Appendix:

Functional Analysis

A critical step in implementing the systems engineering process is the accomplishment of the functional analysis and the definition of the system in "functional" terms. Functions are initially identified as part of defining the need and the basic requirements for the system. System operational requirements and the maintenance concept are defined, and the functional analysis is expanded to establish a functional baseline, from which the resource requirements for the system are identified; that is, equipment, software, people, facilities, data, the various elements of maintenance and support, and so on. The functional analysis is initiated during the conceptual design phase. As design and development continues, the functional analysis is accomplished to a greater depth, to the subsystem level and below, during the preliminary system design phase. This appendix provides guidance as to the detailed steps involved in accomplishing a functional analysis and in the development of functional flow block diagrams (FFBDs).

Functional analysis includes the process of translating top-level system requirements into specific qualitative and quantitative design-to requirements. Given an identified need for a system, supported by the definition of system operational requirements and the maintenance concept, it is necessary to translate this information into meaningful design criteria. This translation task constitutes an iterative process of breaking down system-level requirements into successive levels of detail; a convenient mechanism for communicating this information is through the various levels of FFBDs.

1 FUNCTIONAL FLOW BLOCK DIAGRAMS

Functional flow block diagrams (FFBDs) are developed to describe the system and its elements in functional terms. These diagrams reflect both operational and support activities as they occur throughout the system life cycle, and they are structured in a manner that illustrates the hierarchical aspects of the system. Some of the key features of the overall functional flow process are noted as follows:

1. The functional block diagram approach should include coverage of all activities throughout the system life cycle, and the method of presentation should reflect proper activity sequences and interface interrelationships.
2. The information included within the functional blocks should be concerned with *what* is required before looking at *how* it should be accomplished.
3. The process should be flexible to allow for expansion if additional definition is required or reduction if too much detail is presented. The objective is to progressively

and systematically work down to the level where resources can be identified with how a task should be accomplished.

In the development of functional flow diagrams, some degree of standardization is necessary (for communication) in defining the system. Thus, certain basic practices and symbols should be used, whenever possible, in the physical layout of functional diagrams. The paragraphs below provide some guidance in this direction.

1. *Function block.* Each separate function in a functional diagram should be presented in a single box enclosed by a solid line. Blocks used for reference to other flows should be indicated as partially enclosed boxes labeled "Ref." Each function may be as gross or detailed as required by the level of functional diagram on which it appears, but it should stand for a definite, finite, discrete action to be accomplished by equipment, personnel, facilities, software, or any combination thereof. Questionable or tentative functions should be enclosed in dotted blocks.
2. *Function numbering.* Functions identified in the functional flow diagrams at each level should be numbered in a manner which preserves the continuity of functions and provides information with respect to function origin throughout the system. Functions on the top-level functional diagram should be numbered 1.0, 2.0, 3.0, and so on. Functions which further indenture these top functions should contain the same parent identifier and should be coded at the next decimal level for each indenture. For example, the first indenture of function 3.0 would be 3.1, the second 3.1.1, the third 3.1.1.1, and so on. For expansion of a higher-level function within a particular level of indenture, a numerical sequence should be used to preserve the continuity of the function. For example, if more than one function is required to amplify function 3.0 at the first level of indenture, the sequence should be 3.1, 3.2, 3.3, ..., 3.*n*. For expansion of function 3.3 at the second level, the numbering shall be 3.3.1, 3.3.2, ..., 3.3.*n*. Where several levels of indentures appear in a single functional diagram, the same pattern should be maintained. While the basic ground rule should be to maintain a minimum level of indentures in any one particular flow, it may become necessary to include several levels to preserve the continuity of functions and to minimize the number of flows required to functionally depict the system.
3. *Functional reference.* Each functional diagram should contain a reference to its next higher functional diagram through the use of a reference block. For example, function 4.3 should be shown as a reference block in the case where the functions 4.3.1, 4.3.2, . . . , 4.3.*n*, and so on, are being used to expand function 4.3. Reference blocks shall also be used to indicate interfacing functions as appropriate.
4. *Flow connection.* Lines connecting functions should indicate only the functional flow and should not represent either a lapse in time or any intermediate activity. Vertical and horizontal lines between blocks should indicate that all functions so interrelated must be performed in either a parallel or a series sequence. Diagonal lines may be used to indicate alternative sequences (cases where alternative paths lead to the next function in the sequence).
5. *Flow directions.* Functional diagrams should be laid out so that the functional flow is generally from left to right and the reverse flow, in the case of a feedback functional loop, from right to left. Primary input lines should enter the function block from the left side; the primary output, or go line, should exit from the right, and the no-go line should exit from the bottom of the box.

