to simplify the implementation of the design process using spreadsheet analysis. As an example, many graphs in the book have no other data available besides the graphs themselves. These have been painstakingly digitized for the reader. Additionally, many methods are presented using computer codes written in Visual Basic for Applications (VBA), native to Microsoft Excel.

1.4.1 Conceptual Design Algorithm for a General Aviation Aircraft

The design algorithm is presented in Table 1-4 and illustrated in Figure 1-11. It covers the complete conceptual design process and presents several tasks that help bring the design into the preliminary design phase. Where appropriate, the reader is directed toward a section in this book that provides the needed analysis method. The algorithm treats the design process as a computer program: First, several initialization tasks are performed, followed by a set of iterative tasks.

Note that sketching the airplane is not suggested until Step 10. While this may appear strange to some, the reason is simple: Not enough information exists for an effective sketch until Step 10. Of course, this does not mean a sketch cannot be or should not be drawn before that—just that an accurate depiction of the airplane is not possible. For one, the wing and tail geometry are determined in Steps 8 and 9, so an earlier sketch is unlikely to represent

TABLE 1-4 Conceptual design algorithm for a GA aircraft.

Step	Task	Section
1	Understand requirements, mission definition, and the implications of the regulations to which the airplane will be certified.	–
2	Study aircraft that fall into the same class as the one to be designed. These may present you with great design ideas and solutions. They can also show you what to steer away from—which is priceless! • Qualitatively evaluate what configuration layout may best suit the mission. • Decide on a propulsion methodology (propeller, turbofan, others?).	–
3	If the target weight and maximum level airspeed are known, estimate the development and manufacturing costs for a projected 5-year production run. If the target weight is not known, perform this task once it is known (see STEP 6 or 12). Evaluate how many units must be produced to break-even and the required retail prices. Evaluate operational costs and labor force as well. How do these compare to the competition?	2.2 2.3
4	Create a *Constraint Diagram* based on the requirements of STEP 1 (target performance).	3.2
5	Select critical performance parameters (T/W or BHP/W and W/S) from the Constraint Diagram. Once T/W and W/S are known, the next step is to estimate the gross weight so that wing area and required engine thrust (or power) can be extracted.	3.2
6	Estimate initial empty and gross weight using W-ratios with historical relations and conduct a thorough mission analysis.	6.2
7	Using the results from the Constraint Diagram of STEP 4 and the initial gross weight of STEP 6 estimate the initial wing area and thrust required. This calls for a guess for an expected $C_{L_{max}}$. Thrust will reveal what sort of an engine is required for the airplane. Keep in mind the requirements for stall speeds (e.g. LSA limit is 45 KCAS, "old" 14 CFR Part 23 is 61 KCAS, etc.) to ensure the selected W/S and T/W (or BHP/W) will allow the design to simultaneously meet all performance requirements and stall speeds.	3.2
8	Estimate initial tail surface area and special position using V_{HT} and V_{VT} methodology.	11.4
9	Propose a wing layout that suits the mission by establishing initial AR, TR, airfoils, planform shape, dihedral, washout, etc. Note that many of these parameters are likely to change in the next iteration. For the airfoil selection, use a method like the one shown in Section 8.3.9, *Decision Matrix for Airfoil Selection*.	8 9
10	If not already done, sketch several initial configurations and methodically evaluate their pros and cons. Select a candidate configuration.	4
11	Based on the selected propulsion methodology (see STEP 2), select the engine type and layout (number of, types, properties of, location of) to be evaluated.	7
12	Using the candidate configuration, estimate empty, gross, and fuel weight using the appropriate combination of *Statistical*, *Direct*, and/or *Known Weights* methods.	6.3 6.4 6.5
13	Determine the empty weight CG, develop a CG loading cloud, gross weight CG, movement due to fuel burn, and inertia properties (I_{xx}, I_{yy}, …).	6.6
14	Determine a candidate CG envelope based on results from STEP 13. Expect this to change once STEP 16 will be completed.	6.7
15	Layout fuselage (space claims, occupant location, baggage, cargo) using a method similar to that of Section 12.3, *Sizing the Fuselage*.	12.3

