F-22 RAPTOR

High performance micro EDF model with thrust vectoring

Version 2.0 published 7-29-10

Introduction

This model was designed for a micro EDF competition on RCGroups.com and won the 40mm category. I wanted to make an F-22 that was easy to build but also scale looking with great flying qualities. Thrust vectoring is done with simple paddle extensions on each elevon which gives excellent control authority at all speeds.

I hope you enjoy building and flying it.

Matt Wherry
February 2008

Model Specifications

Wingspan: 15” (384mm)
Length: 21” (535mm)
Wing area: 98 sq.in (6.3dm^2)
Weight: 4.7 - 5oz (133 - 142g)
Wing loading: 7.4oz sq.ft at 5oz (22.5g/dm^2 at 142g)
Controls: combined elevons/thrust vectoring paddles and throttle

Components

GWS EDF-40 housing and impeller
Feigao 1208425L 5866kV 12mm brushless motor (use GWS heat sink for summer flying)
Thunder Power 3S 730mAh li-poly pack
Castle Creations Berg Microstamp 4L receiver
E Flight Products Lightenna72 lightweight antenna
Castle Creations Phoenix-10 brushless speed control
2 Blue Bird BMS-303 servos

Materials and Tools

3mm Depron sheet
2mm carbon rod
.032" music wire
1/8" balsa sheet scrap
2 Du-Bro #848 micro control horns
Foam safe paints
Foam safe CA glue and accelerator
Foam safe spray glue
3M double sided foam tape
Blenderm and or Scotch tape
100 and 600 grit sandpaper
X-Acto knife with #11 blades
Cutting rail
Drafting triangle

Design notes

My original plan was to make this model very compact with a wingspan around 12". At that size the battery back and other components were difficult to package in a scale fuselage so I reluctantly scaled up the design. This turned out to be for the best since the larger model is a very friendly flyer and all the gear fits inside comfortably.

The exposed fan installation is not the most attractive solution but it is a functional one. Since the F-22 has a relatively thin rear fuselage this model would have to be quite large to house even a small fan unit like the EDF-40. With an exposed installation airflow into the fan is relatively unimpeded in high throttle/low airspeed flying where a significant amount of air is drawn from the sides and rear.

Markings are included for United States Air Force and Japan Air Self Defense Force (JASDF) versions. As of this writing foreign sales of the F-22 are banned by Congress, but Japan is likely to be the first foreign operator if and when this ban is lifted.

The model was designed with Rhinoceros modeling software and plans prepared with Adobe Illustrator.

Assembly Guide

1 – Print the templates with the page scaling option set to “None”. Refer to the scaling square on plan page 1 to verify size after printing. Some part templates are split due to their size and will need to be spliced together with tape. Use the alignment lines and a straight edge to get the pieces joined perfectly. Check the grain direction of your foam sheets and refer to the template sheets for recommended orientation. Spray the templates with a very light dust coat of foam safe spray adhesive and apply them to the foam. Cut out the parts. Note that some lines appear straight but are actually slightly curved.

Leave the paper in place until the part is needed and refer to the printed notes during assembly.

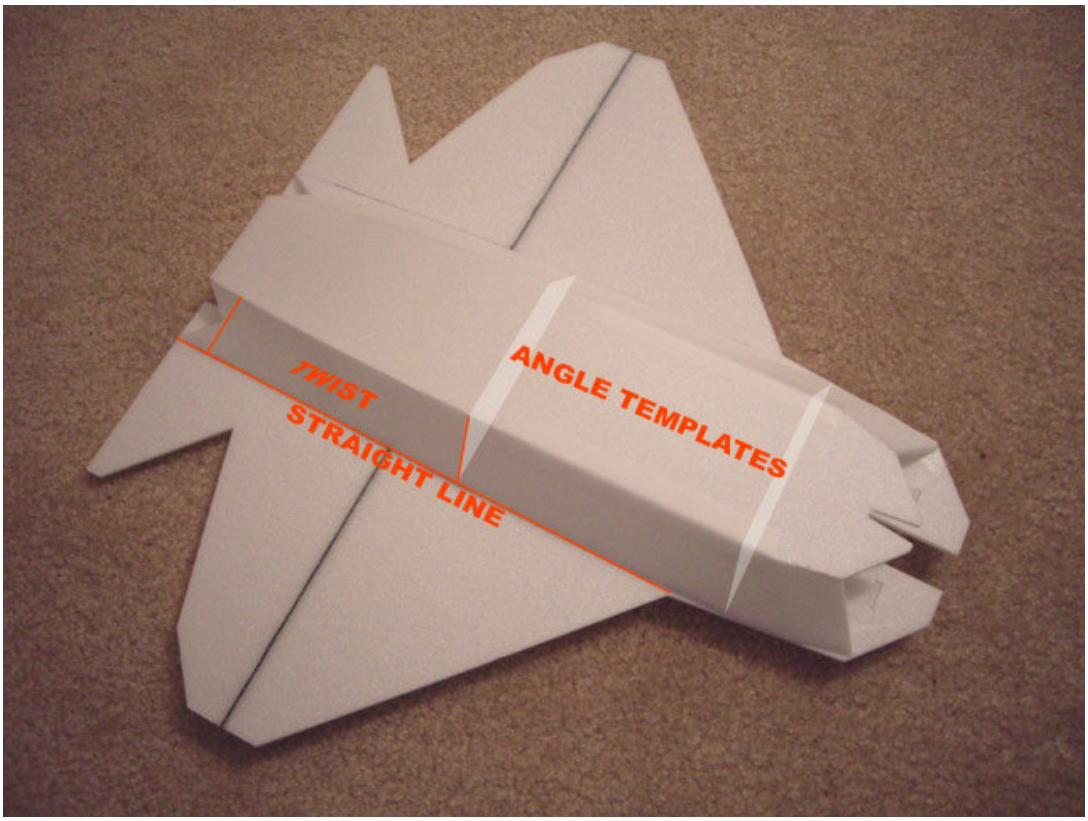
2 – Cut wing sheet from wingtip to wingtip for carbon spar installation. Cut a length of 2mm carbon rod for the spar running the width of the wing. Use the spar as a sanding block with a piece of 100 grit sandpaper and sand a half circular channel in each piece of foam. The two pieces of the wing should come back together with the spar inside leaving no gaps.

Glue the spar to one half of the wing using CA glue very sparingly so it doesn’t squeeze out onto the wing surface. When that joint is cured, glue the wing halves together on a flat work surface to maintain alignment. Dress the ends of the carbon with CA to prevent splintering.

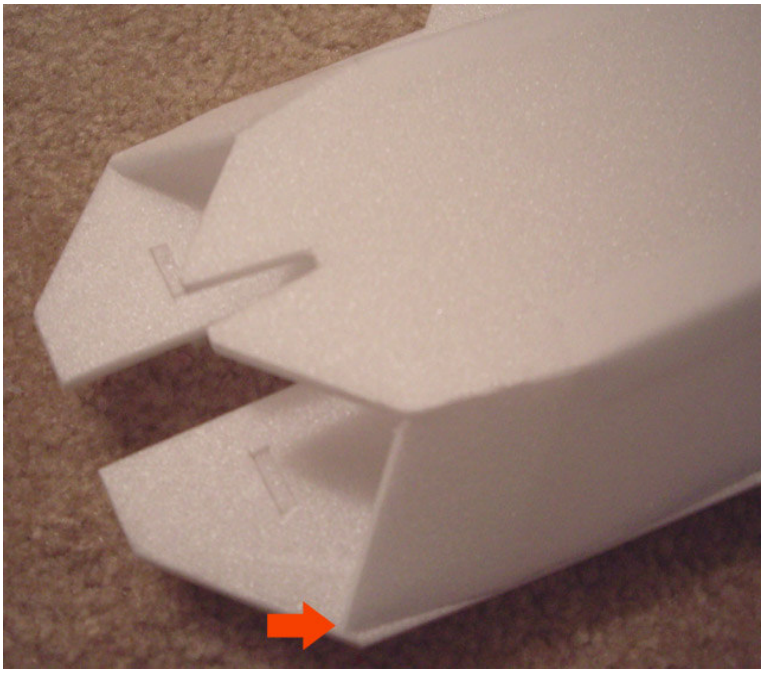
Round off the forward facing edges of the wing, horizontal tails, and vertical tails.

Raptor trivia: The F-22 is cleared for tailslides up to -50 knots.

