Those of you who know me, and of my devotion to Golden Age aircraft, might think this project is a little out of character. But those who know me well know I have always had a soft spot in my heart for Navy Air-craft. I'm sure it's because I grew up with them. My father was a pilot in the Navy, and I was born and raised on Naval air stations and have vivid memories of NAS At-lanta (a Reserve base), where my father was stationed after the Korean War.

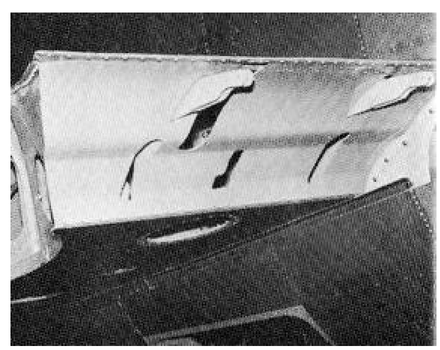
I was five or six at the time and remember play-ing in Link Trainers, or pretending I was struggling against a hurricane as I stood in the propwash of Corsairs warming up their engines near an open, grassy area. I also remember the time my father took me inside a PBY. While I couldn't compre-hend it at the time, it had been a mere ten years earlier that he had flown PBY's in the Pacific Theater.

I explored every inch of that airplane, and thirty-five years later, I can still close my eyes and picture the zinc chromate green passageway lead-ing from the radioman's compartment to the cockpit.

In the late 1950's, we were stationed at NAS Cubi Point. Cubi Point juts out across the mouth of Subic Bay and a run-way stretches across it from the bay to the ocean. There is a small hill overlooking the runway, and I spent many hours sit-ting there watching F8U Crusaders shoot touch and go's. I was fascinated by the wing-tilt mechanism of the Crusader. The forward part of the wing center section was painted a reddish-orange, and when the wing was cranked up, you could see that color against the white of the fuselage from miles away, as the airplane approached. While the Corsair II resembles the crusader, it doesn't have the wing-tilt mechanism and has never held my in-terest in the same way.

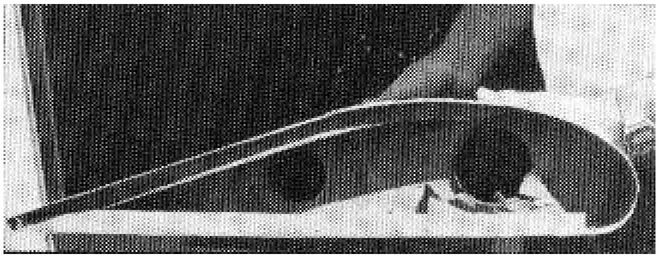
There is a point to this digression. Many airplanes have distinctive features that give them much of their character. With the F4U Corsair, it's the gull wing; with the F8U Crusader, it's the variable-incidence wing. While no scale modeler would attempt to simplify the construction of a Corsair by building a straight wing but most would choose to ignore the wing-tilt mechanism of the Crusader. The Hellcat also has some very distinctive and some subtle features. It is an airplane that has appealed to me since my youth and I have built several plastic models of it. I built a U-control model many years ago but have managed only false starts at a full-blown scale R/C model. Then at the 1986 Masters in Fountain Valley, I was talking with Jerry Heaton and he showed me the unfinished prototype of a 1/5 scale Hell-cat he was designing for Don Lein. I immediately fell in love and the following spring, ordered a kit from Don. When I finally pulled all the parts out of the box and carefully studied my documentation to plan the construction, I noticed something that I had glossed over in all my previous studies - THOSE FLAPS! How in the world do they work? No conventional actuating mechanism could possibly make them look right and even worse …would actually make them look wrong! I studied every photograph I had and became obsessed with this question. While my efforts to discover the answer and miniaturize it delayed the construction of my model for a full year, I have enjoyed the hunt. In the process, feel I have captured a subtle but distinctive feature of the Hellcat.

