was more of a secondary consideration. The overall difference between the planes was due to the fact that the Hurricane was an evolutionary step in aircraft design, built directly upon older biplane plans from Hawker’s with a focus on ease of manufacture [11]. The Spitfire, on the other hand, comprised the latest and most cutting-edge trends in aerodynamics and construction [12]. These advances – reflected in the superior
speed, rate of climb, and overall performance of the Spitfire – were not apparent when comparing the canopies of these aircraft. As an example, the prototype Spitfire featured a design that was very similar to the Hurricane, albeit with slightly less metal bracing.

The production version, somewhat improved the visibility for the pilot with a center canopy section designed and built by the company R. Malcolm, Ltd. Often referred to as the ‘Malcolm Hood’ after this company, this canopy made more extensive use of Perspex to minimize the ‘birdcage’-type supports and incorporated a higher dome-like shape (Fig. 2). This shape both provided the pilot with better viewing and made opening and closing the canopy easier. Although the Malcolm Hood was thus an improvement over the older cage-like design on the Hurricane, it was not without its problems. The slight curve in the sides of the dome resulted in a distorted perspective which was an impediment to long-range scanning. Additionally, the view to the rear was still blocked by the fuselage as the designers had prioritized drag-minimization over improved pilot sighting in that direction. Given that the most dangerous situation for fighter pilots was being surprised from behind, the obstructed view in both the Spitfire and Hurricane design was a major shortcoming. Despite calls from Fighter Command pilots to remEDIATE this issue as early as 1939, it would be several years before it was addressed [13]. Overall, the Spitfire canopy looked little different to that of the Hurricane from the point of view of the pilot and was only marginally better in comparison [14].

The pre-war trend of improved canopy designs took a major step forward with one of the last fighters designed before hostilities began in 1939. The Westland Whirlwind, which underwent initial design and testing from 1937 onward, featured a spacious, bubble-shaped canopy (Fig. 3). Combined with the relatively high seating location of the pilot, this meant that the Whirlwind offered unparalleled pilot visibility in comparison with the other planes of the era. A main reason for these improvements was the fact that the Whirlwind was based on a two-engine design. In theory, this gave the aircraft much more available power, offsetting the drawbacks of a canopy shape which produced more drag than those in the single-engined Hawker and Supermarine planes. Despite the relative breakthrough in canopy design, the plane was an overall failure due to limitations with the Rolls-Royce Peregrine engines. Due to the high demand for the proven Rolls-Royce Merlin engines which were powering the Hurricane and Spitfire, Whirlwind was forced to base their new fighter on the newer Peregrine. This newer engine was beset with problems, with the result that the reliability and performance of the Whirlwind never met expectations. In the end, only 114 production models were actually built and the influence of the novel features of its design, canopy included, appears to have been minimal [15].

Development during the war
After the war started, the RAF’s pre-war assumptions on the nature of air-to-air fighting, which had shaped both aircraft design and fighting tactics in the inter-war era, were quickly shown to be incorrect. In the skies over France in May and June of 1940 and during the Battle of Britain soon thereafter, it became apparent that the era of maneuvering combat between fighter planes had not ended in World War I and was very much a distinguishing feature of the new war. In some regards, the RAF was able to quickly implement needed technical changes in response to the experiences of the fighter pilots in combat. For example, by late 1940 the Hurricane had been fitted with additional armor and improved wing-tank lining to minimize burn injuries pilots had been suffering. Additionally, both the Spitfire and Hurricane were fitted by August of 1940 with variable-pitch propellers, increasing their performance to meet the standard of the main Luftwaffe fighter, the Messerschmitt Bf 109.

However, any changes to improve the ability of RAF pilots to better see their enemy via improved canopies was absent during the first year of the war. It is worth adding that RAF Fighter Command tactics could have also been amended to help as well. These tactics were another product of the pre-war assumptions about air-to-air combat within the RAF, and took the form of strict flying formations and the use of prescribed ‘standard attacks’. Both of these required the RAF pilots to dedicate a large amount of attention to formation flying; combined with the close-in formations this meant that they were at a disadvantage in spotting enemy fighters. The Luftwaffe, in comparison, had learned from their experiences in the Spanish Civil War and had adopted more wide-open formations and much more flexible methods of attack, both of which proved far superior in combat to the RAF approach [16]. These tactics underwent only minor official changes until the spring of 1941.

During this time, it became clear the Hurricane was headed for obsolescence, so its development shifted to the incorporation of new weapons for air-to-ground missions rather than any improvements for air-to-air fighting, where pilot viewing, particularly to the rear, would have been more important [17]. In the theaters where the Hurricane was still forced into air-to-air fighting later in the war, such as North Africa or Malta, the lack of improved cockpit design forced pilots to routinely fly with their cockpits open to improve their vision as much as possible [18].

For the Spitfire, the suggestions which made it through official channels mentioned improved pilot comfort and visibility, but again the priority was sheer performance [19]. The Spitfire canopy finally underwent its first major improvement late in 1941, due to the intervention of one of Supermarine’s lead test pilots, Jeffrey Quill. Quill had left Supermarine for a short operational tour with Fighter Command specifically to get additional insight into what the frontline pilots needed in newer versions of his company’s aircraft. His experiences scanning the sky during fighter sweep missions over occupied France highlighted the detrimental effects of the optical distortion caused by the curved Perspex sides of the Malcolm Hood [20]. He returned to Supermarine and provided the impetus for an improved design which incorporated optically-true glass [20]. Around this time the official RAF guidance on air-to-air fighting had also evolved, reflecting the more open and flexible formations and aggressive tactics that the Luftwaffe had successfully demonstrated since the very start of the war. These design and tactics changes meant that the front-line RAF pilots by mid to late 1941 would be much more well-prepared for aerial combat than their predecessors.