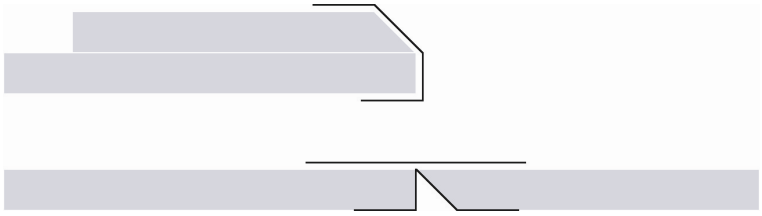
3 – Gently press the bend line into each lower fuselage side panel with a straight edge. Using the lower fuselage angle templates as reference, bevel the lower fuselage sides and belly as needed for a good fit. Give the side pieces some twist with your fingers as pictured below. Glue the sides and belly together using the angle templates for alignment. I found it helpful to tape these in place and remove them once the glue was cured. The lower fan cutout is made later.



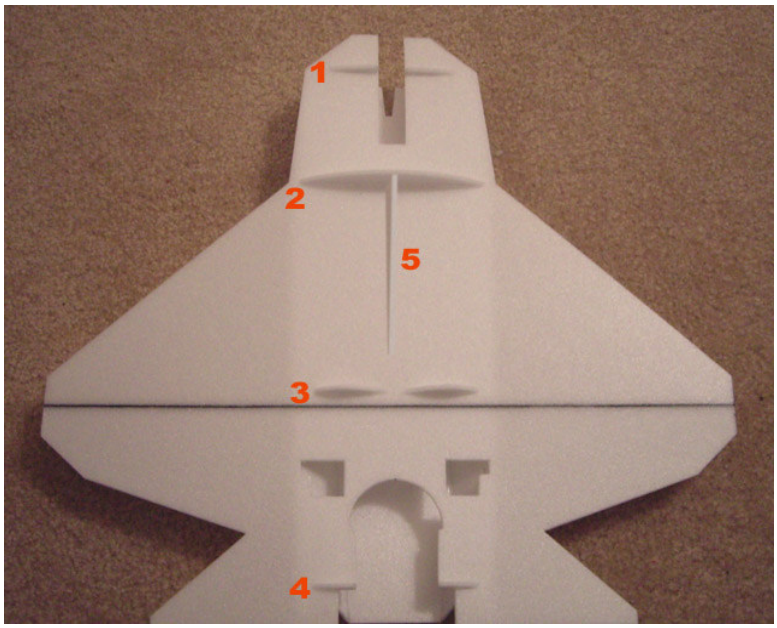
4 – Bevel the top edges of the lower fuselage cover so that it fits flush with the underside of the wing. Eliminate any twisting that will warp the wing. Glue the lower fuselage cover in place as shown then make the lower fuselage fan cutout. Note the pictured misalignment of the chine and intake edge - this is a scale detail.



5 – Bevel the lower forward edge of each elevon and hinge them to the wing with Blenderm tape on the upper and lower surfaces.



6 – Glue fuselage formers in place on the upper surface of the wing.

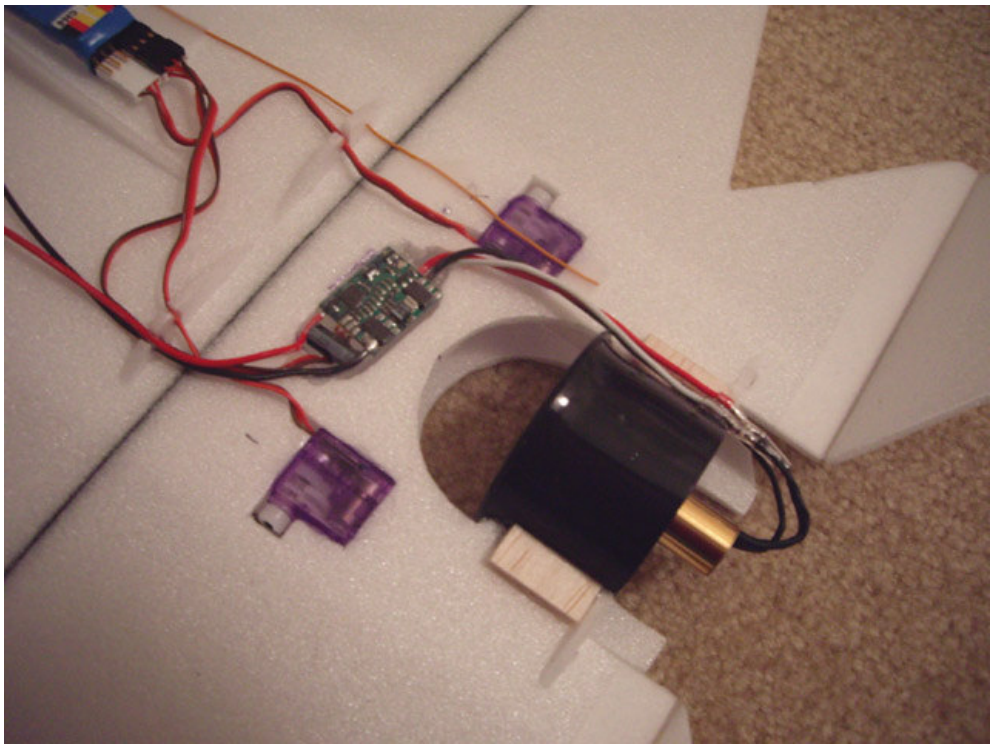


7 – Prepare all flight gear for installation. Use a new fan impeller. Make sure the servos are centered for the next step.

Raptor trivia: The classified top speed of the F-22 is determined by the melting temperature of the canopy.

8 – Trim away servo mounting lugs taking care not to split the cases open. Attach control horns. Test fit servos and cut slots in the lower fuselage sides for control horn clearance as needed. The top surface of the servos will be flush with the top of the wing panel. Scuff the outer edges of the servos with sandpaper and glue in place. Cut small slots in the rear fuselage formers as needed for servo wiring runs.

9 – Glue 4 pieces of scrap balsa (2 on the upper side, 2 on the lower) for fan mounting with left-right grain orientation as shown. The motor wires will need to clear the thrust vectoring paddles so orient them up at a 45° angle when viewed from the rear. Scuff the contact points on the fan case with sandpaper and sand balsa mounts for a good fit. Check that the impeller turns freely and the fan case is not distorted when the unit is in place between the mounts.



TAKE YOUR TIME HERE! I have wrecked a lot of models because the thrust line of the fan was set incorrectly. Use a drafting triangle or similar tool to get the fan case perfectly aligned with the centerline of the model.

When everything fits just right glue the fan in place.

10 – Position the motor wires and ESC as pictured above. Note that the upper fuselage cover will glue to the wing panel right in front of the fan cutout so this area needs to be clear. Mark and cut a hole for the ESC so it sits flush inside the wing panel with the FETs (small black squares) exposed on the underside of the wing for cooling. Secure the ESC in place using very small amounts of CA on the wiring at either end. Battery connector should extend about 1” (25mm) beyond the forward edge of the wing panel.

11 – Mount the receiver with double sided tape and secure all wiring. Cut small holes through fuselage former #2 rather than notches so it is not weakened.

12 – Refer to the pushrod template on plan page 9 and make 2 elevon pushrods from .032" music wire. Because the elevons control pitch and roll simultaneously, you will need to set up your transmitter for 50% travel on each channel to prevent binding. The outboard corner of each elevon should move approximately ½" (13mm) from neutral for full elevator or full aileron input from neutral.

Glue the elevon control horns in place and adjust pushrod length as needed.

Raptor trivia: The F-22 uses thrust vectoring for trim adjustment which greatly reduces drag.

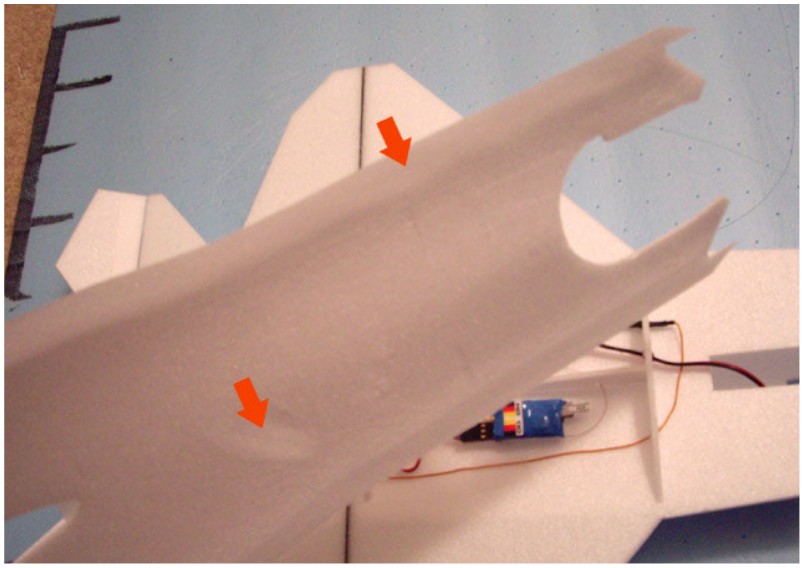
13 – Cut the fan exhaust duct from a thin sheet of plastic transparency film or similar material and mark the overlap line. Paper can be used but will buckle if exposed to moisture. Overlap the ends to the marked line and tape them together. Test fit the duct to the fan, trim for motor wire clearance, and mount it with scotch tape.