So what is it about Hellcat flaps that took me so long to figure out? If you study a good set of three-views you will notice that the flap seg-ments are rectangular, with a chord of 20 inches. Viewing the wing from the bottom, you can see the full 20-inch chord. In top view, however, only the rearmost 11 inches are exposed. The top surface of the wing extends back over the flap, covering the forward 9 inches. Because of this, if the flap were hinged at its leading edge, it would look like a split flap when deflected (much like a P40, or a Wildcat). But looking at pictures of Hell-cats shows that this is not the case. There is a distinct, but relatively narrow, gap be-tween the flap and upper wing surface. The airfoil of the deflected flap actually arcs smoothly toward the upper wing sur-face, forming a graceful (although steeply curved) line between the wing and flap. Simply moving the hinge point deeper into the flap will not reproduce this line. In fact, if the hinge line were moved very far back, flap deflection would be restricted because the leading edge would ro-tate upward, and jam against the extend-ed upper wing surface (see the upper figure in my drawing).



Rear view of fixed (Non Folding) part of the port wing. The vertical slots below the fixed hinge arms are the exits for the pushrods which move the flap rearward during the extention cycle.

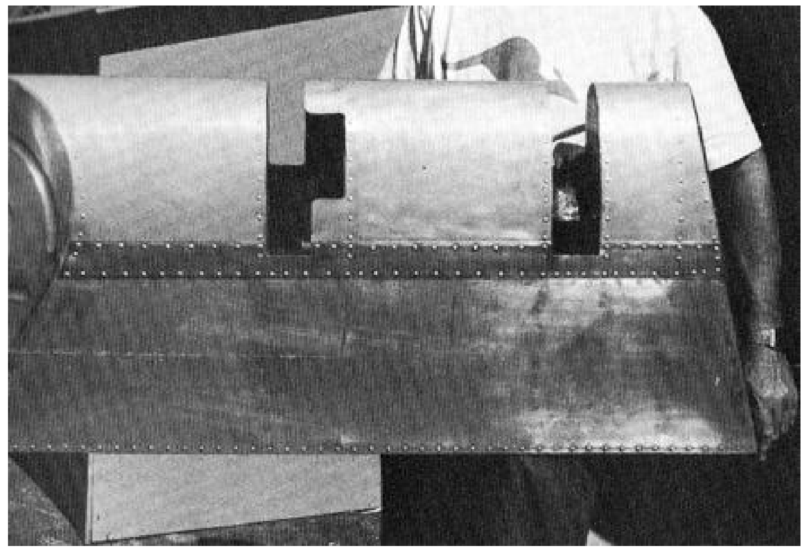
I purchased a copy of the Warbird Checkout Ride video that includes the Hellcat and was pleased to find it has a couple of good close-up scenes of the flaps deflecting and retracting. What they appear to do is drop away from the wing a couple of inches, and then rotate. It is hard to tell exactly what is happening, but it is clear that something more than a simple rotation is occurring.

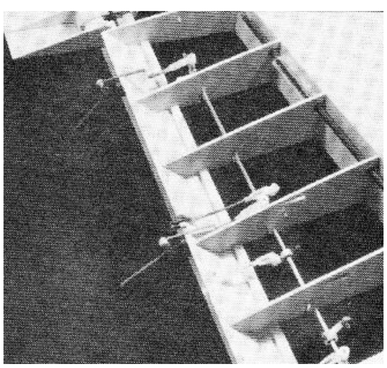


Side view of the port invoard flap segment. The bottom surface follows a stright line from the trailing edge to the begining og the curvature at the leading edge. The top surface follows a striaght line from the trailing edge to the chafe strip.

I have heard people declare "Yeah, the Hellcat had a funny Fowler flap" - but that is not the case. A Fowler flap moves in a track and serves to increase both wing camber and (through its rearward movement) wing area. There is no such mechanism on the Hellcat. Willis Nye, in drawings he did for the June and July 1959 issues of Model Airplane News, identifies the mechanism as a "slotted flap:' Grumman actually experimented with slotted flaps on some late versions of the Wildcat (prototypes of the FM-2 series), but did not incorporate them on a production aircraft until the Hellcat.

