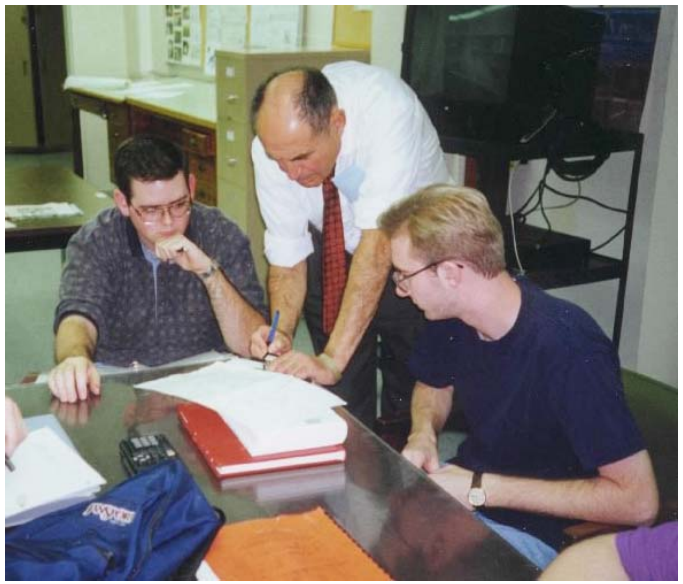
Aircraft Layout

From the master, Nathan Kirschbaum

at NAS Willow Grove
mid 1940s

at USAF Museum around 1990, showing students the Bomarc he worked on at Boeing in the early '50s

Helping students, mid 1990s



From Kirschbaum's ***Aircraft Design Handbook***, *Aircraft Design Aid and Layout Guide*

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Outline

- The start
- Basics of aircraft drawing layout
- How to start & the initial sketch

- The working drawing
- The inboard profile
- The three-view drawing
- After the drawing

From Nathan's Book: *Aircraft Design and Layout Guide*

Input to Designers

- Corporate Management
- Aerodynamics & Propulsion Groups
- Weights & Aero performance groups
- Systems Groups
- Operational & "illities" groups
- Self "Doodling"

Output of designer

Integrate geometrical & dimensional req'ts, equipment, structural components, & expendables into a:

Balanced Vehicle

In ALL Phases of Flight & Ground Operation

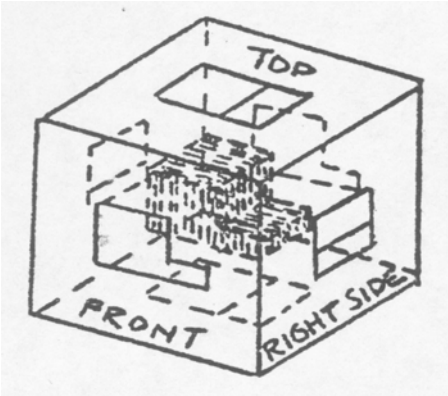
The Basic Three-View Drawing (or General Arrangement Drawing)

- Orthogonal Projection
- The International Language
- First Building Block (Save for concept in designer's eye) for project to get started

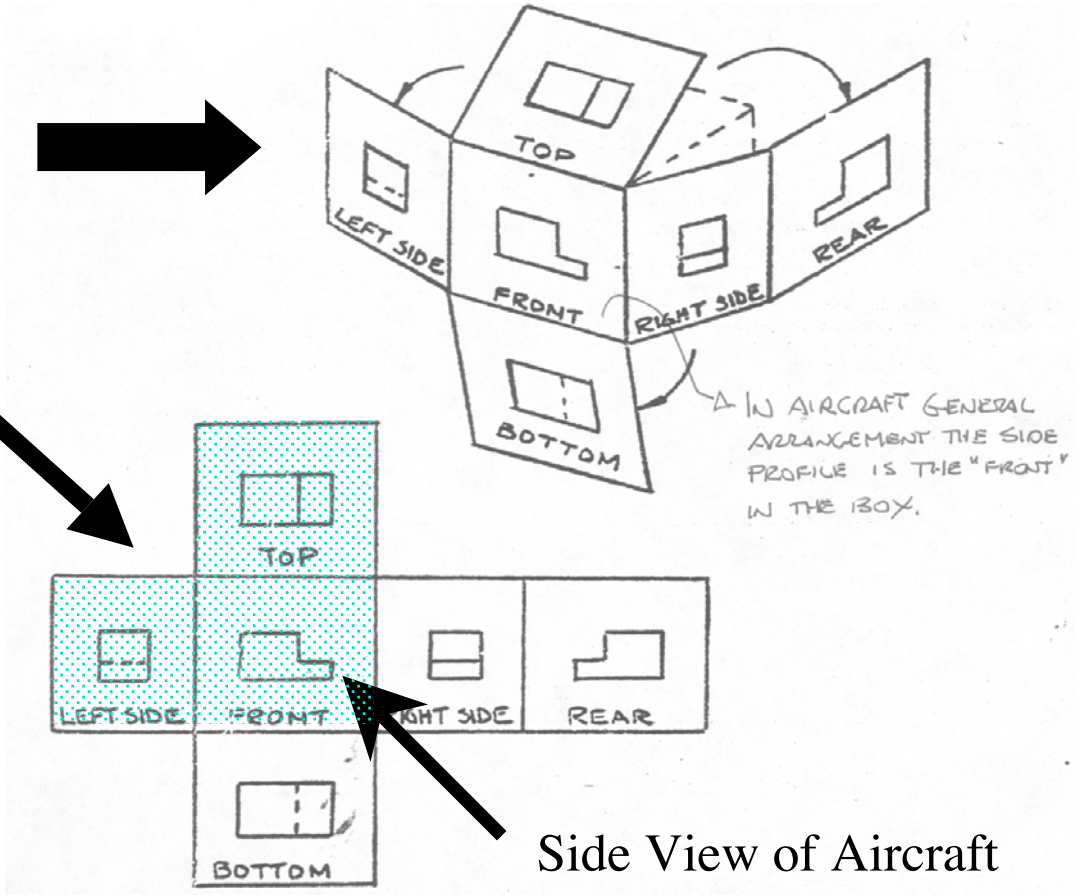
A Poor Three-View Drawing and Inboard Profile Can Undo a Good Concept or Proposal

