Aircraft Design Education Newsletter

Vol. 2, No. 1 December 1, 1991

A Practical Design "How To"

This issue of the newsletter features an article on how an airplane designer actually gets started on a new design. The intent is to fill a void in existing aircraft design texts. It is perhaps slightly more useful, though less humourous, than the frontispiece in K.D. Wood's *Aircraft Design*, and is being expanded for use teaching undergraduate students interested in the details of configuration design. The brief version is suitable for more experienced readers. The extended version includes numerous examples, and an Appendix defining the information that should be included on three-view general arrangement drawings and inboard profiles.

The orientation is fighter design, but the insight into the process is valuable for any design project. This information was developed to help beginning configuration designers get started. It represents the kind of experience that we hear Expert Systems developers talk about "capturing." This is precisely the kind of information that can help future designers, but isn't available in the academic world.

Nathan Kirscbaum has over 40 years of experience in aircraft design, including 34 at Grumman, where he retired as chief configuration designer in 1989. Luckily for VPI, he is now an adjunct professor in Aerospace and Ocean Engineering. Having been written by an oldtimer, it doesn't reflect current CAD technology. But extension to modern CAD is clear, and in spite of the importance of CAD, I've not been able to find a configuration designer that doesn't make that first sketch on a piece of paper!

The next newsletter will examine broad design issues within the context of *Made in America* and *Improving Engineering Design: Design for Competitive Advantage*. I'm trying to discover the impact these reports are making in the academic community.

W.H. Mason

ON-THE-BOARD DESIGN PROGRESSION

by

Nathan Kirschbaum

I. Before Drawing Start

1a. Receive a set of desires from "someone" in the company as to what they "want to see": a design with swept forward wings; a span ruled, five-body configuration; a triangular stealth shaped, low winged, canard; or, as it was so succinctly put once, "it won't leave this company if it doesn't have a (wing) pivot on it,"—*etc*. This is sometimes accompanied with such detail "requirements" as: tangent/semi-submerged/internal weapons carriage; three 600-gal. external tank carriage; inlet and/or nozzle type; over-"spec" pilot vision over nose/side; rotodomes; *etc*.

lb. Or, if given free reign, subjectively set about picking a configuration to suit mission high point requirements or a mix thereof: super-cruise; loiter; low level transonic Mach; STOVL; carrier landing; etc. If drawing turn-around time is short ("we need it in three days") modify a configuration that is/was in being or update an old drawing of similar type if available or remembered.

2. Receive a set of parameters from an aircraft sizing program that has been run for a set of mission requirements for (if possible) the type of configuration that has been dictated or subjectively selected, above: TOGW, fuel weight, wing and control surface sizes, fuselage length, etc.

3. Immediately compare fuel weight and fuselage length dictated by the aircraft sizing program with these parameters in current aircraft of similar configuration (single/twin seat, single/twin engine, engine location, A/B equipped, etc.) to see if there is any discrepancy. If a discrepancy exists, always bias fuselage length with respect to fuel weight toward that of real aircraft.

4. Sketch two- or three -view on "A" size quadrille paper. "What-is-it" has to be shown and arranged with respect to configuration dictates or "someone's" desires. Try to establish wing spar locations, control surface fixity points, engine locations, weapon fixity (and/or submergence), inlet type and location, aerial refueling system and location, gun location respecting access and inlet location, -- ***and where does the landing gear go, - to what is it attached*** -, where is it stowed in relation to above assemblies and installations. The latter is usually true for emergency/arresting gear tail hooks, especially on odd ball configurations. If weapons fuselage mounted, with eyeball scale see if weapons can be placed in/on aircraft within fuselage length respecting nose gear envelope, special accessibility dictates and the tail-down rotation ground line.

5a. Simultaneously, sketch typical cross sections at what appears to be decisive confluence planes with respect to the above assemblies and installations. Establish where-does-the-fuel-go and where-do-the-control-lines-run in the sections. These cross-section shapes can be influenced by RCS stealth requirements, control lines accessibility dictates, protected fuel requirements, weapon installation or palletizing requirements, etc. -- ***and*** landing gear stowage.

5b. These cross sections establish the shape and character of the fuselage which influences the nose section/relative inlet location, internal duct lines, and the aft retreating lines when the layout is started.

5c. If the landing gear can't be attached or stowed -- ***start anew*** (unless blisters or sponsons are allowed on slowish or cargo type aircraft).

II. Drawing Start

6. Draw Fuselage Reference Line (for side elevation) and centerline (for planview) on paper allowing sufficient space between these lines for wing semi-span and side view.