Making these ducts can be tricky so don't be afraid to start over if necessary. Remember that you want the thrust line perfect and if the duct is crooked the model won't fly as well, and might even be uncontrollable. I've been there!

14 – Gently pre-bend the upper fuselage skin referring to the fuselage formers for shape reference. The skin will transition from one curve at former #2 to a triple "wave" curve at former #3 and continue this shape rearward. Run strips of tape on the underside of the skin to make the sharp trough bend without splitting the foam.

Raptor trivia: A combat loaded F-22 has reached .99 Mach in a vertical climb.

15 – Very carefully bevel the edges of the upper fuselage skin with an X-Acto knife and sanding block as shown. These bevels will be quite wide so take your time and get a nice clean fit. This part is really the key to making the model look like the real thing.



Test fit the panel and make adjustments as needed. Check the inside of the panel for marks that indicate interference with installed components and sand small clearance pockets if required. It's important that this panel is installed without a lot of tension or the wing and chine area will warp.

16 – Reconfirm that the flight gear is working correctly and glue the center of the upper fuselage skin in place first leaving the sides and forward "fingers" free for now. You'll need to put glue on the inner halves of the fuselage formers and spine for this step gluing the rest later.

17 – Mark the wing panel where the fuselage skin sides touch down very lightly as a reference for glue application. Glue the upper fuselage skin sides down one at a time, making sure to run glue up onto the exposed formers for a good bond. Leave the forward fingers for last, trimming them as needed for a good fit.

Congratulations – that was the most difficult part of the build! It's pretty easy from here.

18 – Apply a piece of tape to forward fuselage skin 1 as noted. Gently bend a curve to fit around the radome former. Glue the skin to the former.

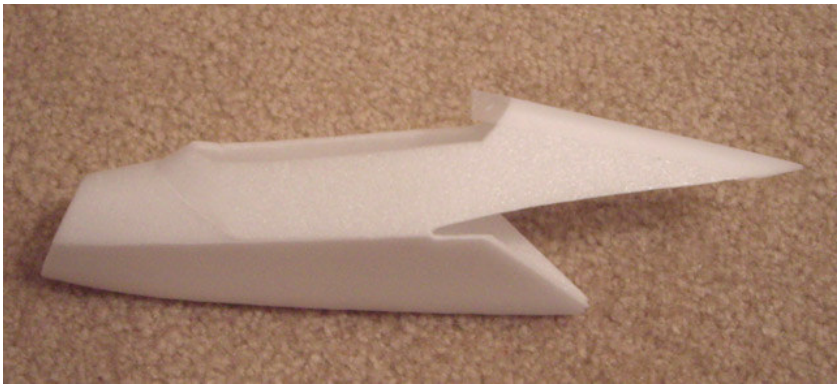
Raptor trivia: The F-22 can reach altitudes well above 63,000 feet. This is not done operationally since there are no provisions for a pilot pressure suit.

19 – Prepare the two forward fuselage lower skin pieces. These pieces transition from a curve at the radome former to a straight wall at the rear, and have a slight outward curve when viewed from above.

20 – Test fit the lower skins to the existing skin/former assembly beveling the edges as needed for a gap free fit. Use the forward fuselage former template to get the correct angle at the rear. Glue the lower skin pieces in place.

21 – Using a straight edge press several gentle creases in forward fuselage upper skin 2 as noted. Apply a piece of tape on the opposite side and carefully bend in a curve. Use the fuselage former template as a guide to get the correct angle - this piece is not glued.

22 – Glue the two small fingers at the front of the skin together edge to edge, then apply a piece of tape to the outside and create a gentle bend.

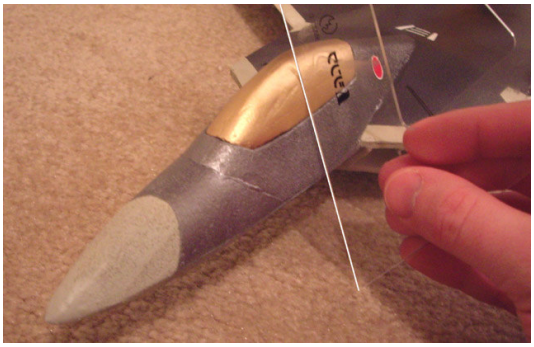


23 – Bevel the edges of the forward fuselage assembly and upper skin as needed for a gap free fit and glue in place.

24 – Make a slightly oversized radome block from sheets of foam laminated together with spray glue. Glue the block in place and shape using the radome block templates as guides. Continue the horizontal break line of the forward fuselage through the nose block. To protect the forward fuselage from sandpaper scratches wrap it in scotch tape blotted on fabric to reduce adhesion – this will prevent damage to the foam when it is removed.

Apply a little CA to the tip of the finished radome block for durability.

25 – Make the canopy using the same techniques or a clear plastic version as desired. The sides of the canopy continue the angle of the forward fuselage walls with a radius along the top also matching the fuselage.



Add tabs from scrap material to attach the canopy to the forward fuselage.

Raptor trivia: One of the key advantages the F-22 has over other fighters is that its fuel and weapons are carried internally and do not incur a drag penalty.

26 – Bevel the rear edges of the inner duct walls and glue them together to make a "V" shape. Twist the forward edges outward to match the angle of the lower fuselage sides. Bevel edges and adjust fitment so it is snug without distorting the wing or lower fuselage. If you will be flying in temperatures above 55°F (13°C) you will need to cut cooling holes in this part.

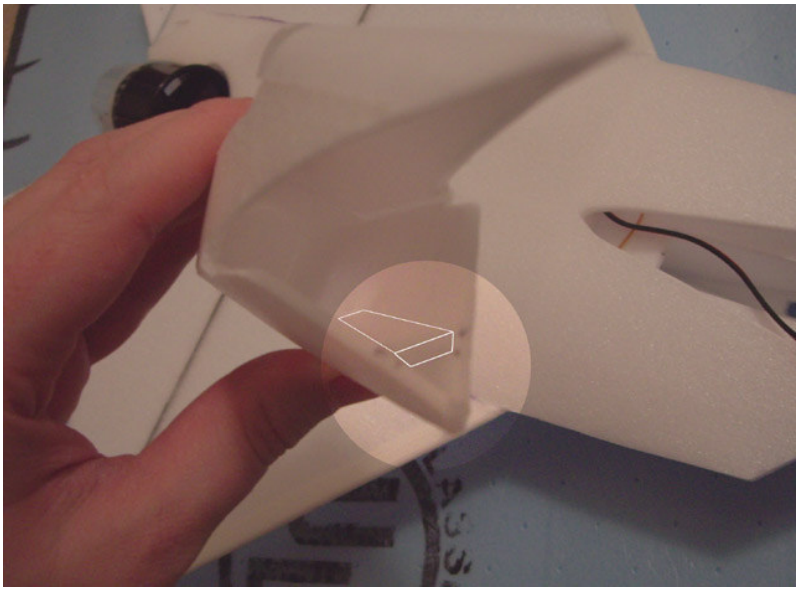
27 – Test fit the forward fuselage to the main body, adjusting for a gap free fit.

28 – Test fit the inner duct walls and check clearance to the forward fuselage. Glue the inner duct walls in place when everything fits right.

Raptor trivia: The F-22 can carry four 592 gallon fuel tanks or weapons on external pylons although this capability is rarely used.

29 – Position the forward fuselage but do not glue it in place yet. Apply a strip of Velcro to the edge of the battery and insert it through the canopy opening. Lay the vertical tails and thrust vectoring paddles in their approximate positions – these will be glued in place after painting the model.

With the canopy in place, check the CG of the model. Adjust the position of the battery as needed then remove the forward fuselage with the battery in place as a reference for the position of the battery tray. Bevel the edges of the battery tray, test fit, and glue it in place. Apply a strip of Velcro to the tray.



30 – Glue the forward fuselage in place. Sight down the model and aim the rearward point at the center of the fan.

31 – Bevel the lower edges of the vertical tails using the tail angle template for reference. The vertical tails will be glued on after the model is painted.

Raptor trivia: An FB-22 bomber variant with a large delta wing has been engineered and wind tunnel tested although there are no immediate plans for production.

32 – The model is now ready to paint. The porous surfaces of the foam canopy and radome can be filled with spackle and sanded with 600 grit sandpaper if desired.