Opening the Box: Orthographic Projection

Consider the object to be inside a box

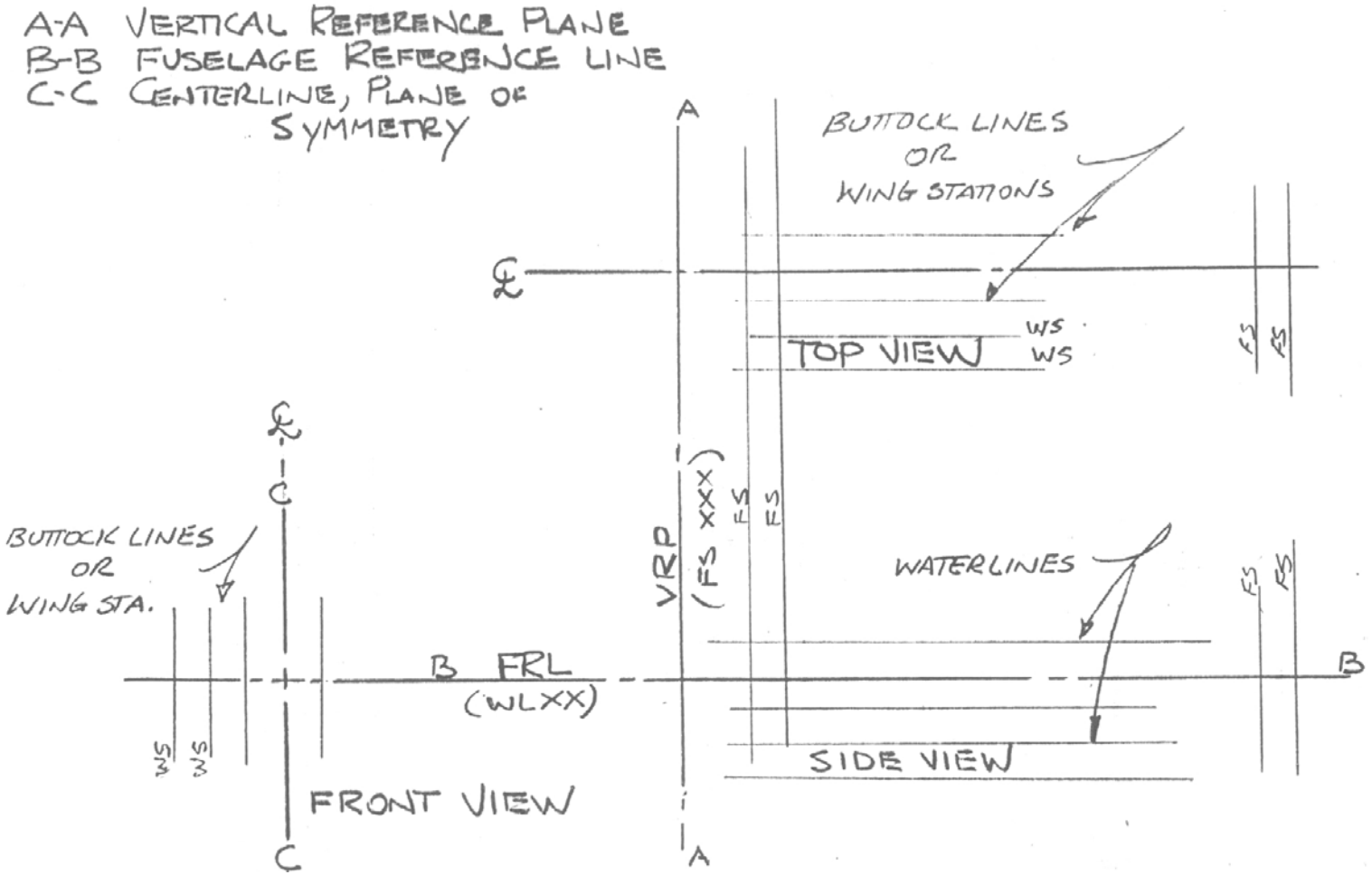


Shaded sections are standard for A/C dwg:



Side View of Aircraft

Airplane Layout - Reference lines



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FS: fuselage station
drawn by Nathan Kirschbaum

An Example

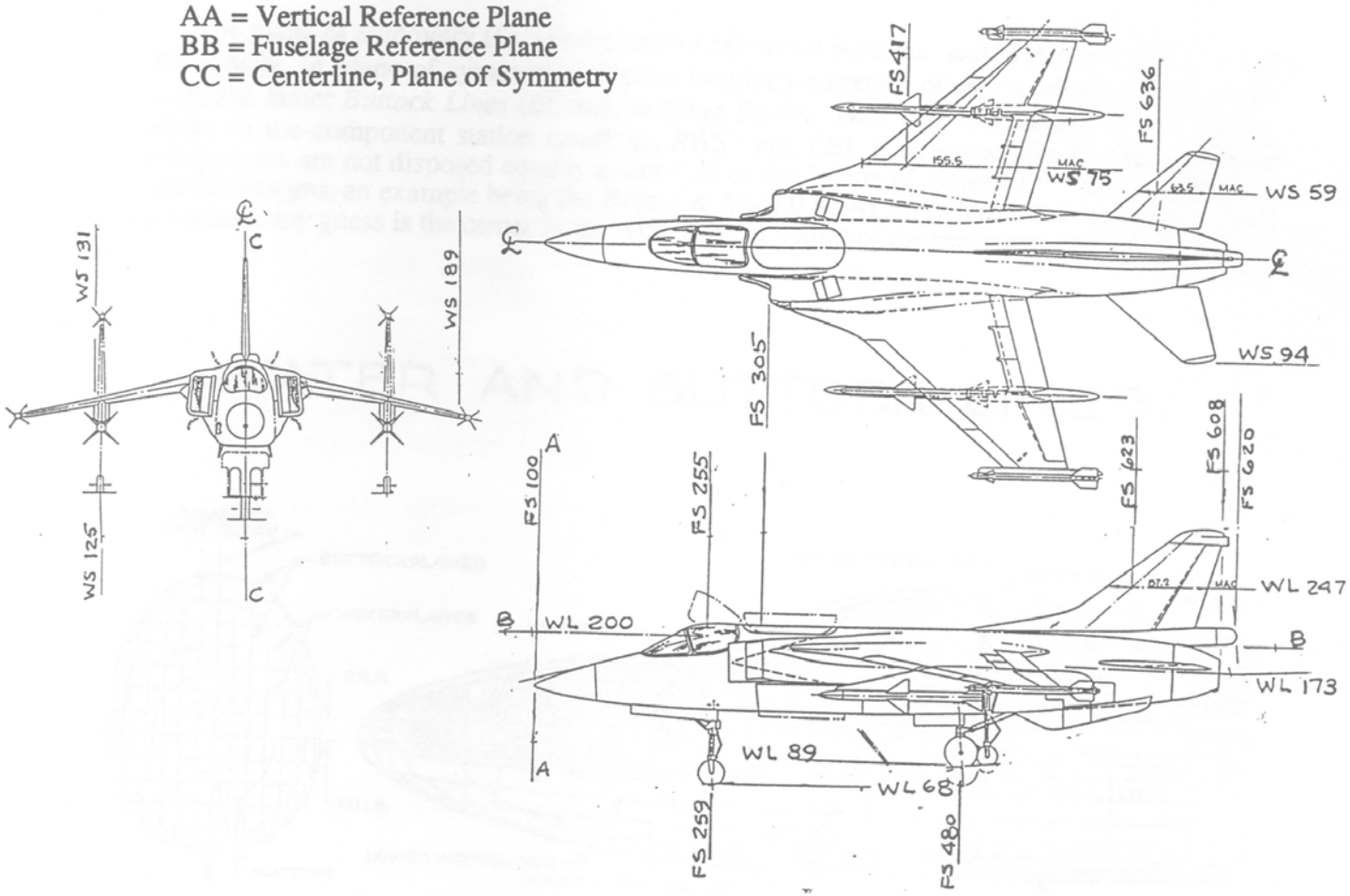
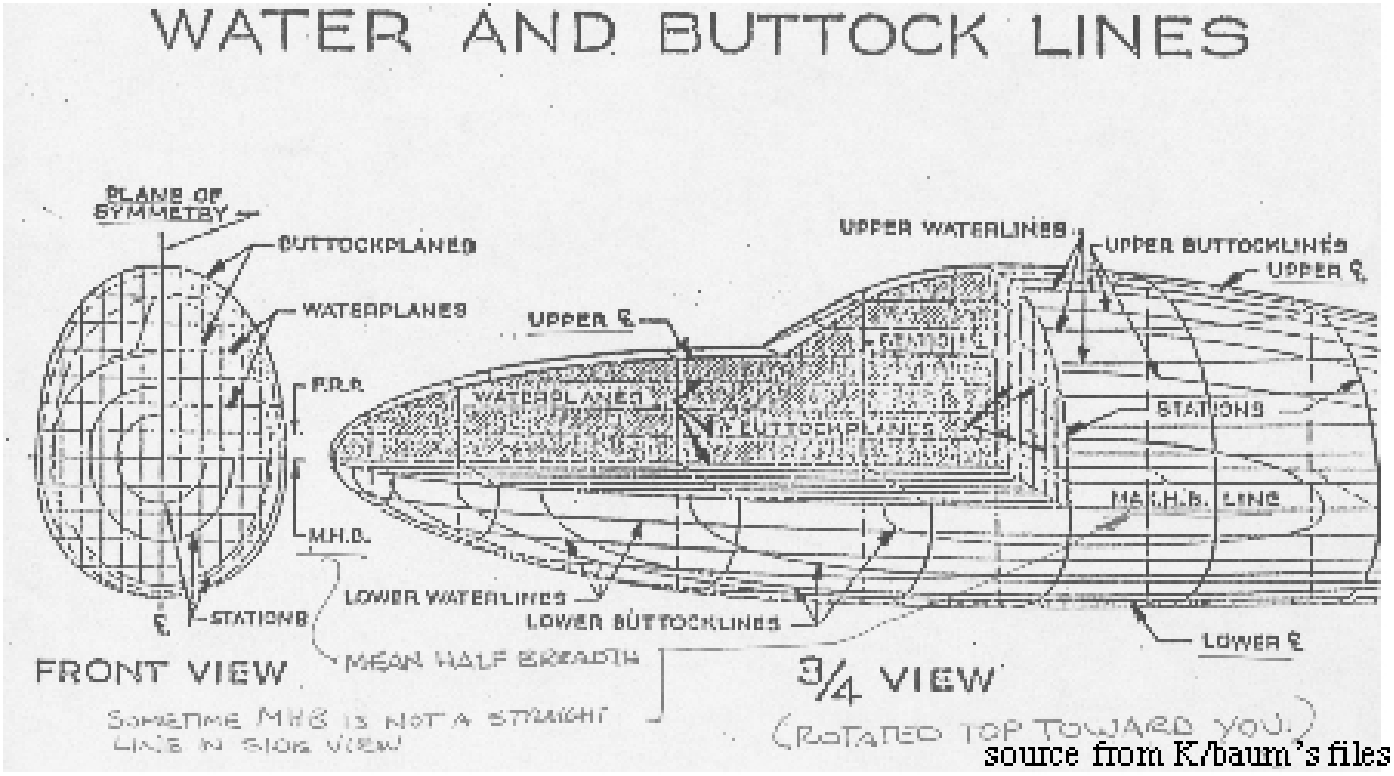