7. *In side elevation*, draw the desired cockpit -- either spec, HAC, fixed-inclined, VAC, single/twin, tandem/ side-by-side, or special -- with the pilot's eye level on the FRL; and draw the canopy/windshield outline. Cockpit choice is either dictated from “above” or picked subjectively. From the pilot's eye, establish Forward Vision Line (FVL) from spec, customer requirement or crew and equipment dictate; and draw radome/noise shape directly beneath FVL. Establish clearances to sweep of target seeker dish if known. If Air Force inflight refueling receptacle required, allot distance for it between radome bulkhead (or radar dish arc) and forward windshield attachment.

   With reference to "A" size sketch, allow sufficient volume to stow as yet undermined nose gear beneath cockpit, or ahead of or behind it. Retraction direction, and concomitant wheel location, may be specified. Stowage volume is by feel at this point. If gun carried and installed in nose section (referring to "A" size sketch with respect to inlet location) locate weapon and ammo cans. Establish Vertical Reference Plane (VRP) on nose point.

8. *In planview*, establish fuselage width at the pilot's shoulders. This is a function of radar dish size, avionic suit, tandem/side-by-side seating, stealth requirements, etc. Draw radome and nose shape starting from VRP established in side elevation. Check clearance to swept arc of radar dish if known.

9. *In side elevation*, if fuselage camber specified, try to wave fuselage bottom line -- by eyeball guess -- to the engine nozzle exit plane. Establish nozzle-airframe customer connect. If fuselage weapon installation dictates, draw flats on bottom so weapons can be installed co-planar along their length.

10. Quick cross-section cuts at, and before-and-after, the cockpit are made. Spec of dictated vision-over-the-side is satisfied by indicing the sections where the fuselage and canopy interface at the required vision angles. These indices are transferred to the side and plan elevations and establish the canopy sill.

    Install the required avionics system and establish nose section length for that part of the avionics (sometimes a guess) to be installed there making allowance in the appropriate section cuts for the nose gear, gun, ammo, refueling system, and -- by feel -- allowance on each side for control line runs.

    (The cross sections may be modified later to blend in with the character of the mid-fuselage section and inlet system)

11. *In side elevation*, establish size and shape of engine inlets and locate with respect to nose shape, cockpit, avionic access, and, if there installed, gun and ammo (and their access). Establish the inlet location lightly and iterate gun location if required, back feeding through sections.

12. *In side elevation*, draw upper backbone line of aircraft from behind canopy to engine nozzle customer connect. Draw engine(s) <u>lightly</u>. Indicate, <u>lightly</u>, the inlet duct to the engine face making allowance (via the "A" size sketch, or feel) for spar boxes, internal weapon installations and control surface actuators. The engine-duct installation is usually iterated after cross section cuts through this area are made and “things-are-made-to-fit.”

13. From historical perspective or by feel (based on configuration T/W, engine T/W, and engine placement) ordain a *cg* along the fuselage length. Ordain vertical *cg* location biasing for wing location, engine placement and fuselage camber.

14. *In planview*, draw the wing, placing *cg* on wing *mac* as a function of tail or canard configuration and RSS level. Establish near spar location.

15. *In side elevation*, draw weapons on or about *cg*. If internal weapon carriage, iterate engine duct passage if obvious interference exists. Draw required wheel locations with adequate takeoff and landing groundlines and required tip back angle with respect to *cg*. Check weapon fin clearance with tip back angle if weapons carried externally, and for auxiliary fuel tanks. Check to see if aircraft bottom is sufficiently high off the ground to load weapons if they are carried on the fuselage.

16. Draw cross sections of decisive confluence planes, referring back to the "A" size sketches, and using as a guide lightly drawn fuselage sides that interface with the wing. Try to area rule fuselage sides that interface with the wing. Try to area rule fuselage contours locally with respect to wing “à la” Küchemann if transonic or supersonic design. *Interactively*, locate components and installations in proper orientation with each other and with respect to side elevation. These cross sections are usually at the air inlet, gear attachment, tire stowage and engine inlet/accessories planes. Establish widths of configuration at these cross section planes and index in planview. Establish a contour-set, or character, through the midsection. Result:

    a) Modify upper backbone in side elevation, if necessary.

    b) Establish engine duct lines and harden.

    c) Get a fuel tank picture together.

    d) Locate keel and heavy longerons.

    e) If main gear can't be attached or stowed - ***start anew***.

17. *In planview*, draw fuselage side profile lines connecting the indices established above. Smooth if necessary, maintaining the Küchemann contour at the wing interface, making section wider or narrower if required and correcting the cross sections. Draw engine duct lines. Draw engines, interactively aligning the engines and the end of the ducts so as to allow one duct diameter of smooth transition length to the engine face.

18. Establish wing structural box specifying spar box geometry with respect to fuselage contours, its attachment to the fuselage (through box, banjo framing, on-top links, etc.), and interface with landing gear attachment or wheel stowage cavity requirements, with weapon attachment clearance if required. Draw high lift devices specified or subjectively. If required, select area for wing fold with respect to store location, flap geometry, etc.