The Luftwaffe provided further technical inspiration as well as tactical. In late 1941, their newest fighter the Focke-Wulf 190 first began appearing in great numbers in the European theatre. This aircraft was perhaps the pinnacle of the German piston engine fighter design, and resulted from a push from German High Command for both improvements to the Bf 109 and a new fighter to avoid the losses seen in the Battle of Britain [21]. With its large radial engine and massive roll rate, it proved to be far ahead of the best RAF fighter of the time, the Spitfire Mk V, in air-to-air fighting. This spurred a crash development program that resulted in the fielding of the much improved Spitfire Mk IX in late 1942. As the Spitfire IX was undergoing final preparations for production, an intact FW 190 was captured by the British when the German aircraft’s pilot got lost and accidentally landed in England instead of occupied France. This aircraft was studied at the RAF’s flight test establishments, where the pilots not only substantiated its superior performance in flight but also its canopy design. The official test notes remark that the canopy offered a outlook “the likes of which had not been seen before” with an unrestricted view in all directions [22]. The key to the unparalleled view offered by the FW 190, was an avoidance of

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17
the type of metal supports used in previous canopy designs and the long, tapered aerodynamic shape (Fig. 4). This design reached a balance between aerodynamic considerations and pilot perspective without resorting to the obstructed rear view which characterized the previous RAF and Luftwaffe fighters.

Combined with independent progress being made with less-obstructed canopy designs for the pressurized, high-altitude reconnaissance Spitfire models, the example set by the FW 190 would help ultimately result in a vastly improved cockpit and canopy layout in late-model Spifires. Starting in the middle of 1943, testing was undertaken on a “bubble canopy” design that was essentially a more rounded version of the FW 190 canopy which had previously so impressed the RAF test pilots. This new canopy was combined with a slightly remediated, or “cut out”, fuselage to finally provide the unobstructed rear-viewing that pilots had requested since the earliest days of the war [4]. The first production model to feature these changes was the Mark X Spitfire (they were retrofit onto previous Marks at that time as well). Attesting to the relatively low priority of this design consideration, however, is the fact that these changes were not widely implemented until 1945 when the war was all but over (Fig. 5).

**Newer fighters, newer designs**

These improvements in canopy design were incorporated somewhat earlier on other aircraft, underscoring their utility despite the delays involved in adding them to the Spitfire. The Hawker Typhoon, which first became operational in 1941 after an unexpectedly difficult development process, initially featured a complicated canopy structure which resembled more closely the older design typified on the Hurricane (Fig. 6). There was improvement in terms of how the cockpit and canopy were located along the fuselage, reflecting possibly the influence of pilot demands and the example set by the Whirlwind. By 1943, the Typhoon was tested with the new “bubble canopy” along with the Spitfire, and later that year this feature became a standard on the new RAF fighter. This example was followed in the Hawker Tempest, which was basically an aerodynamically improved version of the Typhoon and entered service in 1944. Although the earliest versions of this aircraft used the same complicated canopy layout of its predecessor, by the time it was in service it, too, featured the Plexiglas bubble canopy (Fig. 7).

An important development which made the implementation of these new canopies possible were the improved engines and aerodynamic features of the planes designed after the war began. As engines became more powerful, and new lower-drag wing profiles and other engineering upgrades lowered the overall drag of new airframes, the additional drag from a larger canopy became more tolerable from a design perspective. Combined with the changes in official RAF training guidance which fully recognized that visual engagements with other fighters – dogfights – were still an essential part of air combat, these advances supported the evolution of more spacious and unobstructed canopies.

The British advances in canopy design manifested in the Tempest and Typhoon were also very influential on two American-built aircraft which entered the European theater after 1942 – the North American Aviation P-51 Mustang and the Republic P-47 Thunderbolt [23]. The initial versions of both aircraft again relied on the orthodox “birdcage” type layout, but joint testing with the RAF introduced American pilots and engineers to the prototype bubble canopies piquing their interest in this design. Similar to the evolution of the Spitfire hood, but on a much shorter timeframe, both aircraft types quickly standardized by their respective “D” versions in 1943 to the bubble-type, although most earlier P-51B and C Mustangs had been modified in-theater to the new style. From that point onward, until the final implementation of the bubble canopy on the Spitfires in 1945, it became rarer and rarer to see an Allied fighter in Europe equipped with the obstructive canopy types.

**Conclusion**

This legacy has carried through to today. The birth of jet-powered fighters, which began in the closing chapters of WWII, would present engineers with new challenges in balancing structural strength, aerodynamic qualities and pilot vision. However, a look at the designs of the vast majority of the fighters built during the Cold War and beyond shows that maximizing a pilot’s vision was a much higher priority than at the beginning of WWII. The results of the development of fighter canopies which took place from 1939 to 1945 are thus seen throughout the aviation community today.

Drawings by the author.

**BIBLIOGRAPHY**


[9] Minutes of the 1st Meeting of the Air Fighting Committee, 1 November 1934, The National Archives (dalej jako NA), sygn. AIR 16/1024


[14] Charlesworth Max, wywiad z Imperial War Museum (nagranie audio), 23.04.2006, sygn. 28898


[17] Letter, from Air Marshall Sholto Douglas, Air Officer Commanding, RAF Fighter Command, 1 February 1941, NA, sygn. AIR 16/328

[18] Leggett Percival, wywiad z Imperial War Museum (nagranie audio), 26.07.2004, sygn. 27075

[19] Letter, from Air Marshall Sholto Douglas, Air Officer Commanding, RAF Fighter Command, 1 February 1941, NA, sygn. AIR 16/328