Figure 1-1 Aircraft Reference Planes and Baseline Reference Lines

Waterlines and Buttock Lines (FS & Wing station too?)



source from K/baum's files

Initial Assumptions or Dictates

- No ground support equipment for daily maintenance, or passenger or weapon loading
- Engine Removal Schemes - back/bottom
- Weapon Carriage Schemes
  - Weapon bays, conformal semi-recessed, conformal tangential, etc.
- Pressurization - fuselage cross section
- Hangerage size - dimensional & area limitations
  - Especially with respect to Aircraft Carriers
- Center of Gravity - VTOL, Thrust Vectoring
- Direction of landing gear retraction
- Air inlet location/orientation/type - Jet A/C engine and/or propeller location - propeller A/C
- Stealth

Systems

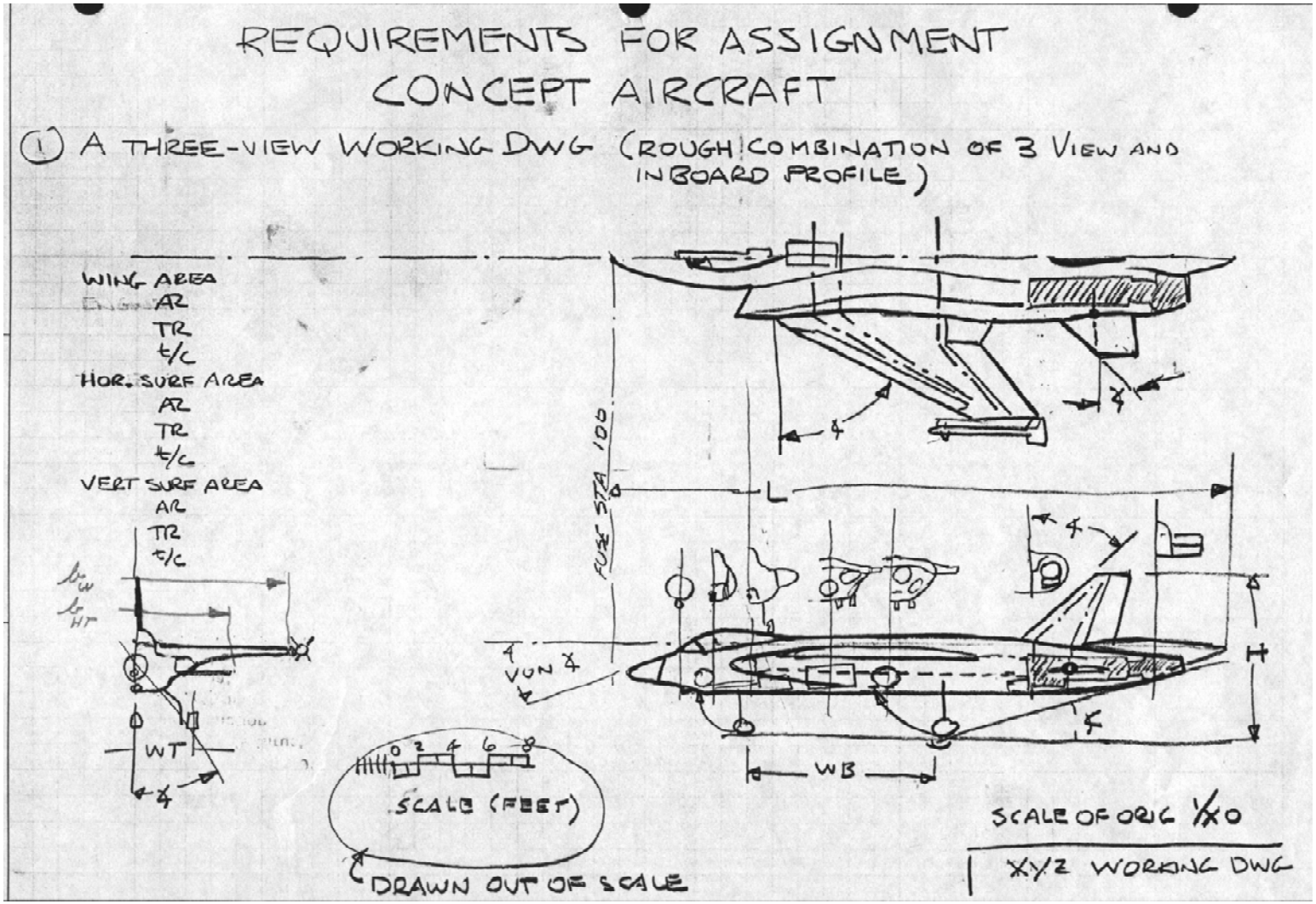
- Flight control system
  - Speed brake & vectoring nozzle(s), if any, included
- Fuel tank system (coordinate with propulsion & structures)
- Hydraulic and pneumatic, if any
- Electrical system
- Landing gear system (coordinate with configuration designer)
- Environmental control systems
- Avionics & sensor systems
- Anti-icing system(s)
- Defense/self protection systems
- Weapon systems, if any (coordinate with designer)
- Loading systems, if any (coordinate with designer)

Initial Sketch: Approach

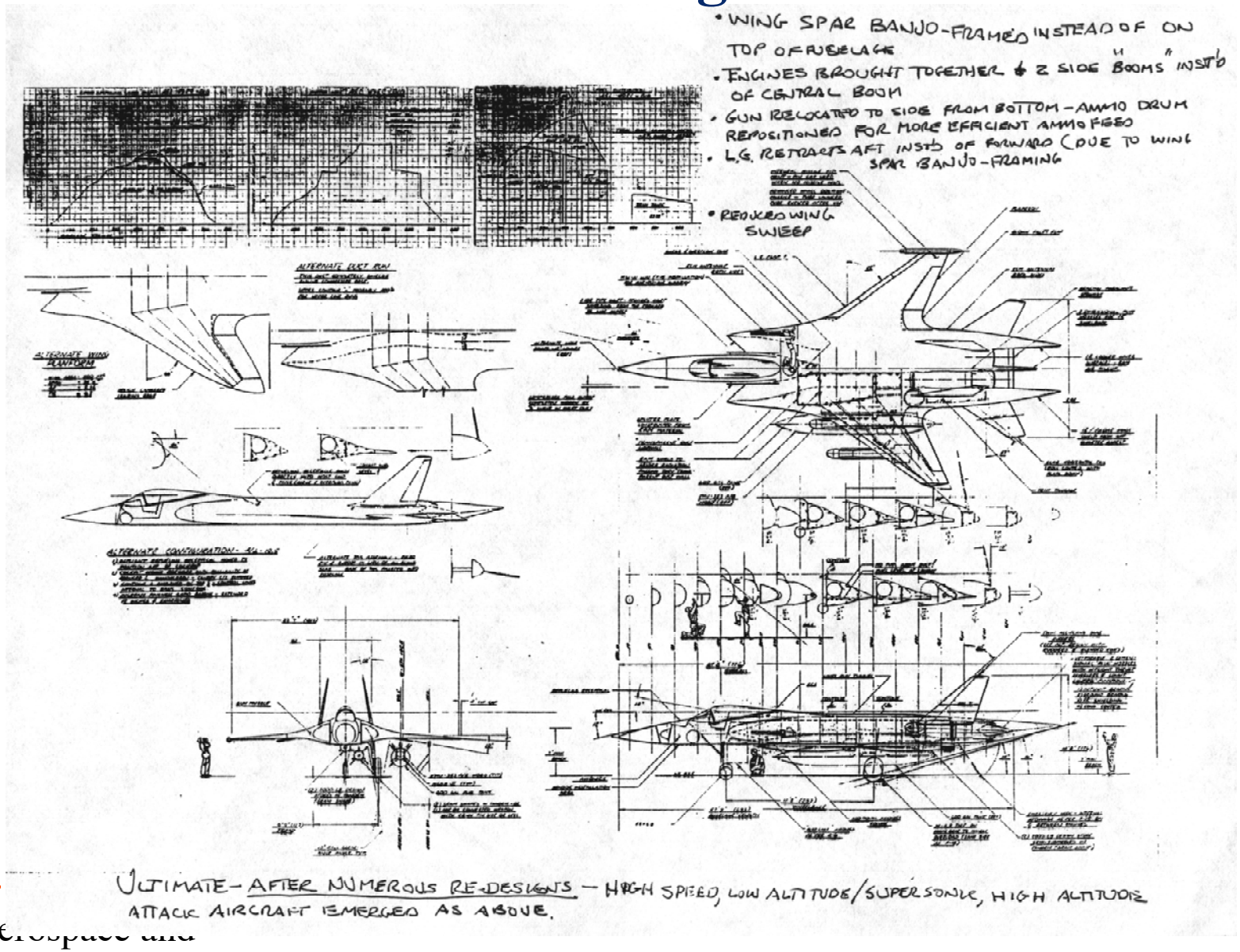
- Sketch 2 or 3 view of aircraft on quadrille pad or cross-hatched paper (wives's tale - sort of - an “old envelope”)
- Organize assumptions
- Keep relative scale for trueness (don’t kid yourself)
- *Use a straight edge to draw straight lines!*
- Make initial tradeoffs between components whilst you -
- Re-do “initial sketch until components fall into, place and assumptions seem satisfied