The real F-22 has a subtle silvery sheen that is difficult to reproduce. These are the colors I used to approximate the look:

Base color - Tamiya Spray TS-42 Light Gun Metal
Camouflage lozenges – Tamiya Spray TS-38 Gun Metal
Edges – Testors Spray Enamel 1233 Flat Light Aircraft Gray
Canopy – Design Master 731 Brilliant Gold

Test your paints on a scrap of foam to make sure they won't damage it.

Raptor trivia: The silvery appearance of the F-22 comes from its special topcoat which has a very low infrared reflectance.

33 – Glue the vertical tails in place using a drafting triangle and the wing spar for alignment reference. Use the tail angle template for the correct "V" angle.

34 – Round off the forward edges of the thrust vectoring paddles and wrap a piece of tape around these edges. Glue the paddles to the elevons taking care to get them perfectly aligned. These can be left unpainted or painted in a color contrasting the main body so they aren't as noticeable in flight.

Raptor trivia: The F-22 does not use differential thrust for yaw control since aerodynamic surfaces were found to be effective in early testing. Pilots can use split throttles for some low-speed maneuvers although the flight control computers will attempt to compensate with control surface movement.

35 – Detail the model as you like with panel lines and miscellaneous markings. A good reference site is www.f22fighter.com

36 – Wrap the leading edge of the wing and bottom edges of the intakes with Blenderm or Scotch tape to prevent dings.

37 – With the model balancing on the specified CG, run up the fan slightly to check for trim changes under power. Small movements are ok but if the model pitches strongly up or down you will need to correct this before flight.

Flying

Check that the model balances on the specified CG.

Recheck control throws for travel and direction; I am flying with -50% exponential (softening) on the elevon channels. Perform a radio range check.

Check that the fan is mounted securely and free of debris. Also check inside the fuselage for foreign objects.

To launch, grip the model just ahead of the wing /fuselage intersection. Throw the model firmly into the air at a 45 degree angle with 75% throttle.

Maintain 75% throttle and climb for a few seconds. This model is very responsive in pitch due to the thrust vectoring so be ready for very quick response at all speeds.

Roll rate is good for a taileron model but not as good as an aileron model so take care when rolling inverted close to the ground.

This model can slow down to a point where it is not controllable although it remains in a stable nose up attitude. At this point if it slows further it will abruptly stall and require about 20' of altitude to recover. Be careful when flying low and slow since it is easy to get overconfident.

When landing, close the throttle several seconds before touching down to prevent damage to the fan. Elevator response will be reduced at this time.

Miscellaneous notes

For increased roll response it should be possible to add ailerons linked to the existing tailerons. Very short pushrods would run from the servo horns in their current positions. This may be too much load for the BMS-303 servos although I suspect it would be ok.

Alternately the elevons could be linked to make a single elevator and conventional ailerons used for roll control.

A lightweight gyro on the pitch channel may allow this model to fly with an aft CG for even better maneuverability.

Enlarge plans 200% for a 30" WS model suitable for pusher prop conversion. Offset fuselage formers and templates by 3mm to use 3mm skins with 6mm wing panel. Fan cutouts and vectoring paddles can be eliminated.

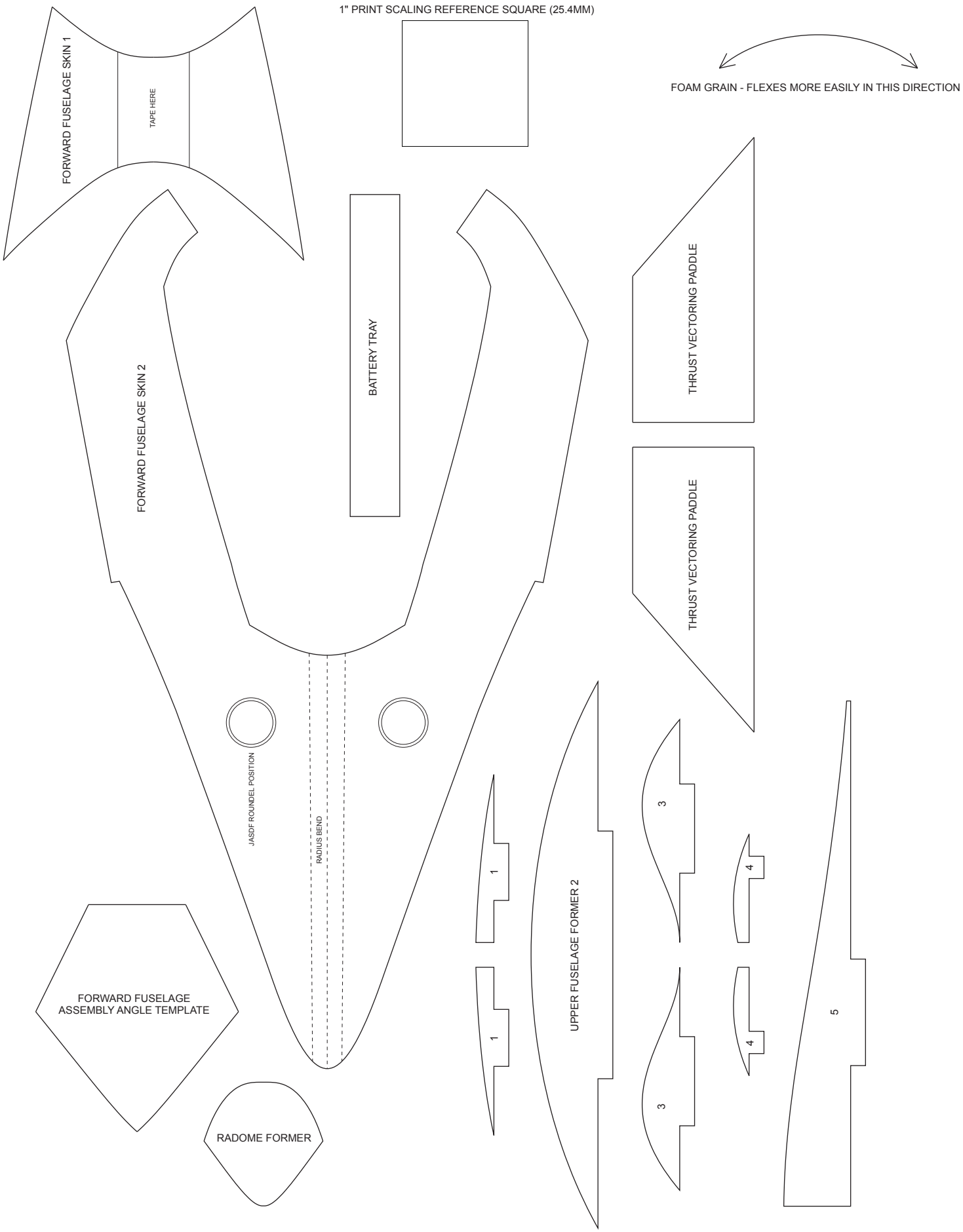
It should be possible to take off from a smooth surface without landing gear, just make sure nothing is sucked into the fan.

All "Raptor trivia" information was gathered from public sources.

Version 2.0 includes untiled plans

I'm interested in your feedback on this design, so please check in on my RC Groups F-22 thread:

http://www.rcgroups.com/forums/showthread.php?t=782213

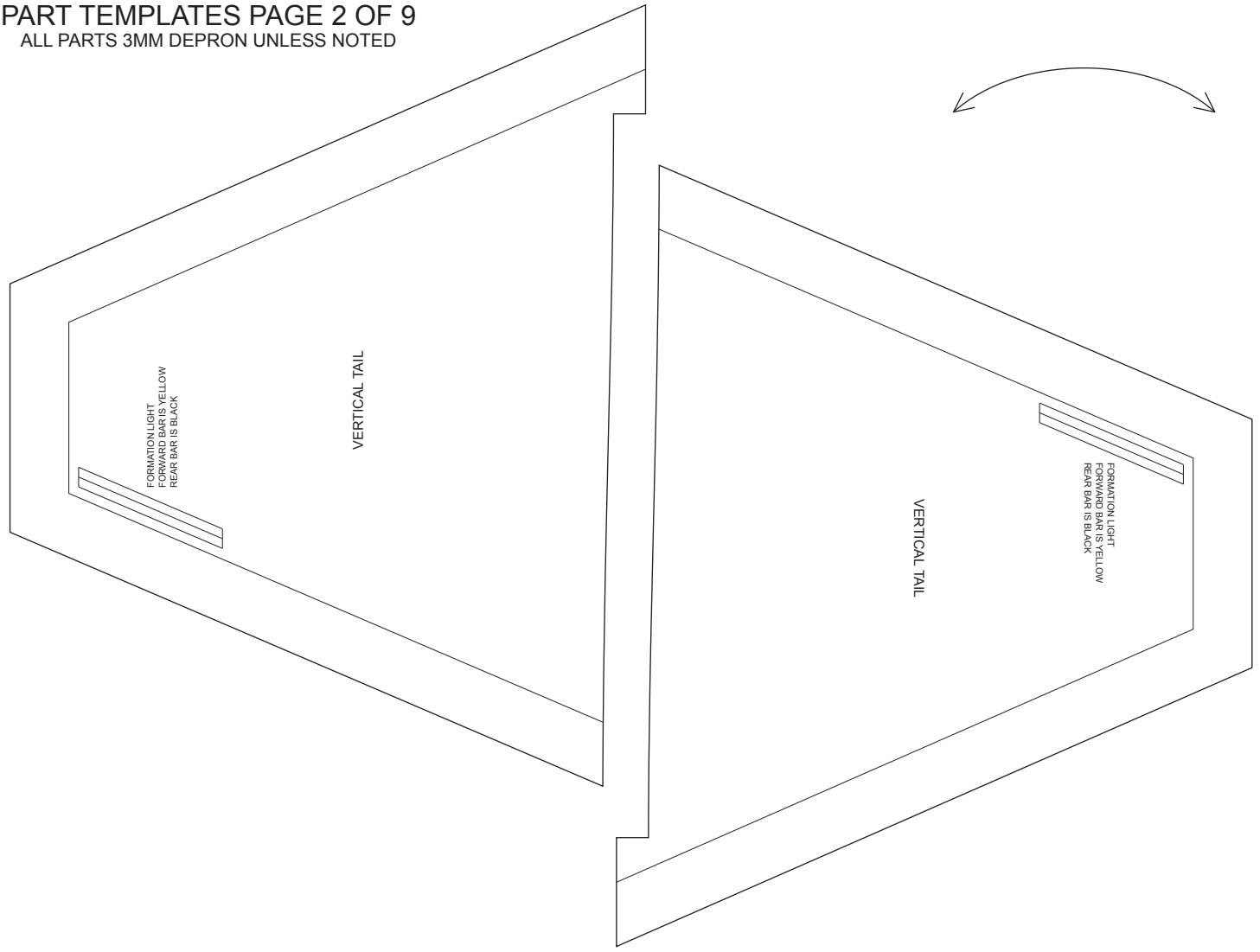


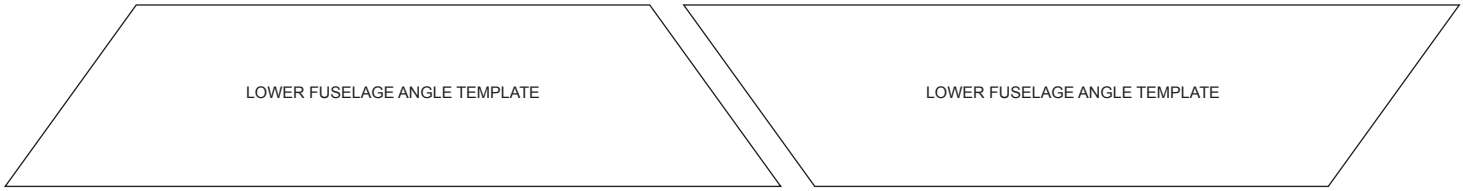
PART TEMPLATES PAGE 1 OF 9

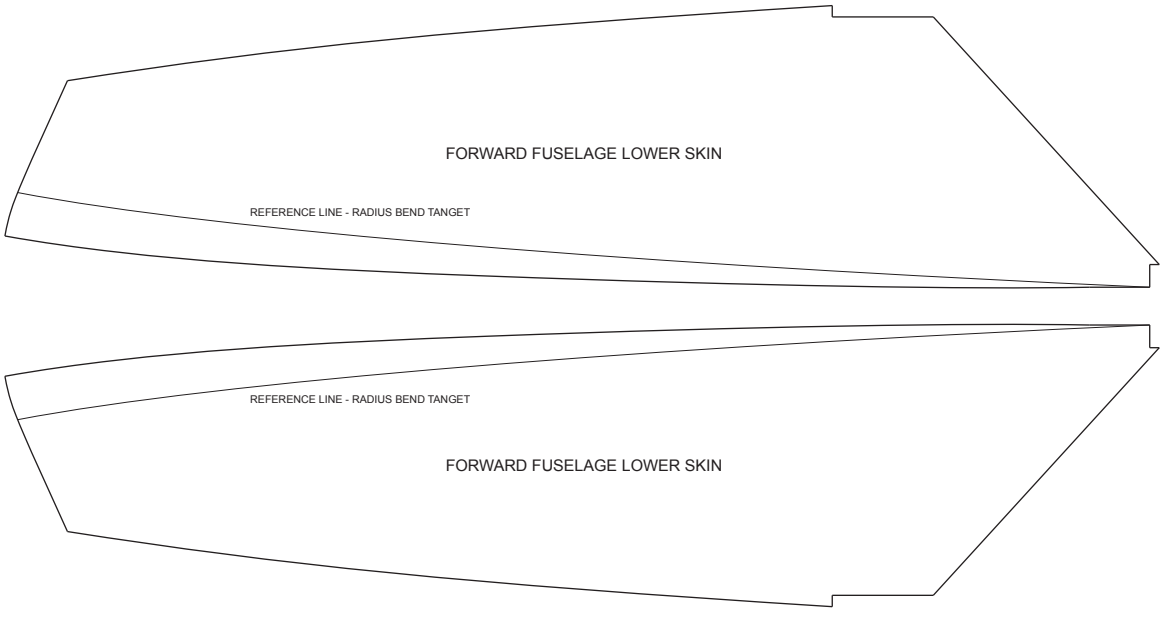
ALL PARTS 3MM DEPRON UNLESS NOTED

PART TEMPLATES PAGE 2 OF 9

ALL PARTS 3MM DEPRON UNLESS NOTED







PART TEMPLATES PAGE 3 OF 9

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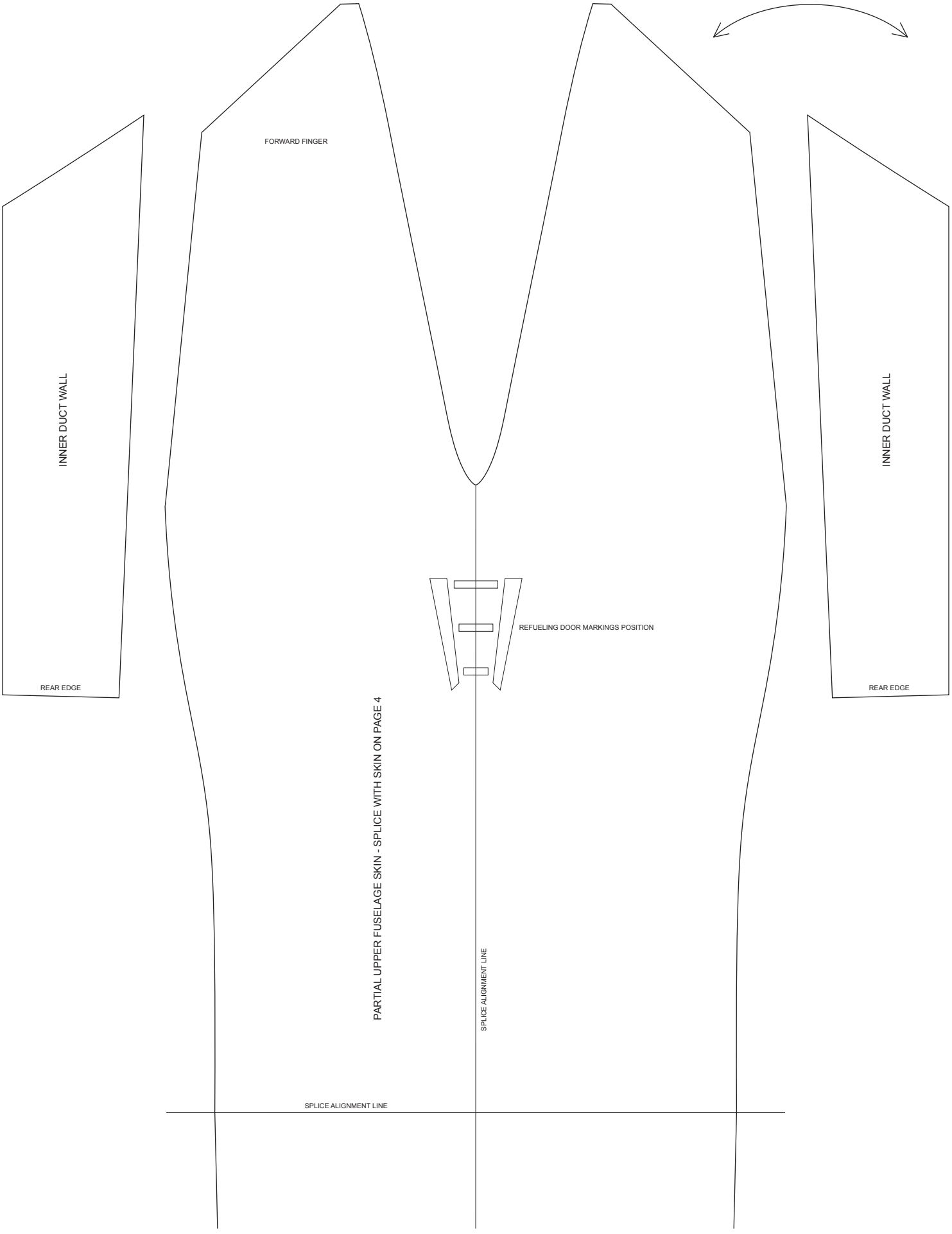