TABLE 1-4 Conceptual design algorithm for a GA aircraft—cont'd

Step	Task	Section
16	Perform a detailed static and dynamic stability analysis of the candidate configuration.	Various
17	Modify the tail surface geometry in accordance with the results from the static and dynamic stability analysis of STEP 13. Note that dynamic stability modes should be converging, and the geometry will likely have to be "morphed" to eliminate any diverging dynamic modes.	11 24 25
18	Evaluate the following layout design modifications as needed based on the above analyses: • Structural load paths (wing, HT, VT, fuselage, etc.) • Control system layout (manual, hydraulic, fly-by-wire/light) • Flight control layout (geometry, aerodynamic balancing, trim tabs) • High lift systems and layout (flap types, LE devices) • Landing gear layout (tricycle, taildragger, fixed, retractable, etc.)	Various
19	Modify the design for benign stall characteristics (via washout, airfoils, slats, flaps).	9 10
20	Perform a detailed drag analysis of the candidate configuration. Design for minimum drag by polishing the geometry for elimination of flow separation areas, including the addition of wing fairings.	16
21	Perform a detailed performance analysis (T-O, climb, cruise, range, descent, and landing). Perform sensitivity analyses of T-O, climb, cruise, range, and landing. Create a payload-versus-range plot.	17–23
22	Optimize and refine where possible.	Various
23	Perform a regulatory evaluation and answer the following questions: **(1)** Will the candidate configuration meet the applicable aviation regulations? **(2)** Does it meet all requirements of STEP 1? **(3)** Does it satisfy the mission of STEP 1? If the answer to any of the three questions is NO, then go back to STEP 10 and modify the candidate configuration. If all can be answered with a YES, then continue to the next step.	14 CFR Part 23
24	Freeze OML. Do this by the release of an electronic solid model of the vehicle that is document controlled.	N/A
25	Create a *V-n* Diagram.	17.4
26	Detailed load analysis.	–
27	Move into the Preliminary Design Phase.	–

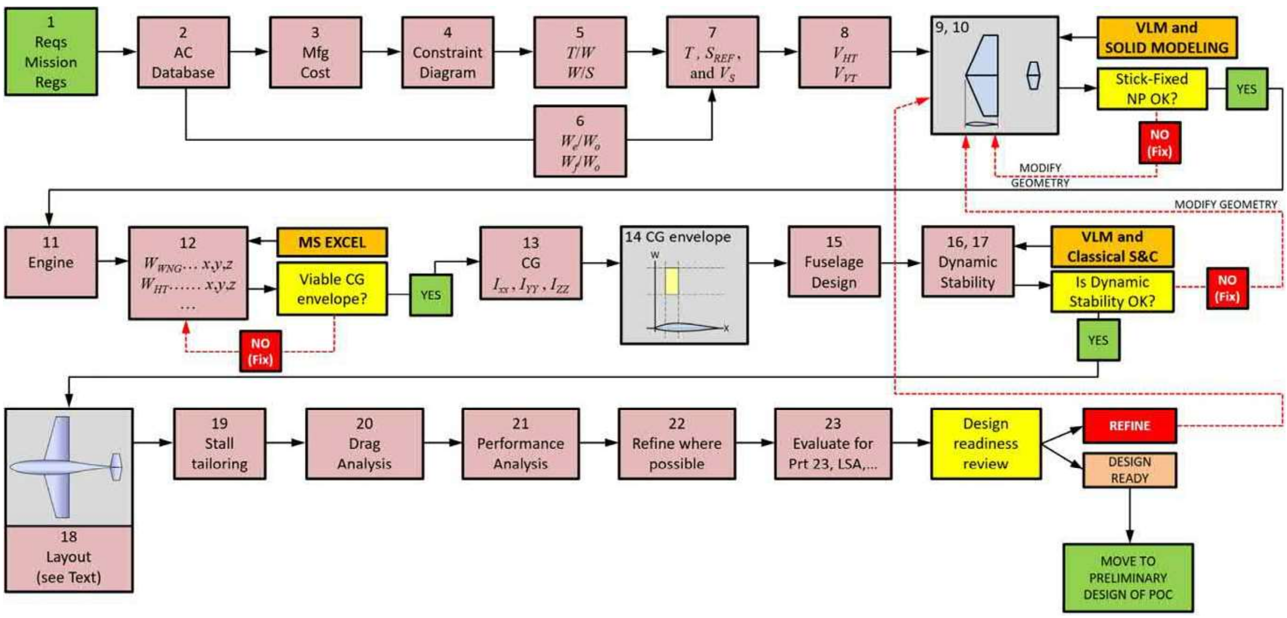

FIGURE 1-11 The aircraft design algorithm shown as a flow chart. AC stands for aircraft, VLM for Vortex-Lattice Method, S&C for Stability and Control, NP for Neutral Point and CG for Center of Gravity.

those with any precision. For this reason, and in the humble view of this author, an earlier sketch is a bit like a shot in the dark. That said, adhering to this algorithm is not the law of the land. It merely represents how this author does things. The reader can bend the algorithm to his or her own style. What works best for the reader is of greater importance.