Does it look like your initial conceptual visualization?
Oft times not

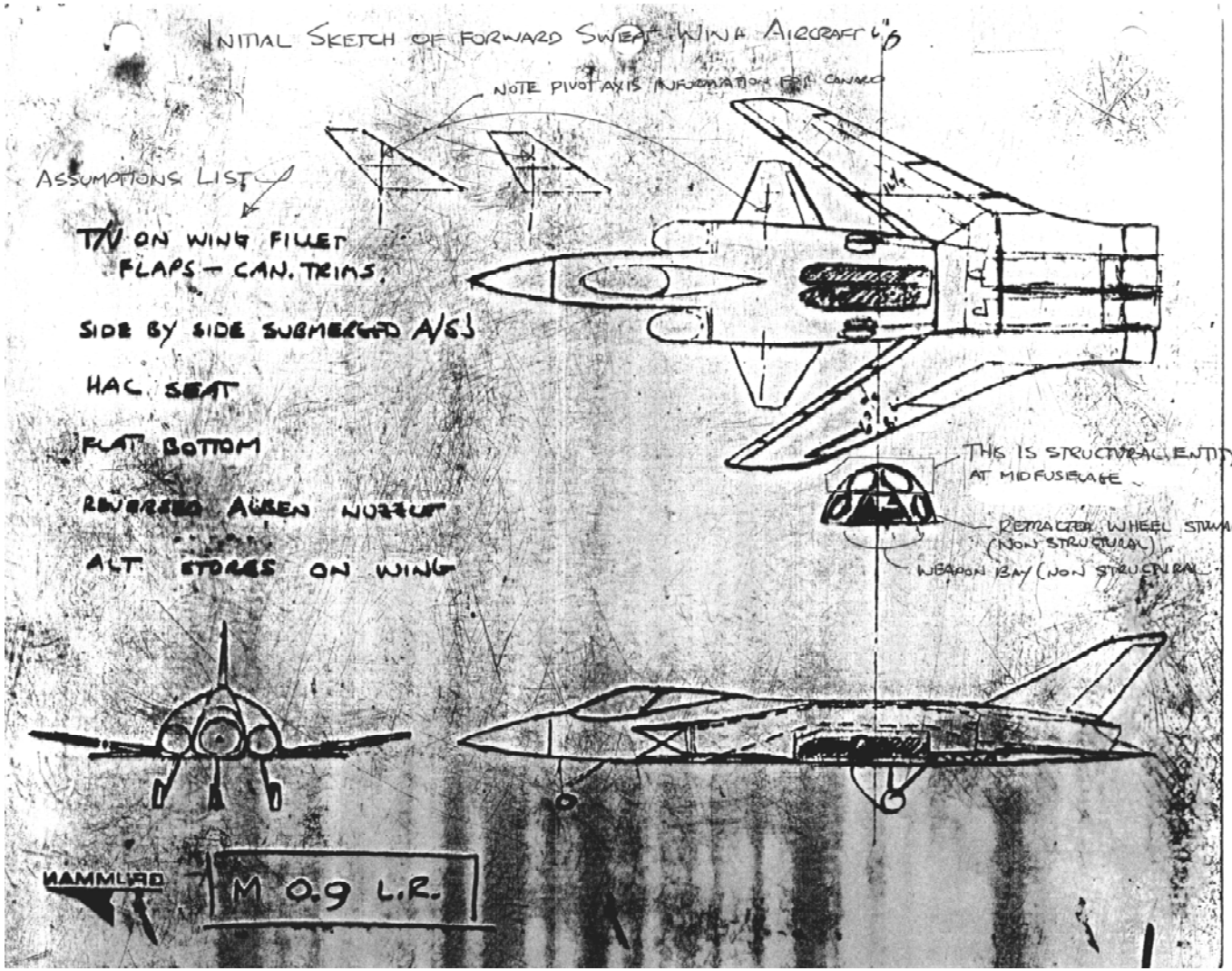
Kirschbaum initial sketch example



Final design



X-29 example: Initial K'Baum Sketch



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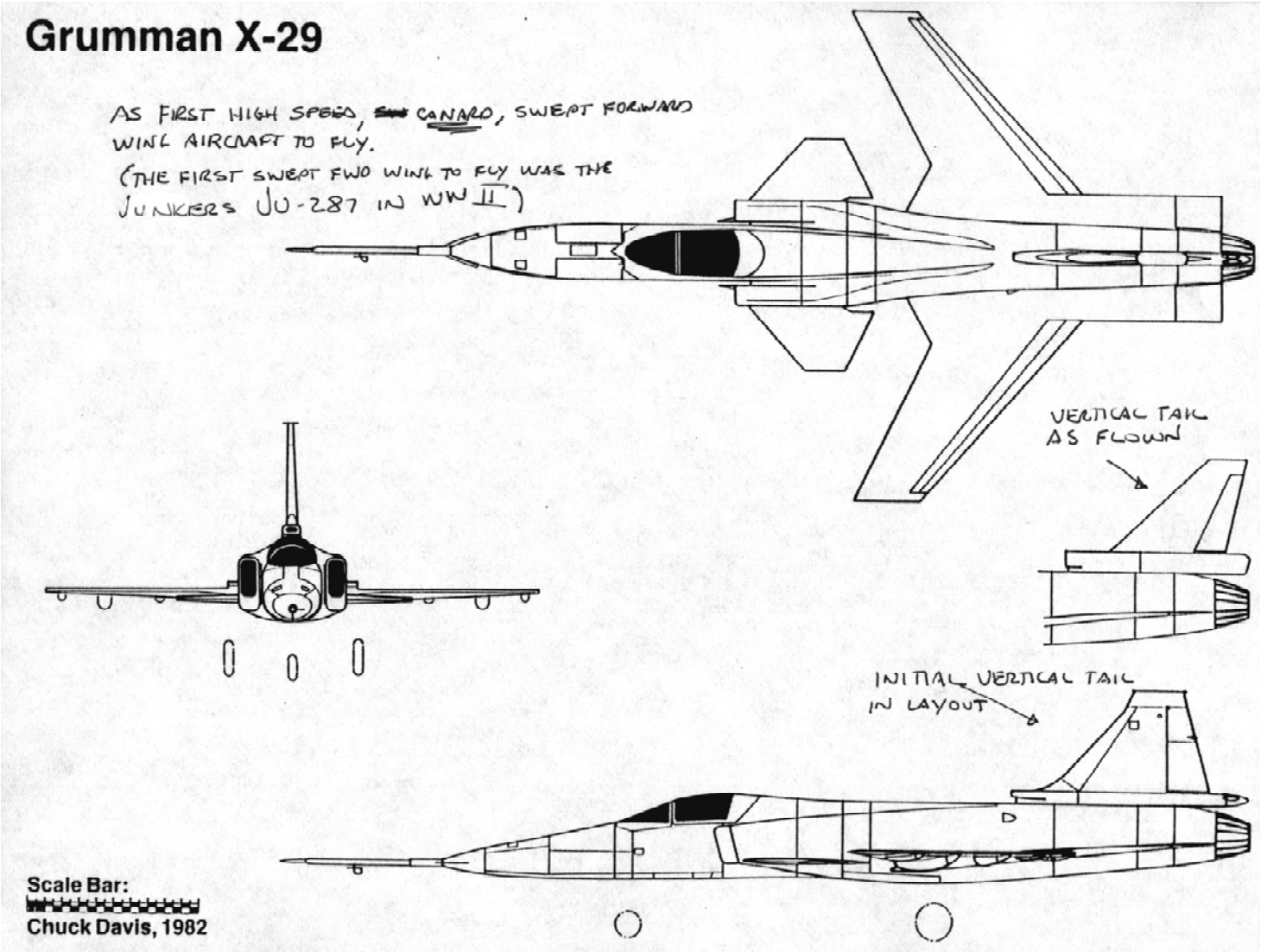
The eventual X-29