19. Draw nose gear to height required by main wheel/ground line/aircraft attitude relationship desired. This is a function of wing planform sweep and aspect ratio, wing loading, accessibility requirements, weapons carriage, etc. Retraction direction may be specified. Check turnover angle with respect to assumed vertical *cg* location and make sure it is within specification (or at least very near spec).

20. *In plan and side views*, put horizontal and vertical surfaces on vehicles, trying to get structural load paths from these surfaces through obvious structural paths such as engine mount frames, engine break removal frames, cockpit pressurized bulkheads, inlet geometry axii points, nose gear mounting frames, etc. Resize these surfaces to equivalent tail volume coefficients if their moment arms to the wing *mac* quarter chord (or *cg*) differs appreciably from aircraft sizing code output -- or by a cursory check if:

a) engine-out control required

b) takeoff rotation impossible -- this is occurring on tailed ATF vehicles where "super aerodynamics" and RSS produce smallish wings and even smaller horizontal tails

c) it lacks pizazz -- tail size and shape sometimes eyeballed to give airplane personality.

21. Establish a set of mold and shoulder lines in top and side views with reference to decisive cross sections <u>and</u>: inlet sections with initial throughput, nozzles, missile stowage requirements (fin span, body length) or weapon bay doors (if any), canopy crease, gun muzzle egress, gun breech envelope, control surface faying “flats”, RCS stealth requirements, etc.

22. With the mold and shoulder lines as guides, draw cross sections putting in fuel, gun(s) and ammo and their access to, control line runs, ECS volume, local weapon shapes, engine access, control surface actuators, etc.

23. *Draw front view* from the confluence of fuselage cross sections, wing and tail surfaces and landing gear units.

24. Using front view and perhaps some local cross sections, establish weapon fall and jettison clearance with respect to engine pods, fuselage side (if high wing), landing gears, gear doors, other weapons and control surfaces. Sometimes wing fold location is established at this point of the procedure.

25. Establish cross-sectional area distribution by planimetering cross sections (if design is transonic or supersonic). Adjust some cross sections if necessary <u>and</u> back feed into side and plan views! Smooth-out local lines and back feed to adjust cross sections.

26. Establish wetted area of fuselage, integrating the peripheries of the cross sections by Simpson's Rule or by planimeter.

27. Establish total wetted area of configuration.

28. Establish fuel distribution and total fuel load. Check fuel load versus requirements.

a) If too, too little, <u>***start anew***</u> and stretch aircraft in length using the fuel load distribution to obtain the delta length required.

b) If too, too much, check to see if you can shrink configuration without causing interferences between components or *cg* misplacement. Internal weapon carriage arrangements *most times*, and fuselage mounted weapon arrangements *sometimes* will not yield with respect to the two above items. If so, try to shave cross sections, but usually not productive.

c) If almost there, or just a little too much, either stretching or shrinking the length or filling-out or shaving the cross sections, or a combination of both will suffice most times. Iterative back feeding into the mold and shoulder lines and adjacent cross sections is required to obtain smooth contours.

29. Find location for speed brakes if not “ascertained” on initial "A" size sketch, and/or tail parachute stowage.

30. Dimension and make cognizant design notes. Determine spotting factor if required.

III. Post Drawing Progression

31. Have weight and *cg* estimated. Iterate -- <u>***or start anew***</u> -- in light of weight or *cg* read-out.

32. Have performance checks made to see what adjustments are required with updated weights, wetted areas, cross sectional area distributions, fuel loads etc. Have stability and control checks run and resize surfaces if required. Iterate -- <u>***or start anew***</u> -- with new engine sizes, fuel requirements, wing loadings, surface sizes, etc.

Items 6 to 32 are repeated until the specification is met.

33. If the design, as such, is “bought” with discrepancies from “someone” in-the-company, or if time runs out:

That's It!

<u>Solicitation of Material</u>

Contributions are actively solicited. They should be submitted on 3 1/2 inch disks. IBM disks should contain plain text files. Mac disks are preferred, and most "common" formats can be handled. Ready to copy artwork can also be handled.

<u>Circulation</u>

This newsletter is, for the time being, circulated free to individuals known to be interested in aircraft design education. This will not continue indefinitely, but will start on this basis. Institutions desiring to receive the newsletter will be requested to subscribe at a minimal fee.

The Aircraft Design Education Newsletter is published twice yearly. Once in early October, with highlights from the AIAA Aircraft Design Meeting (and possibly other meetings), and again on June 1. Requests for additions and changes in the distribution as well as questions and contributions should be addressed to:

W.H. Mason, P.O. Box 816,
Blacksburg, VA 24060.