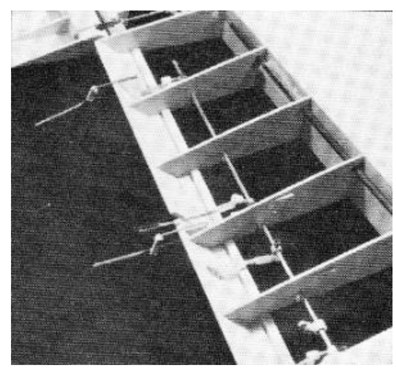
The slot between the extended flap and wing is really quite obvious. If you look in Jim Sullivan's "F6F In Action” you can see some very good pictures. On page 16 is a view of a Hellcat (from the perspective of the LSO) taking a waveoff, and one can clearly see daylight between the leading edge of the flap and the trail-ing edge of the wing. On page 28, is a 3/4 rear view (from above) of a Hellcat being readied for catapult and the carrier deck is clearly visible through the slot. On page 12, there is a picture of a Hellcat go-ing over the port side of the USS Cabot after its tail-hook failed. In its death throe, it gives an excellent view of the undersur-face of the wing. The flap appears hinged at the end of rods which extend out of the wing, parallel to its lower surface. Also, a section of the lower wing skin is seen to be retracted inward, opening a large gap ahead of the flap.





Top view, port wing torque rod is rotated in the “Full Retracted” postion. Arms pulled forward.

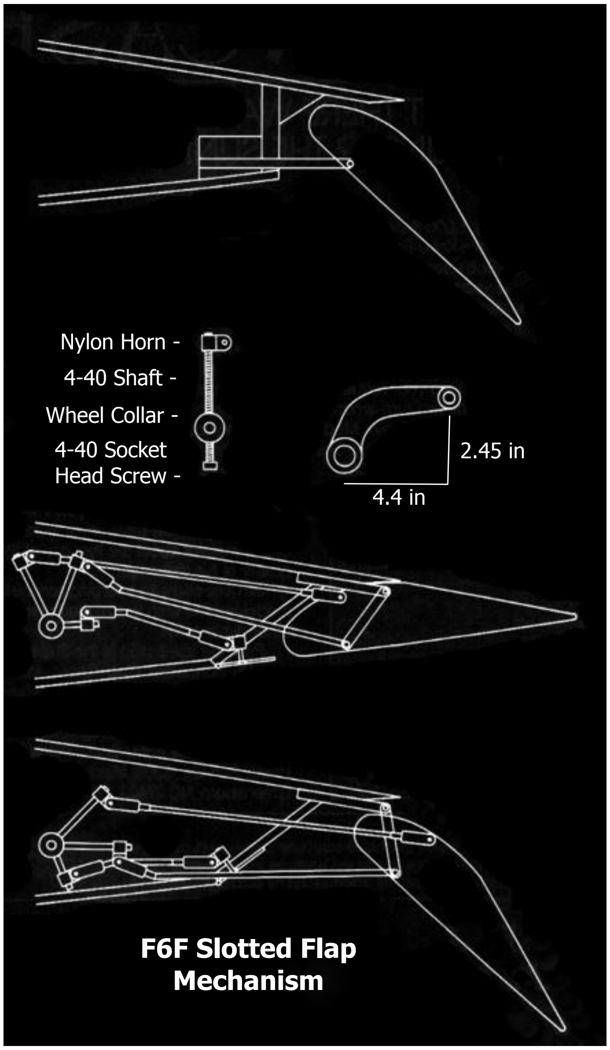
While I am no student of aerodynamics, I assume slotted flaps provide benefits similar to leading edge slots; they should improve the wing's aerodynamic characteristics at high angles of attack and increase the angle of attack at which stall occurs. Not a bad objective for a full scale airplane or a model. But, because of the rearward projection of the upper wing surface, none of the standard modeling approaches to hinging the flaps can produce a functional slot. The question I faced was: how does this mechanism operate on the full-scale air-craft and can it be reproduced ade-quately on a model?