After the sketch, the initial layout and working drawing

Drawing Start

- Establish reference lines
- Use the Final Initial Sketch as guide
- In Side View (side elevation)
  - Draw crew station or passenger envelope
  - Establish required view-over-nose from pilot's eye (forward vision line)
  - If military, draw radome & radar sensor, draw in-flight refueling system
  - If general aviation, draw nose shape to either enclose specified engine (1 engine) or baggage (2 engine)
  - Allow sufficient volume for retracted nose wheel

In Planview (top elevation)

- Establish fuselage width at pilot's shoulder (a min.) or passenger cabin width
- Draw radome and radar (if military) or engine or baggage compartment (if civil)
- Establish A/C length and locate cg
- Draw wing and establish mean aerodynamic chord 9mac). Locate wing on drawing placing mac on cg as function of aerodynamic layout (to start)
- Establish spar locations - these will locate major load bearing bulkheads on the fuselage
- Locate and draw engines

Planview 2: Establish

- Crew station or cabin envelope
  - Vision requirements
  - Ingress/egress provisions
- Engine location & propeller diameter (if prop)
- Inlet type, location & orientation (if jet)
- Nozzle type & location (if jet)
- Nose shape & envelope to house baggage (if civil) or radar/reconnaissance equipment (if military or commercial)
- Wing and spar locations
- Control surfaces & their fixity points
- Landing Gear locations & fixity points
- Stowage for retractable systems
- Proper tip-back & turnover angles
- Fuel tankage - balance

Establish (Pt 2)

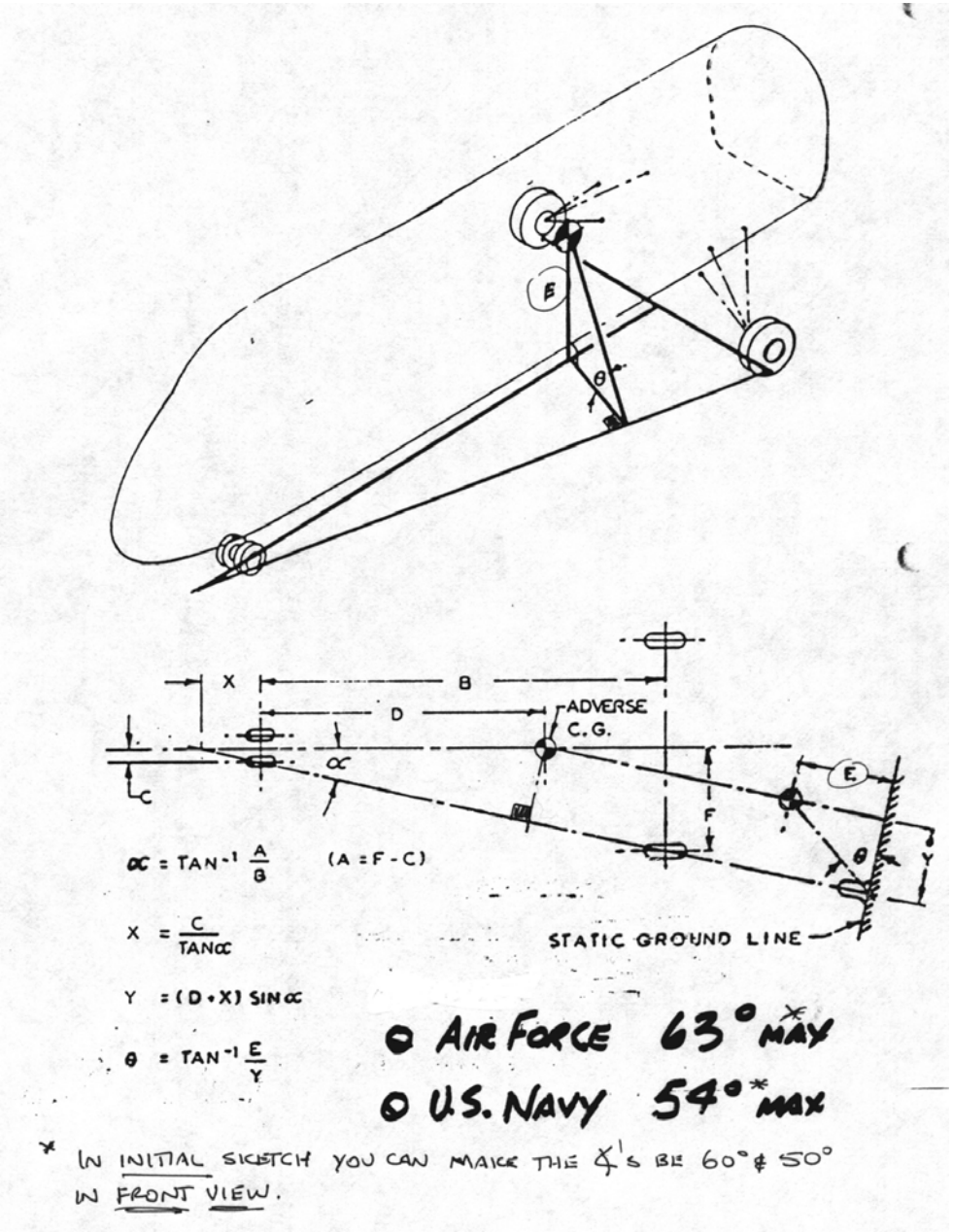
- Gun installation & weapon carriage (if military)
  - Make sure weapons are to scale!
  - Make sure gun has clear bullet path!
- Passenger & cargo volume requirements (if commercial)
  - Doors & emergency exits
  - Lavatories & kitchen facilities
  - Cargo ramp & floor height from ground
- Oft times establishes size of vehicle
  - Irrespective of sizing program

Landing Gear Layout Requirement

See Raymer, Fig. 11.5

and his discussion,

Or Currey, Fig. 3.7



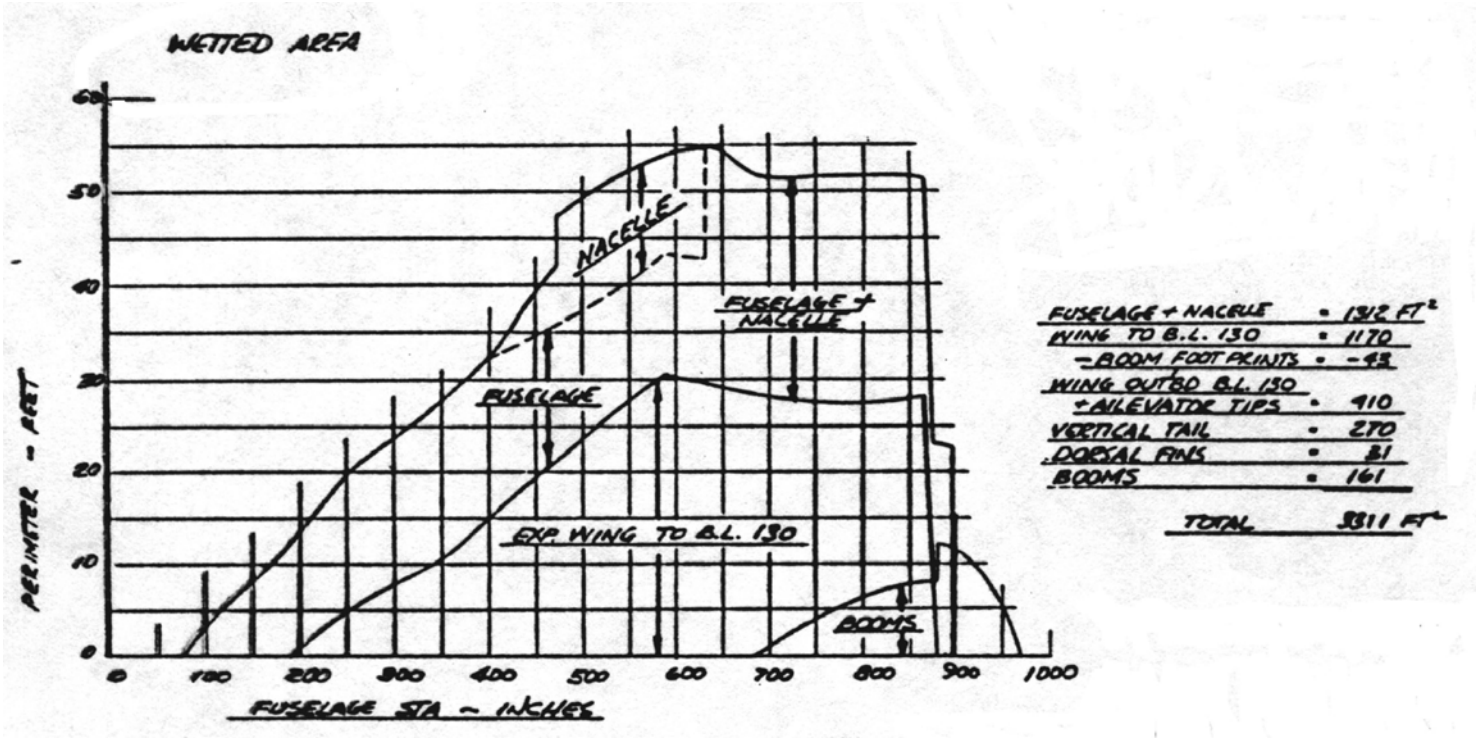
Inboard Profile

- Employed to locate internal equipment to satisfy equipment fit, accessibility & their volumetric requirement (fuel, passengers, cargo, weapons systems)
- Employs side & top view of three-view along with cross sections of fuselage/engine pods (if any)/wing sections at or through fuselage
- ***Cross sections*** taken at critical areas of layout
  - Radar dish envelope (clearance requirement)
  - Pilot's eye (for vision requirements)
  - Jet engine inlet (establish inlet capture area, boundary layer bypass shape)
  - Engine face with its accessory envelope and the complimentary airframe mounted accessory drive (AMAD)