PART TEMPLATES PAGE 4 OF 9

ALL PARTS 3MM DEPRON UNLESS NOTED

PARTIAL LOWER FUSELAGE SIDES AND BELLY - SPLICE WITH TEMPLATES ON PAGE 5

SPLICE ALIGNMENT LINE (3 PARTS)

USAF ROUNDEL POSITION

PARTIAL UPPER FUSELAGE SKIN - SPLICE WITH SKIN ON PAGE 3

SPLICE ALIGNMENT LINE

SPLICE ALIGNMENT LINE

FAN CUTOUT - CUT AFTER LOWER FUSELAGE IS ASSEMBLED

SPLICE ALIGNMENT LINE

PART TEMPLATES PAGE 5 OF 9

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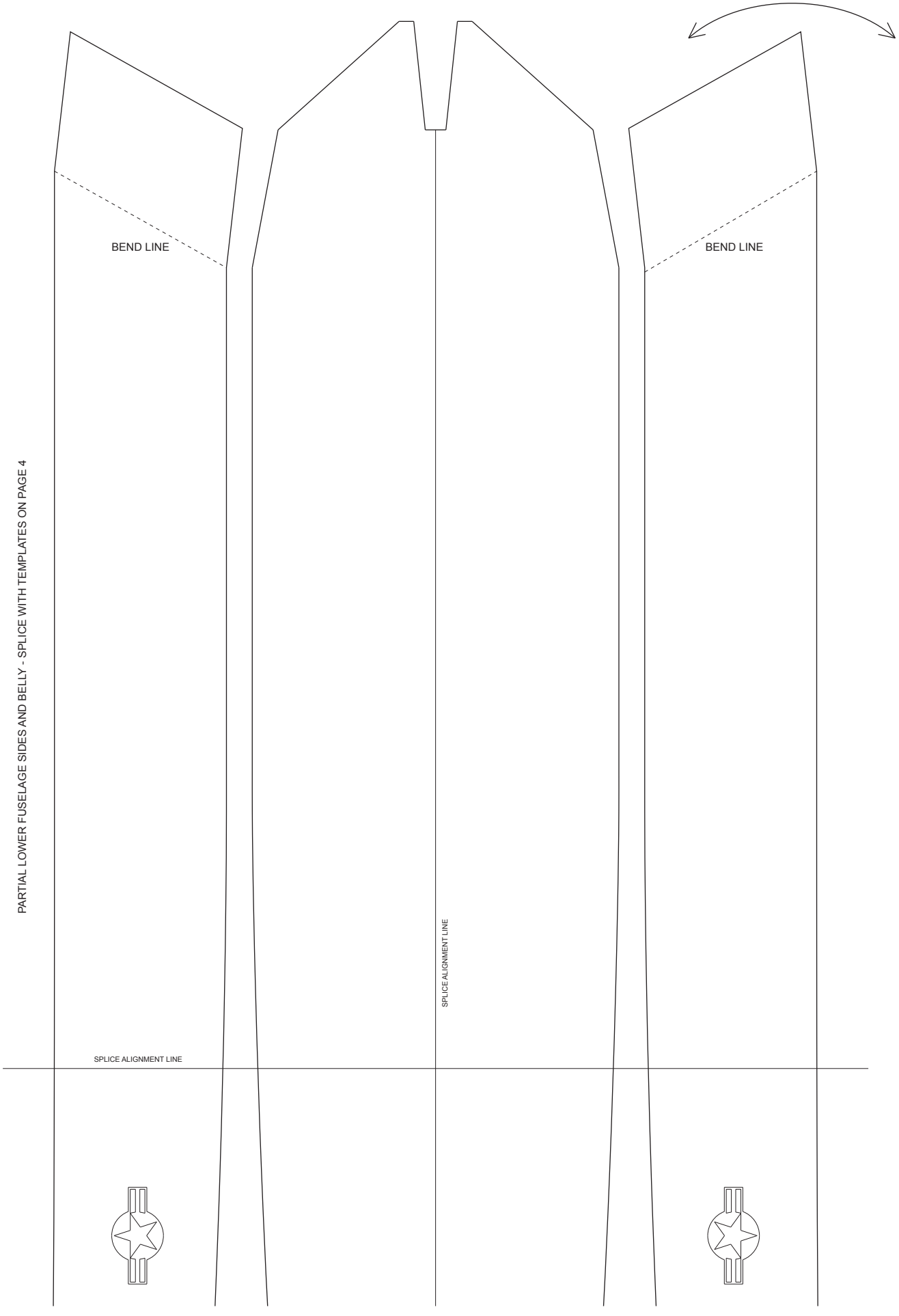