Same view, but with the torque rod rotated to the “Full Extended” position.

What I finally learned is that the flap segments are mounted on a swinging hinge assembly. The motion of the hinge causes the flaps to move down (opening the slot) and back (to smoothly blend with the trailing edge of the wing) as they deflect. My first good views of the hinge mechanism came from some pictures taken by my friend of a Hellcat on display at the San Diego Aerospace Museum. My best views, however, came from examination of a Hellcat undergoing restoration at the Hayward Air Terminal near Oakland, California. Another friend of mine learned of the restoration and knew the person in charge of the project. Last spring, Doug and I spent a full morning photographing, measuring and studying the airframe. It was a great opportunity, because the craft was largely disassembled. The fuselage had been remounted on the wing center section but the tail assembly, control surfaces and wings were in pieces all around the shop. It was a scale modelers dream! One thing that actually surprised me was how much I had learned from my study of photographs and drawings. As I rummaged through the parts boxes, I found I could recognize not just major components, but small parts as well.

Even though I have never seen a disassembled Hellcat before, I had a strong sense of déjà vu as I explored the many boxes and shelves containing parts. Unfortunately, at the time of our visit, the outer flap segments were not in the shop. They had been sent out for covering (Charles Mendenhall is incorrect in his book where he states, "the flaps were of all-metal construction!' Only the inboard segments are all-metal.

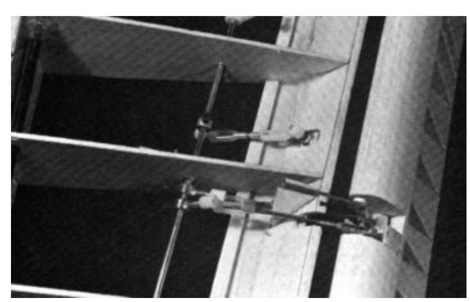


F6F Slotted Flap Mechanism

The outer segments are fabric-covered over an aluminum framework, just like the ailerons, elevator and rudder). I have included some photographs of the port inboard flap. Photo #3 shows Doug Barton holding the flap to show its plan view. The flap is spanned by a chafe strip at the point where it would contact the upper trailing edge of the wing. I don't know what the chafe strip is made of, but would describe it as a "resin-impregnated fiber" material, approximately 1/8th-inch thick. Photo #2 is a side view of the flap segment, showing its airfoil shape. Photo #1 is of the fixed (non-folding) section of the port wing. Photo #3 shows a side view of the stream-lined slot. The slot door was not in place for the photos. It is a flat, rectangular plate, with a chord of 4 inches. It attaches to the lower wing surface by a piano hinge. When the flap is actuated, this door retracts upward and tucks neatly into the recess in the lower part of the slot curvature. This forms a smooth, sweeping curve from the bottom wing surface to the top. The same chafe strip material used on the flap is riveted along the trailing edge of the wing. Just below this edge, the fixed hinge-points can be seen projecting from the rear of the wing. They connect to the hinge point on the lower surface of the flap by means of an L-shaped bracket. I have illustrated that bracket, and the true dimensions of its center points, on my drawing. **Note that in my drawing of the model flap mechan-ism, I used a straight link. The curvature of the full-scale link provides clearance around some of the internal structure of the flap. For a model a straight link is easier to construct and does not alter the flap motion**.