As stated earlier, the algorithm is conveniently implemented in a spreadsheet. It is important to meticulously prepare it such that when any parameter changes, all dependent parameters are automatically updated. Do not leave this to the last minute; do it correctly from the start. This saves time. Where possible, enter formulas rather than numbers in the cells in the spreadsheet. Two common mistakes made by engineering students working on spreadsheets are (1) hardcoding numbers rather than formulas and (2) wait to the end of a semester to make the spreadsheets conducive to iteration. By then it is too late.

1.4.2 Implementation of the Conceptual Design Algorithm

The design algorithm is conveniently implemented using a 3-dimensional spreadsheet software. Such a spreadsheet allows multiple *worksheets*. It assigns one worksheet (called the "General" worksheet) as an information hub, while all remaining worksheets are organized in the hierarchy shown in Figure 1-12. All parameters that affect multiple worksheets are entered in the "General Tab". This ensures that changing multiuse parameters (e.g. wingspan) is automatically reflected in all codependent analyses in the other worksheets. A spreadsheet that requires the user to visit all affected worksheets to change the wingspan is poorly designed. It invites mistakes.

The power of the spreadsheet is further enhanced by writing VBA functions. For instance, it is highly recommended that the drag model (C_D) be developed as a VBA function, using appropriate arguments. For instance, such a function could be called `CD(Href, Vtas, df, ldg)`, where `Href` is the reference altitude (e.g., 25,000 ft), `Vtas` is the true airspeed in knots, `df` is the deflection of the flaps, and `ldg` the status of the landing gear for an aircraft with retractable landing gear. It is essential in teamwork that all members use the same lift, drag, and thrust models. Specific members can be tasked with developing these for the team. The use of such in-house functions reduces the risk of members "accidentally" using incorrect values, thus reducing chances of "late development surprises."

An example of an implementation in a real spreadsheet is shown in Figure 1-13. Note that two easily identifiable colors have been chosen for cells to indicate where the user shall enter information and where a formula has been entered. This reduces the risk of the user accidentally deleting important formulas and helps make the spreadsheet appear better organized and more professional.

1.5 ELEMENTS OF PROJECT ENGINEERING

This section introduces a few tools at the disposal of the project engineer. This is not a complete listing; there is a multitude of ways to conduct business. Readers interested in deeper understanding of each topic are directed toward a host of available texts on project engineering. Experienced project engineers may not find anything helpful in this section, but that is okay. This section is not intended for them, but the novice engineer who is not sure where to begin or how to proceed.

1.5.1 Project Plan

The successful development of a new aircraft requires a *project plan*. A project plan is a chronological listing of

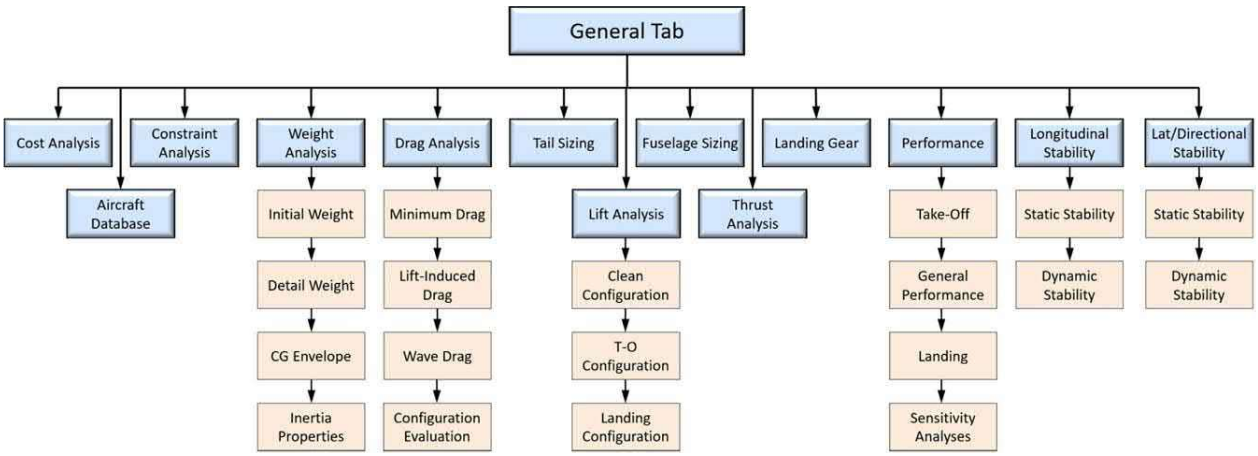

FIGURE 1-12 Organizational hierarchy for a spreadsheet (see text for explanation).