Inboard Profile (Continued)

- Inlet duct path & shapes between inlet and engine face
- Landing gear attachment & wheel stowage
- Wing spar locations (attachment to or through fuselage)
- Horizontal tail & vertical tail at pivot and/or spar locations
- Engine pylon attach if fuselage engine podded design
- Engine nozzle/fuselage interface
- Cargo entry (nose/side/aft)
- Pilot/Passenger boarding/entry if integral boarding system required
- Note: can establish req'd cargo, passenger & stores clearances & accommodation in sections detailed above

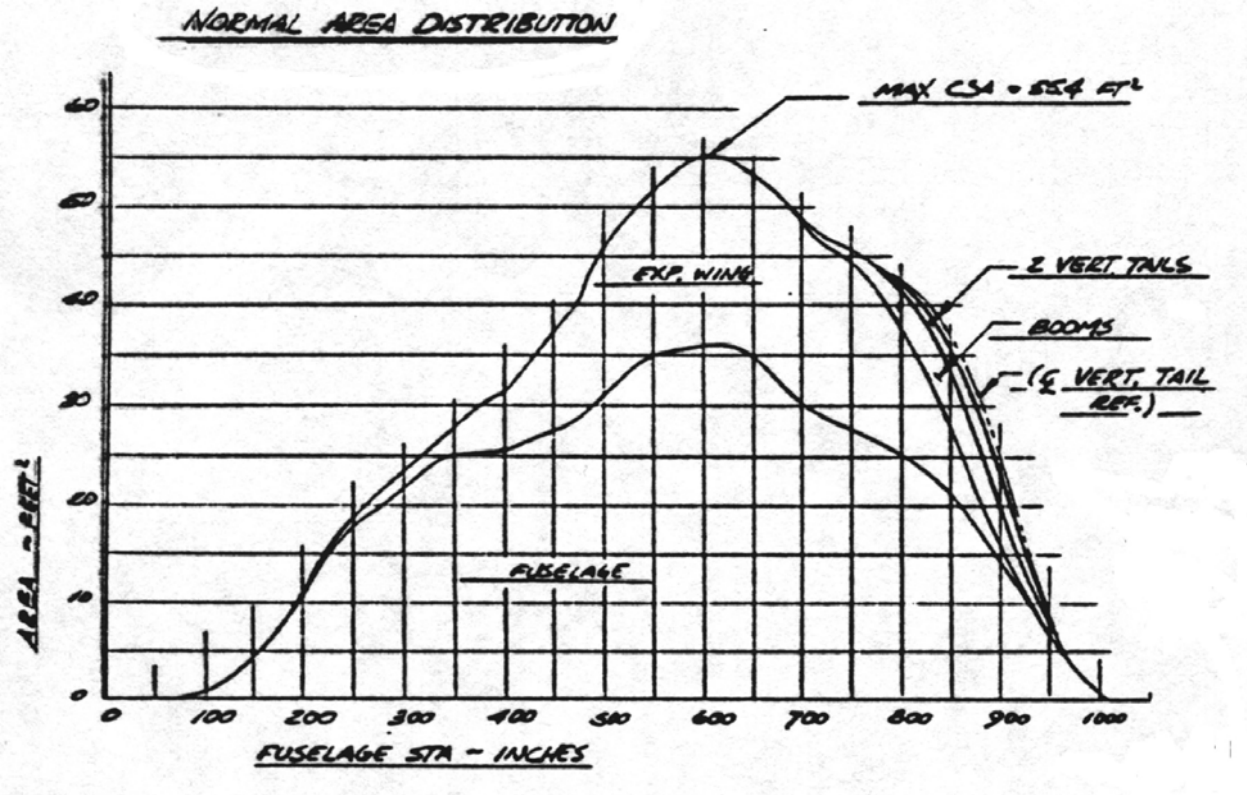
Use drawing to find wetted areas



Cross sections allow you to find accurate fuselage (and nacelle) wetted areas

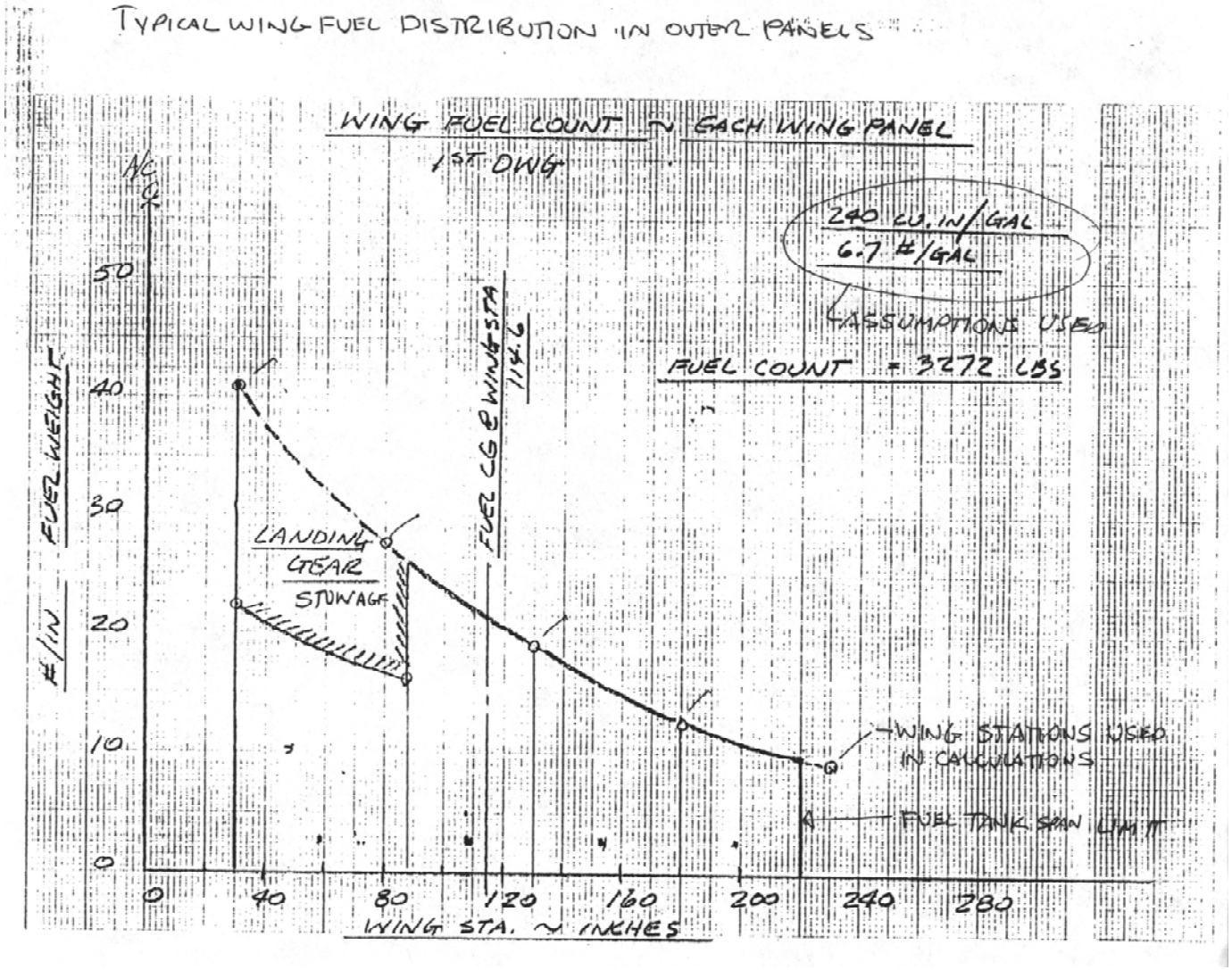
Important for performance & weight estimation