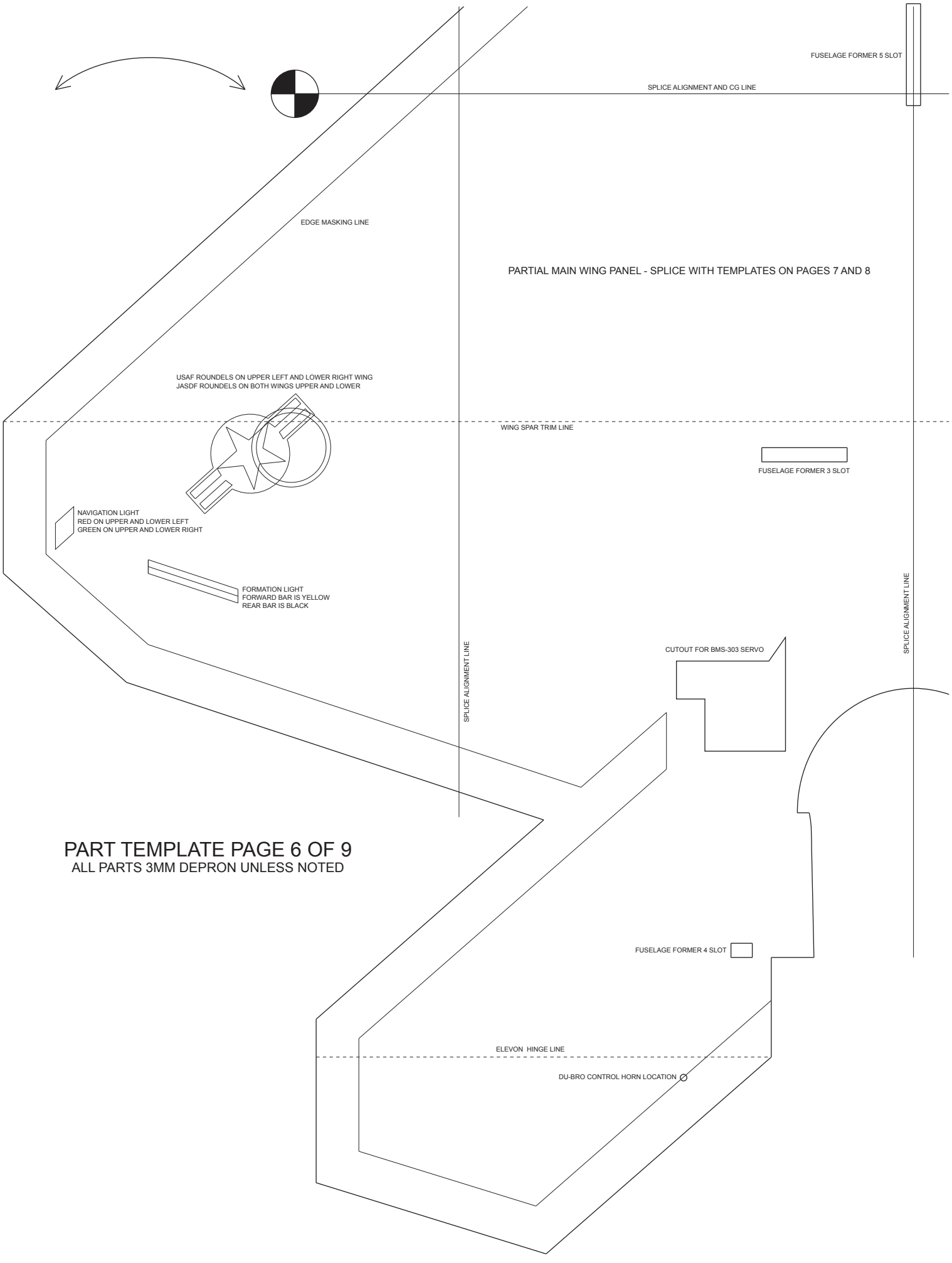

PART TEMPLATE PAGE 6 OF 9

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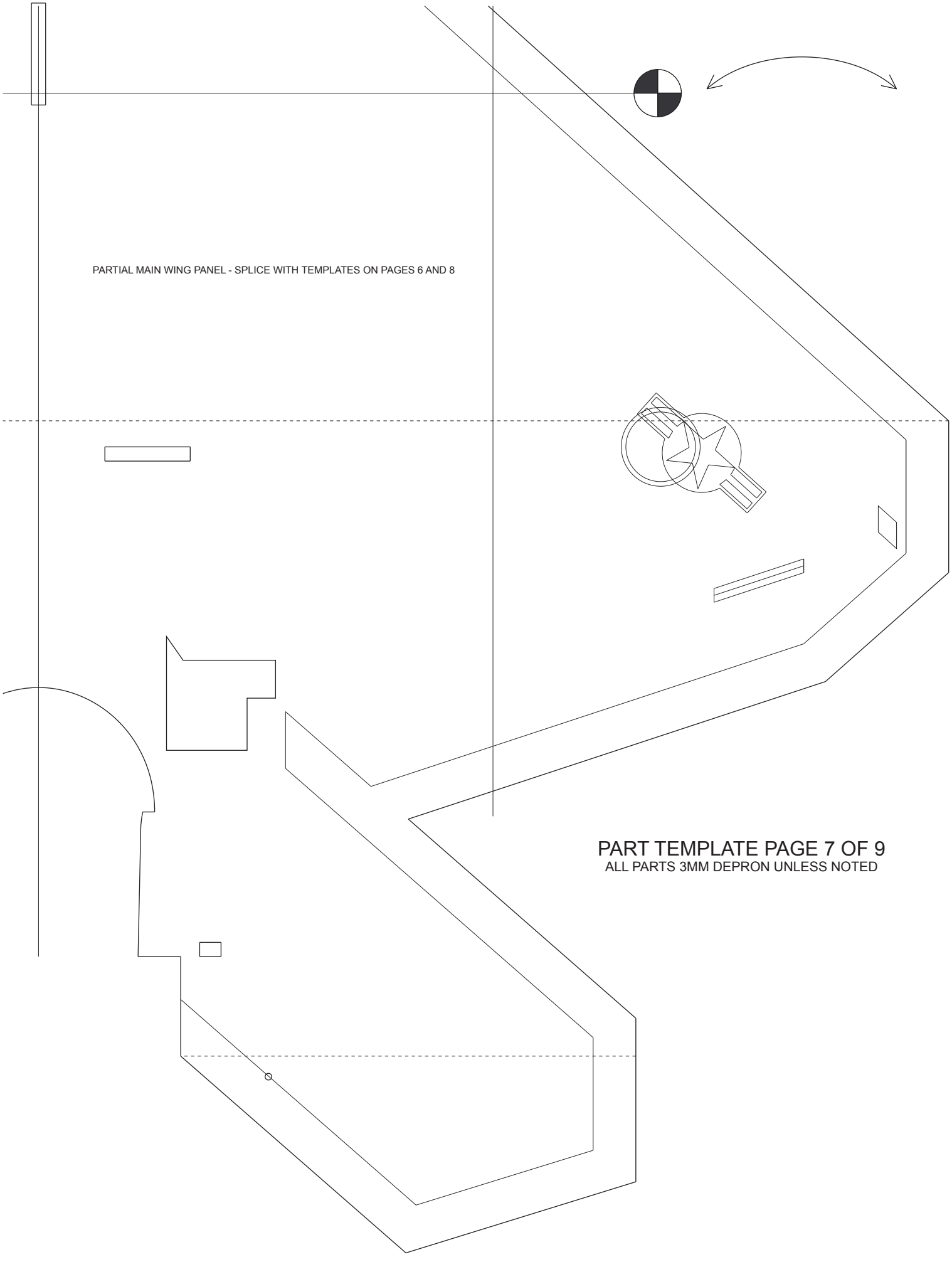

PART TEMPLATE PAGE 7 OF 9

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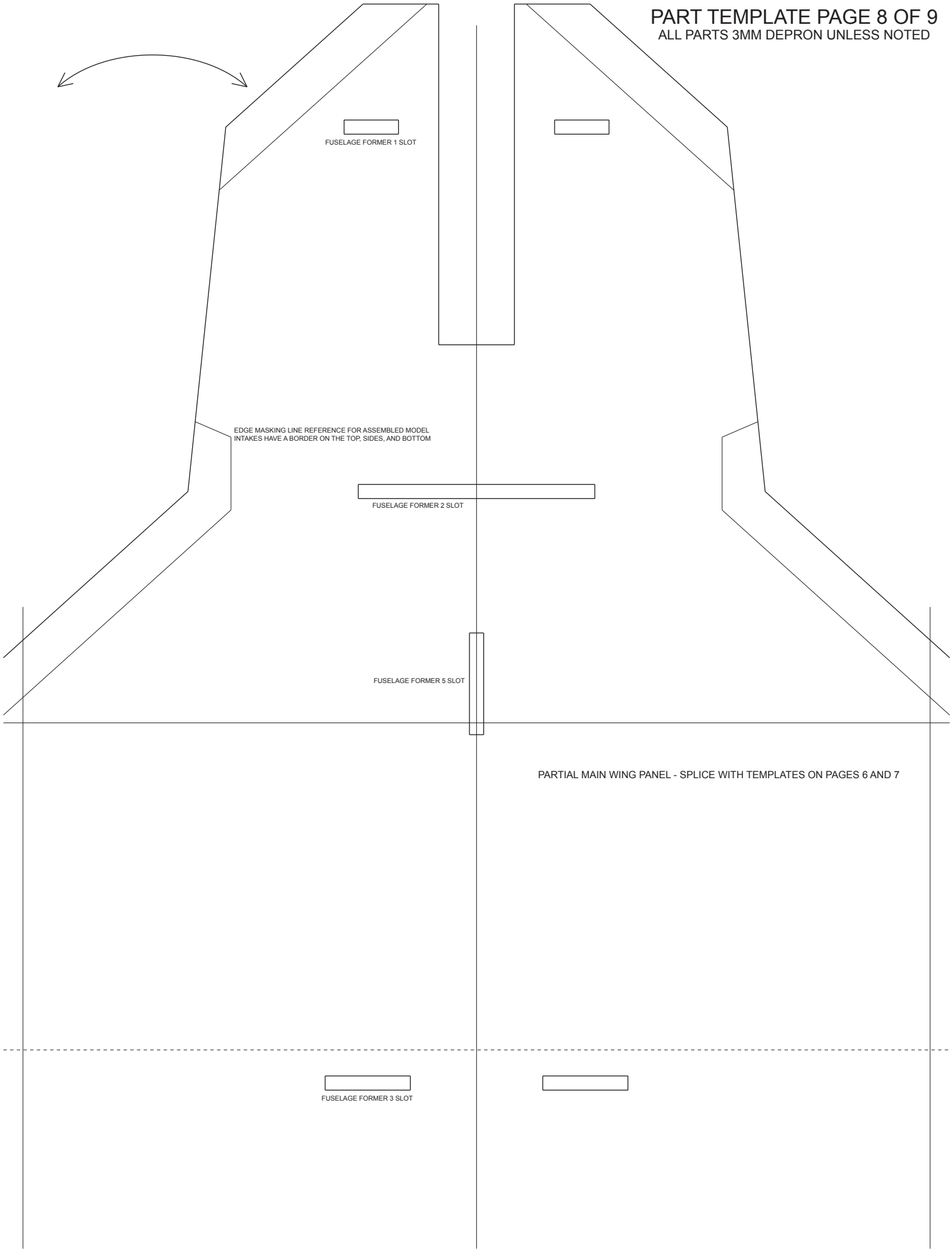
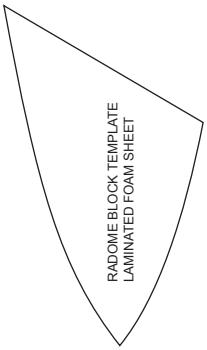
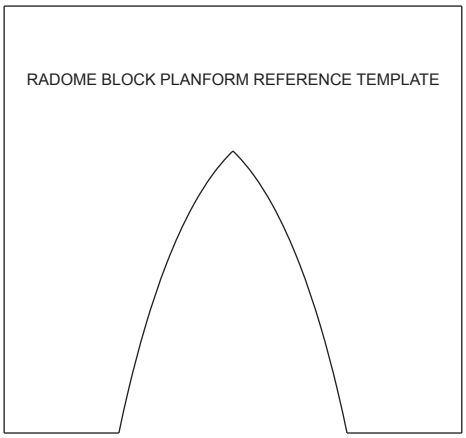