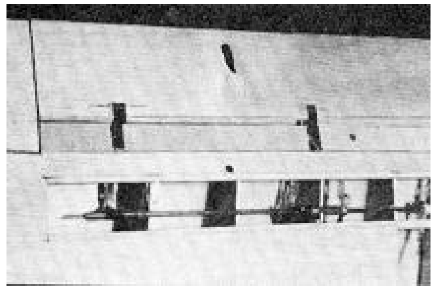
In Photo #1, you can see several cutouts in the rear of the wing. These are for the various pushrods. The large cutout next to the outermost fixed hinge point is where the pushrod causing flap deflec-tion exits. Of the three cutouts near the lower wing surface, the middle one accommodates the link-arm which opens and closes the slot door. The push rods which cause the hinge point to swing backward (during deflection) or forward (during retraction), can be seen just be-low the fixed hinge points. All of these push rods are actuated by a torque rod mounted in the wing. This torque rod assembly (which is illustrated on page 29 of the Maru Mechanic book) is rotated by a hydraulic cylinder. The pilot controls the flaps by means of a 2-position toggle switch located next to the throttle quadrant. There are no controllable positions between "up" and "down!" Intermediate flap positions are determined by air load on the extended flaps. The push rod causing flap deflection actually connects to the flap through a compression spring. Air pressure on the flaps causes them to rotate toward a closed position and push against the spring. At 93 knots, the spring will hold flap angle at 50°, while at 150 knots, it compresses to give a 15° deflection. An airspeed switch automatically retracts the flaps if the speed exceeds 170 knots. It is mentioned in the Warbird Checkout video that the flaps can be deflected to help slow the airplane down prior to lowering the landing gear, since the gear will not lower completely if airspeed exceeds 135 knots.

When I finally understood the flap workings, miniaturizing them became a much more tangible challenge. My approach to the problem is illustrated in the accompanying photographs and draw-ings. These illustrations are meant to guide scratch-builders who may wish to attempt the same thing on their particular model.

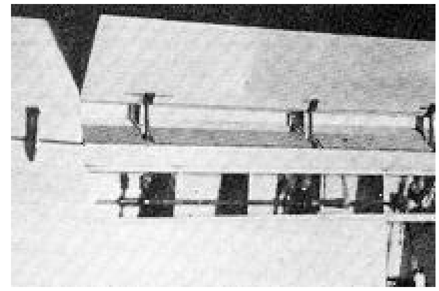


If you study my drawing, you can see how the flap operates. The torque rod rotates the throw-arms in a clockwise direc-tion. The angular spacing of the throw-arms is a critical factor determining flap motion. When the flap is retracted (center drawing), the throw-arm that drives the swinging hinge is angled rearward, while the arm that causes flap deflection is an-gled forward. As the torque rod rotates, these push against the top and bottom of the flap, moving it rearward. The motion of the swinging link arm causes the flap to arc downward, away from the trailing edge of the wing. As the throw-arm push-ing the link reaches its maximum exten-sion, it arcs through a "dead zone" where it neither pushes nor pulls on the hinge link. But while it is moving through this dead zone, the "flap-deflection-arm" is passing through its arc of maximum throw. If the angles are right, the flap will appear to glide down and back, after which it will quickly rotate. While all this is going on the link to the slot door is be-ing pulled forward, opening the door.

As you can see, the angles between the throw-arms are very important. When you build it you can tell pretty quickly if something isn't positioned properly. For example, if the "flap-deflection-arm" is angled too far forward, the flap will initially reflex upward before it rotates downward. As you piece this all together, careful observation of the flap motion during extension and retraction will lead you to the correct angles and throws. Like I said, this is a project for the hard-core tinker-types out there. So, with the concepts in place, let's get down to the model.



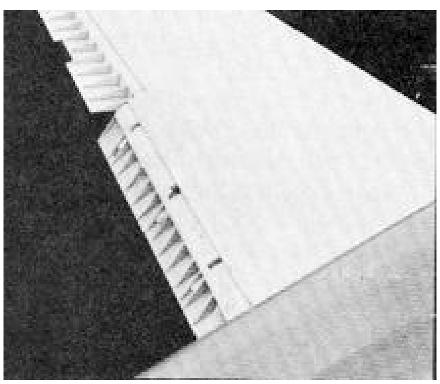
Bottom view of the port wing (aileron to the far left) showing the access hatch to the torque rod assembly and servo. Flap is fully retracted and slot door closed.



Same view but the flap has been deflected and the slot door is pulled open.