Use drawing to find cross sectional areas



- Cross sections allow you to obtain the cross sectional area distribution
- Important for transonic and supersonic performance estimation
- Poor area distribution can be cause for reconfiguring

Find wing fuel volume (and similarly fuel in fuselage)



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Inboard Profile (continued)

These cross sections establish the required fuselage shape(s) and length for fuel, cargo, passengers, weapons/stores

They establish:

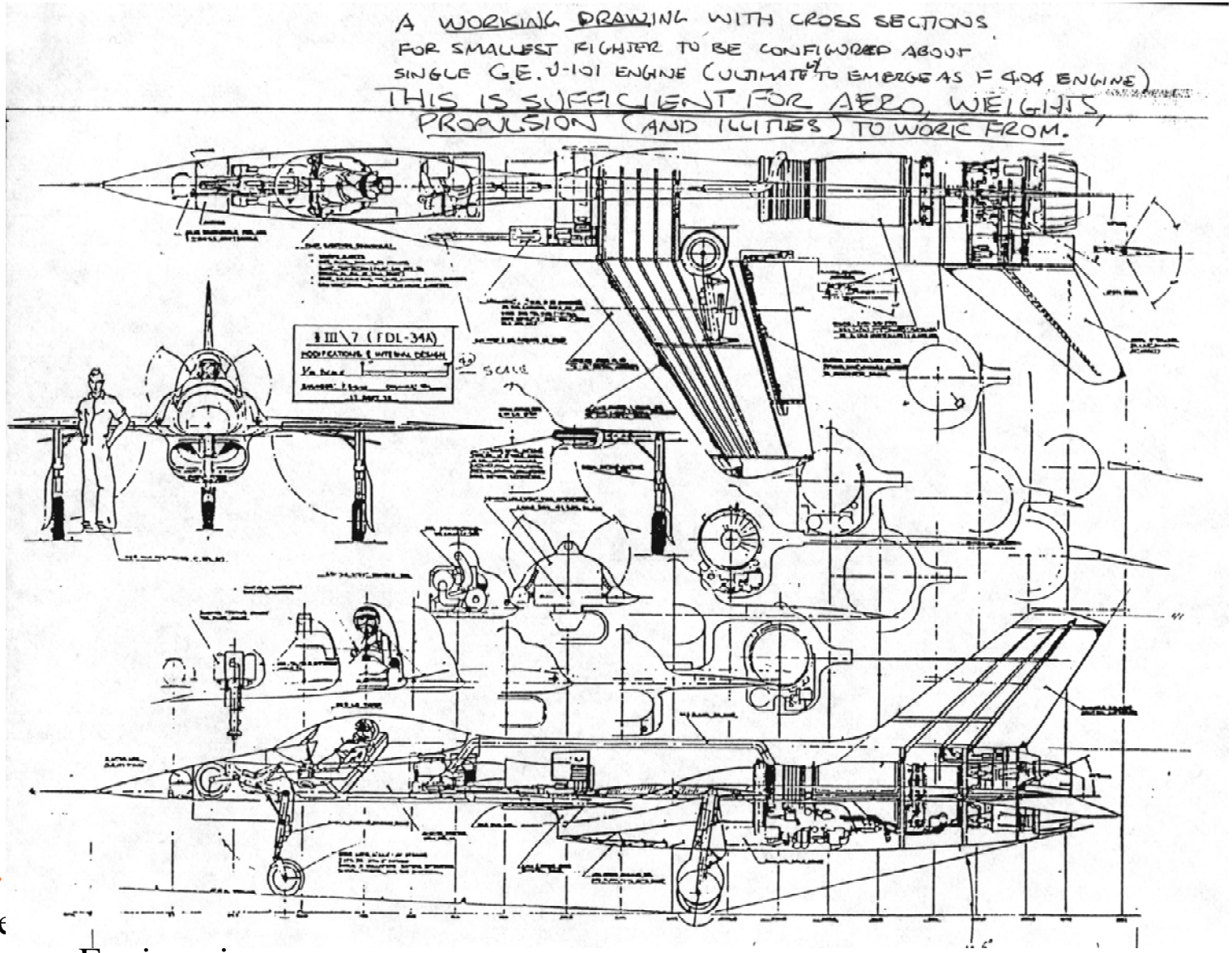
- Quantity & distribution of fuel & it's distributive cg
- Critical fuselage cross section shapes that have to be faired to or otherwise accommodated
- Wetted area & cross section area distribution

Together with top & side inboard profiles they establish the aircraft center of gravity & cg range

Inboard Profile and Working Drawing

- At the start, three-view & inboard profile are the same drawing called a ***Working Drawing***
- Why? Many a change will be required before all known or stipulated equipment can be installed, balance met, and performance requirements satisfied.
- It is an iterative procedure
- The working drawing is continuously changed during the design process to satisfy all of the diverse requirements of equipment integration, balance, performance, stability/control - or if need be, redrawn - starting anew