FUSELAGE FORMER 1 SLOT
EDGE MASKING LINE REFERENCE FOR ASSEMBLED MODEL
INTAKES HAVE A BORDER ON THE TOP, SIDES, AND BOTTOM
FUSELAGE FORMER 2 SLOT
FUSELAGE FORMER 5 SLOT
PARTIAL MAIN WING PANEL - SPLICE WITH TEMPLATES ON PAGES 6 AND 7
FUSELAGE FORMER 3 SLOT

PART TEMPLATES PAGE 9 OF 9

ALL PARTS 3MM DEPRON UNLESS NOTED

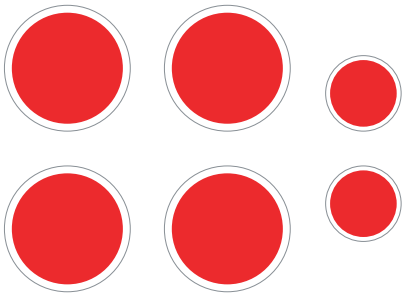


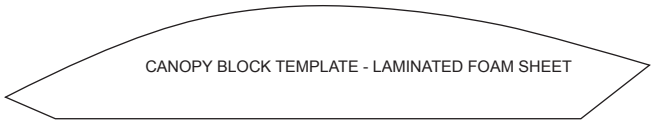


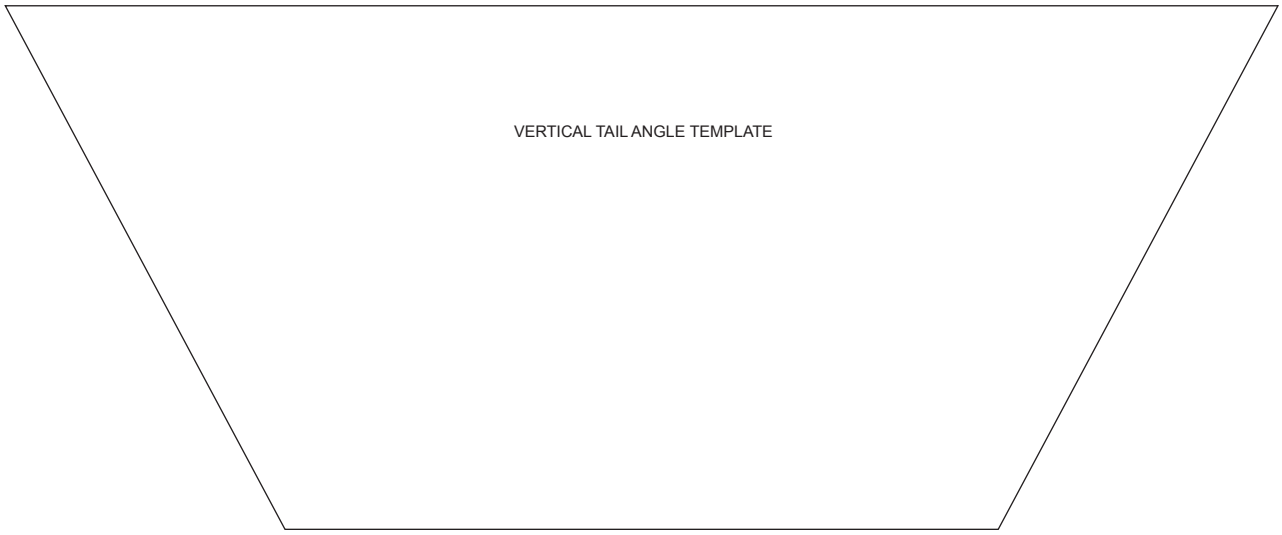
USAF ROUNDELS

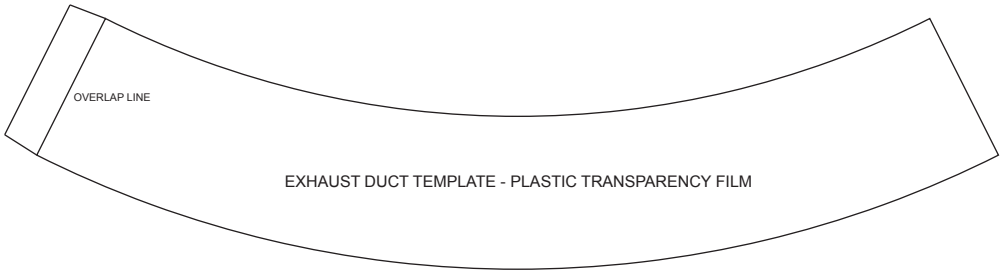
REFUELING DOOR MARKINGS

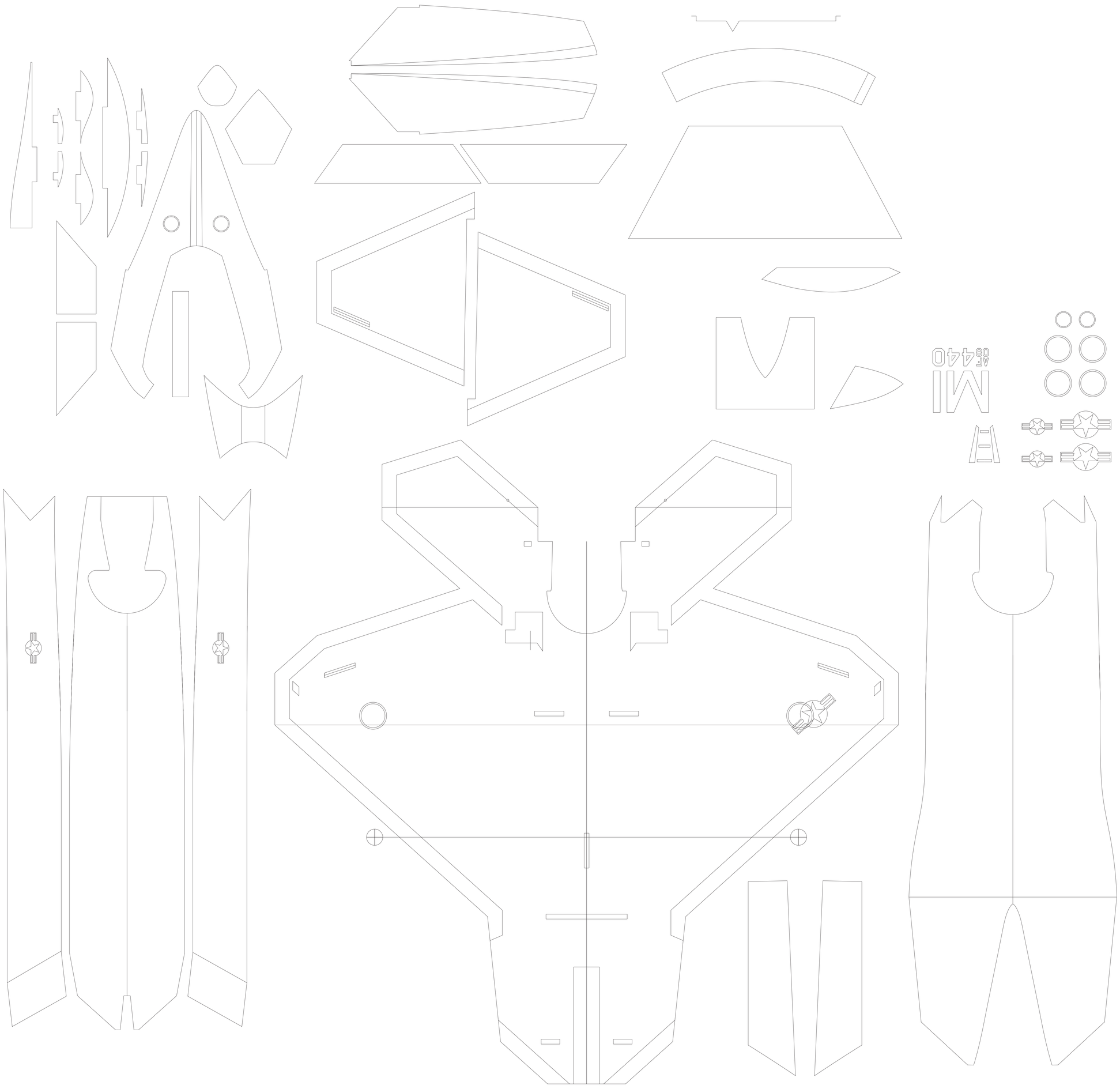
JASDF ROUNDELS







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