As I mentioned earlier, my model is from the Don Lein kit. This kit utilizes foam wing cores, which don't lend themselves well to this type of modification. To accommodate the mechanism, an open-bay rib structure is needed. But, rather than throw the wing cores away (after all, I did pay for them!) I used them in a hybridized structure. I sawed the wing panels in half from the tip to the root and installed a full-span main spar. As you can see in Photos #4 and 5, the foam core was glued to the forward side of the main spar and balsa ribs were glued to the aft side. The rib shapes were obtained by slicing up the foam core on my band saw and making tracings on 3/32 balsa. I aligned everything using the foam core "beds" as building jigs. A piece of 3/16 balsa sheet was used for the angled trailing edge.

Just as on the full-scale Hellcat, there is one torque rod for each flap segment. I used 1/8th-inch diameter landing gear wire for the torque rods and mounted them in sleeve bearings made from nylon bell-cranks. This gives a smooth, slop-free mechanism. The throw-arms took some thought, because I knew I had to have a lot of latitude in adjusting the length of throw and angular offset of the arms. There was no way (for someone of my limited skills) to predict these angles and dimensions in advance and they are absolutely critical to the proper function of the flaps. What I finally came up with is illustrated in the inset box on my drawing. I took standard 1/8th-inch wheel collars and drilled and tapped a 4-40 hole opposite the set screw. I then screwed a 4-40 machine bolt into the hole, soldered it in place and cut off the head. I tapped threads into a nylon horn (the type used for strip ailerons) and screwed it onto the 4-40 shaft. This gave me a driver arm on the torque rod which I could easily adjust to obtain the proper throws. These arms can be seen in Photos #7 and 8.



Here is how the Hellcat flap should look when deflected! Note the relativiely narrow gap between the wing and flap and how smoothly the curve of the flap arcs toward the upper wing surface.

Looking down the outer flap segment (from the tip of the wing toward the root). This shows the pushrods that have moved the flap back away from the wing and the slot door fully retracted upward.

I constructed the fixed hinge points out of 1/4-inch brass strip stock. These were glued into notches cut in the top of the trailing edge, and reinforced with plywood gussets (Photos #4 and 6). The link arm was made of 1/4-inch strips of 3/32 nylon. The hinge push rods were made of 1/8th-inch brass tubing, flattened and drilled at the hinge-end so they could be bolted to the movable end of the link arm. I also used 1/8th-inch brass tubing to form the rotating hinge arms that slide into the flap segments (Photo #6). In Photo #5, the hinge assembly can be seen fully retract-ed, and in Photo #6, fully extended. Photos #6 and #7 show the position of the torque rod, throw-arms, and push rods with a flap segment retracted (Photo #6) and extended (Photo #7).

In Photos #8 and #9, I illustrate the action of the slot door as seen from the bottom of the wing. Notice at this point, that I have sheeted the wing and provided for an access hatch exposing the entire flap mechanism and servo. I learned Murphy's Law of modeling a long time ago; "If you build it so you can't get to it, youcan be sure it will break, leak, or slip out of adjustment!' Photo #8 shows the door in its closed position, sealing the gap be-tween the wing and flap when the flap is fully retracted. In Photo #9, the flap is deflected, and the slot door has rotated inward to open the slot. I glued the individual door segments to a length of piano wire which acts as a torque rod hinge. The reason for this was so I could operate all the segments with one pushrod. The full scale has a separate pushrod for each segment, but I didn't want to have to worry about all the additional mechanism.

You can see that I mounted one servo in each outer wing panel to drive the outer torque rods. The torque rods for the inner flap segments are both driven off of one servo. This arrangement was necessitated by the landing gear more than anything. The rearward retracting gear, with their cavernous wheel wells, made it impossible to mechanically link the inner and outer torque rods in each wing panel. The only reasonable option seemed to be to mount servos in the outer panels and run the wire discretely through the wheel well. While the wing is sheeted with 3/32nds-inch balsa the upper trailing edge is a laminate of 1/16 balsa and 1/32 ply. This can be seen in Photos #10 and 11. The reason for this was to provide a ding-resistant trailing edge, since it has to be feathered out to a thin edge.