A good working drawing example



Another example of a good working drawing

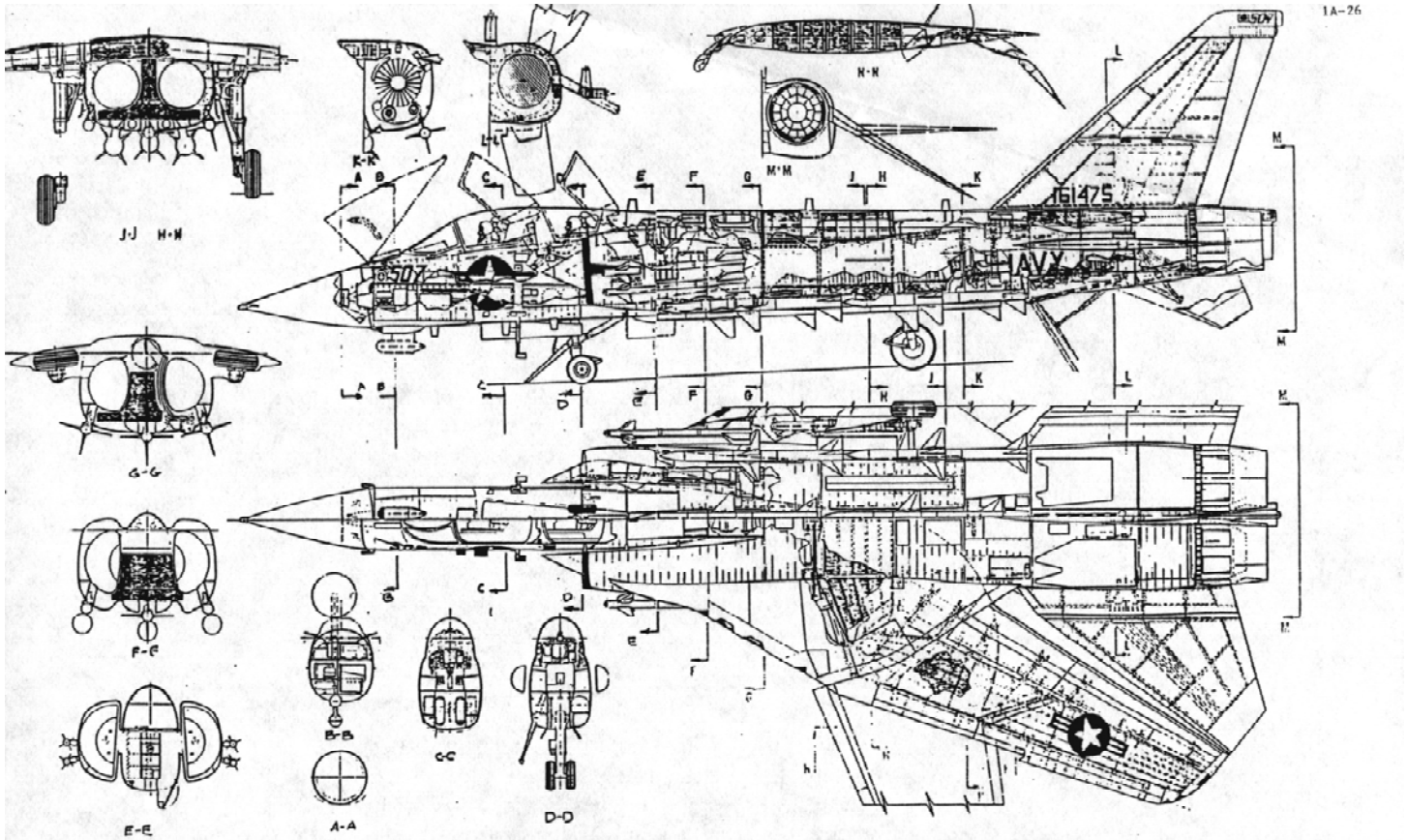
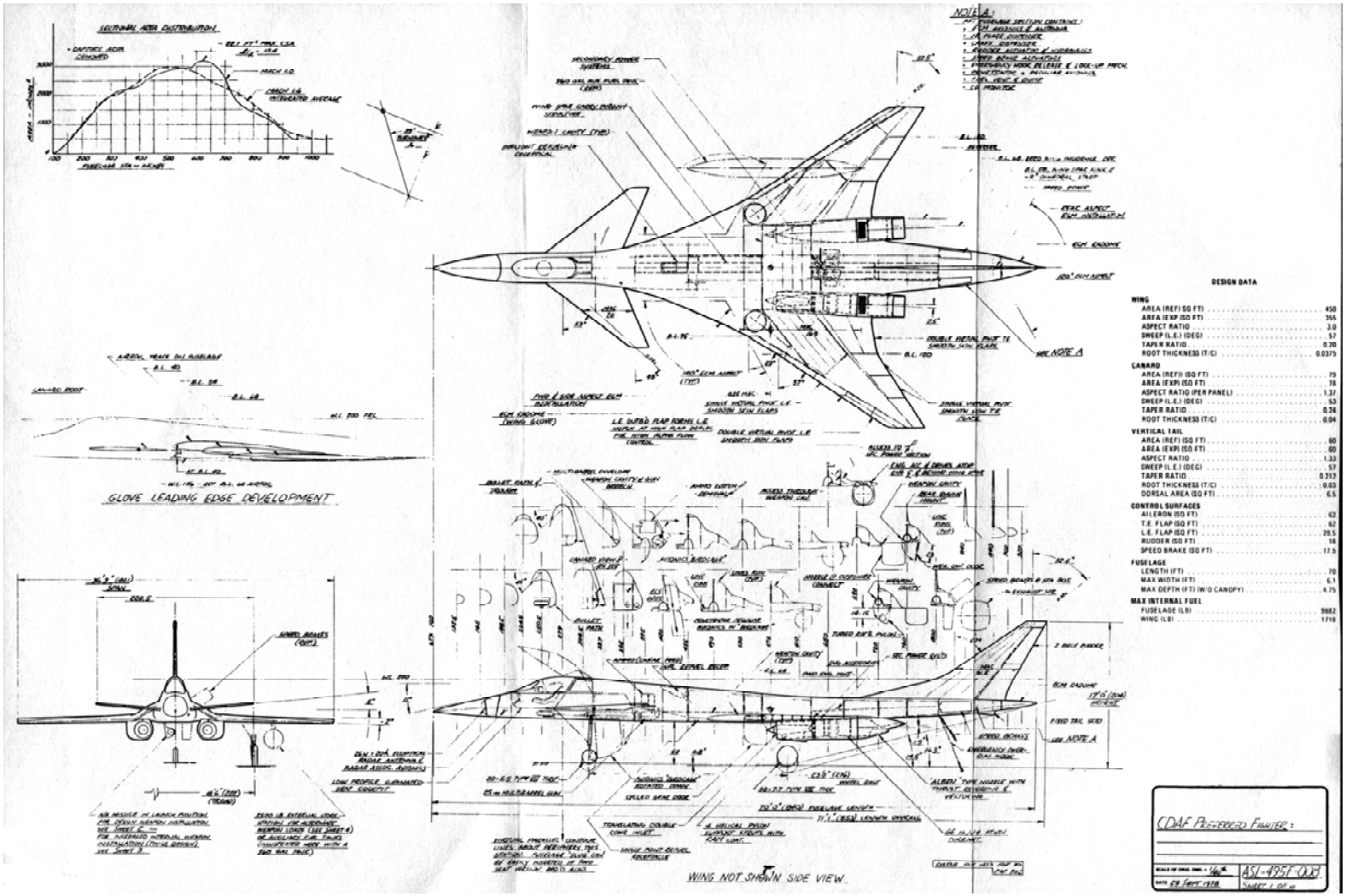


Figure 1A-15. Inboard Profile - Vought Navy Fighter

Report Quality 3-View (normally 11x17 "B Size")



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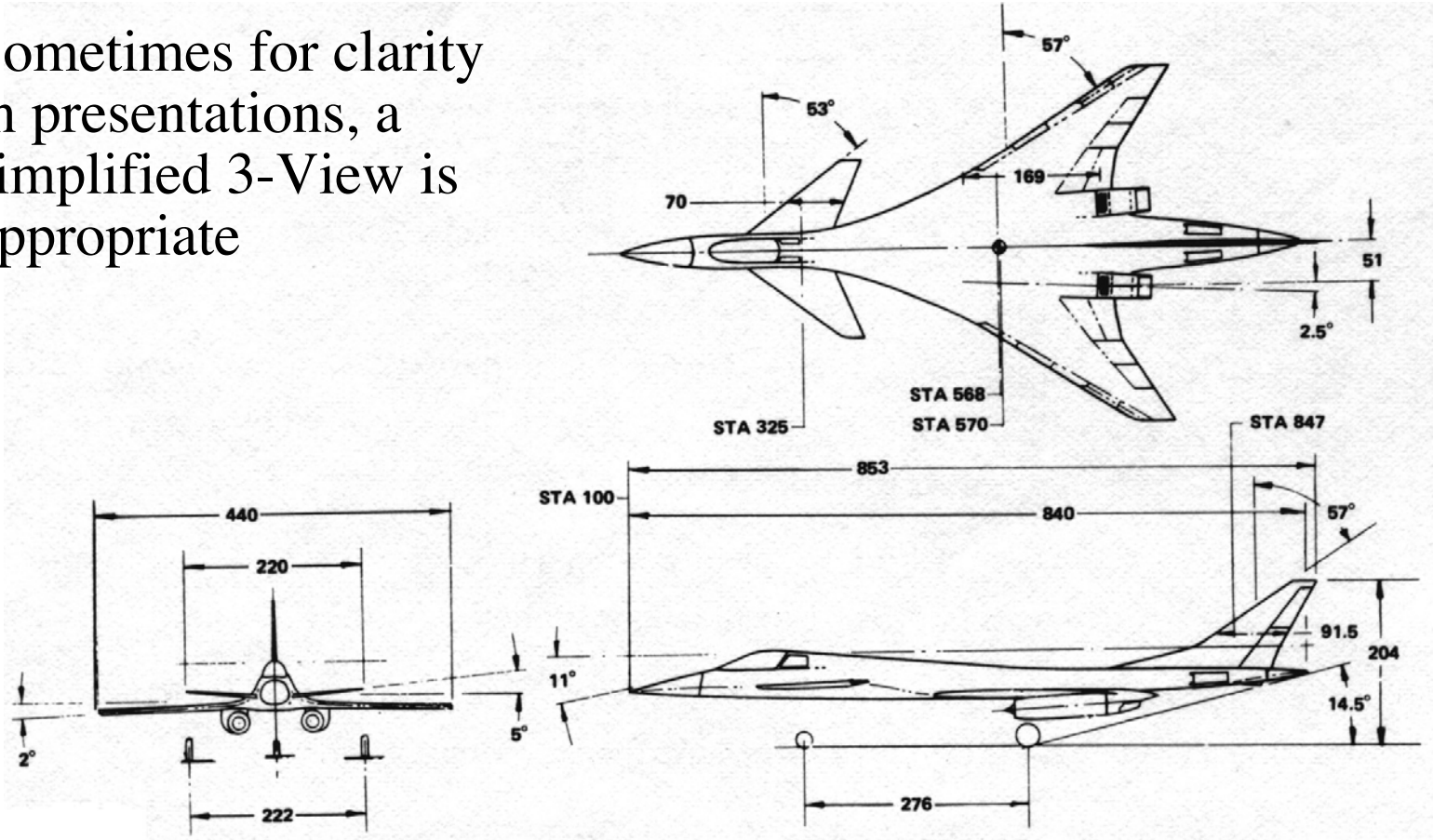
Presentation Three-View

Sometimes for clarity in presentations, a simplified 3-View is appropriate



The post drawing process

- Have weight and *cg* estimated by the weights group.
  - Iterate —or start anew — in light of weight or *cg* result.
- Have performance checks made to see what adjustments are required with updated weights, wetted areas, cross sectional area distributions, fuel loads, etc. Have stability & control checks made and resize surfaces if required.
  - Iterate — or start anew — with new engine sizes, fuel requirements, wing loadings, surface sizes, etc.
- If the design, as such, is "bought" with discrepancies from "someone"-in-the-company, or when time runs out:
  - **That's It!**

To Conclude

"After a while, any ridiculous idea begins to look reasonable after you've been working on it long enough"

Prof. Mowforth
Cranfield University, England

- **Quality sketching and drawing is important**
- **Not emphasized enough to current students**

See related discussion in Raymer, Chap 7 and elsewhere