6. *Summing gates.* A circle should be used to depict a summing gate. As in the case of functional blocks, lines should enter or exit the summing gate as appropriate. The summing gate is used to indicate the convergence, divergence, parallel, or alternative functional paths and is annotated with the term AND or OR. The term AND is used to indicate that parallel functions leading into the gate must be accomplished before proceeding to the next function, or that paths emerging from the AND gate must be accomplished after the preceding functions. The term OR is used to indicate that any of the several alternative paths (alternative functions) converge to, or diverge from, the OR gate. The OR gate thus indicates that alternative paths may lead or follow a particular function.
7. *Go and no-go paths.* The symbols G and $\overline{G}$ are used to indicate go and no-go paths, respectively. The symbols are entered adjacent to the lines leaving a particular function to indicate alternative functional paths.
8. *Numbering procedure for changes.* Additions of functions to existing data should be accomplished by locating the new function in its correct position without regard to sequence of numbering. The new function should be numbered using the first unused number at the level of indenture appropriate for the new function.

2 SOME EXAMPLES OF APPLICATION

With the objective of illustrating how some of these general guidelines are employed, Figures 1–7 are included to present a few simple applications.

1. Figure 1 provides an example of the basic format used in the development of functional flow block diagrams in general.
2. Figure 2 shows a manufacturing capability (top level or Blocks 1.0–7.0), an expansion of the design function (Block 2.0), and an expansion of the operating functions of the manufacturing plant (Blocks 5.1.1–5.1.16).
3. Figure 3 shows two levels of operational flow diagrams for a space system.
4. Figure 4 shows a maintenance functional flow diagram for the space system that evolves from the operation flow in Figure 3.
5. Figure 5 shows two levels of operational flow diagrams and two levels of maintenance flow diagrams for a radar system.
6. Figure 6 shows two levels of operational flow diagrams and a maintenance functional flow diagram for an automotive system.
7. Figure 7 shows two levels of operational flow diagrams and two levels of maintenance flow diagrams for a lawn mowing system.

Although these sample block diagrams do not cover the selected systems entirely, it is hoped that the material is presented in enough detail to provide an appropriate level of guidance for the development of functional block diagrams.

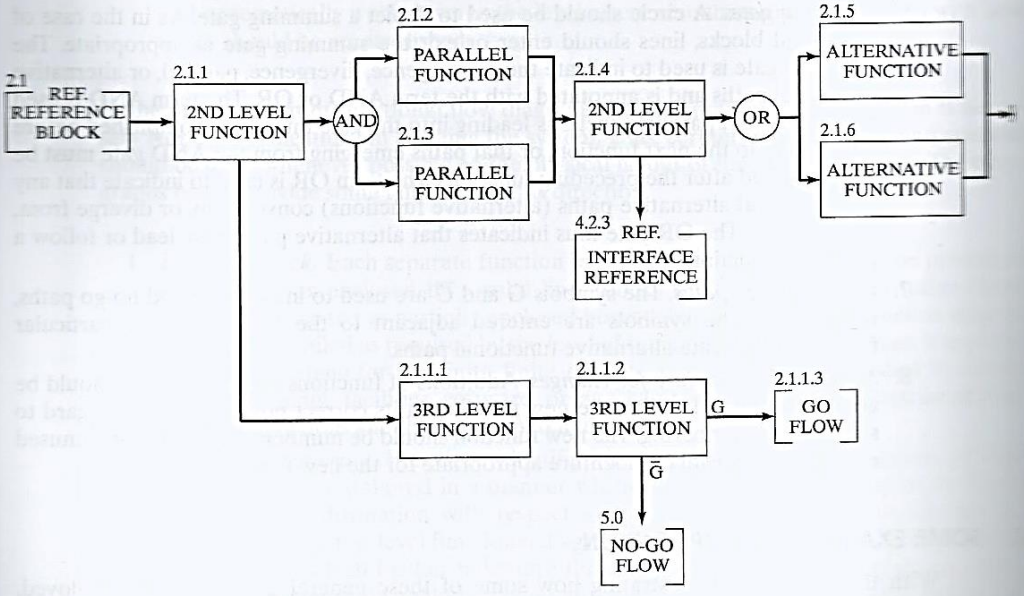

Figure 1 General format for the development of functional flow block diagrams.

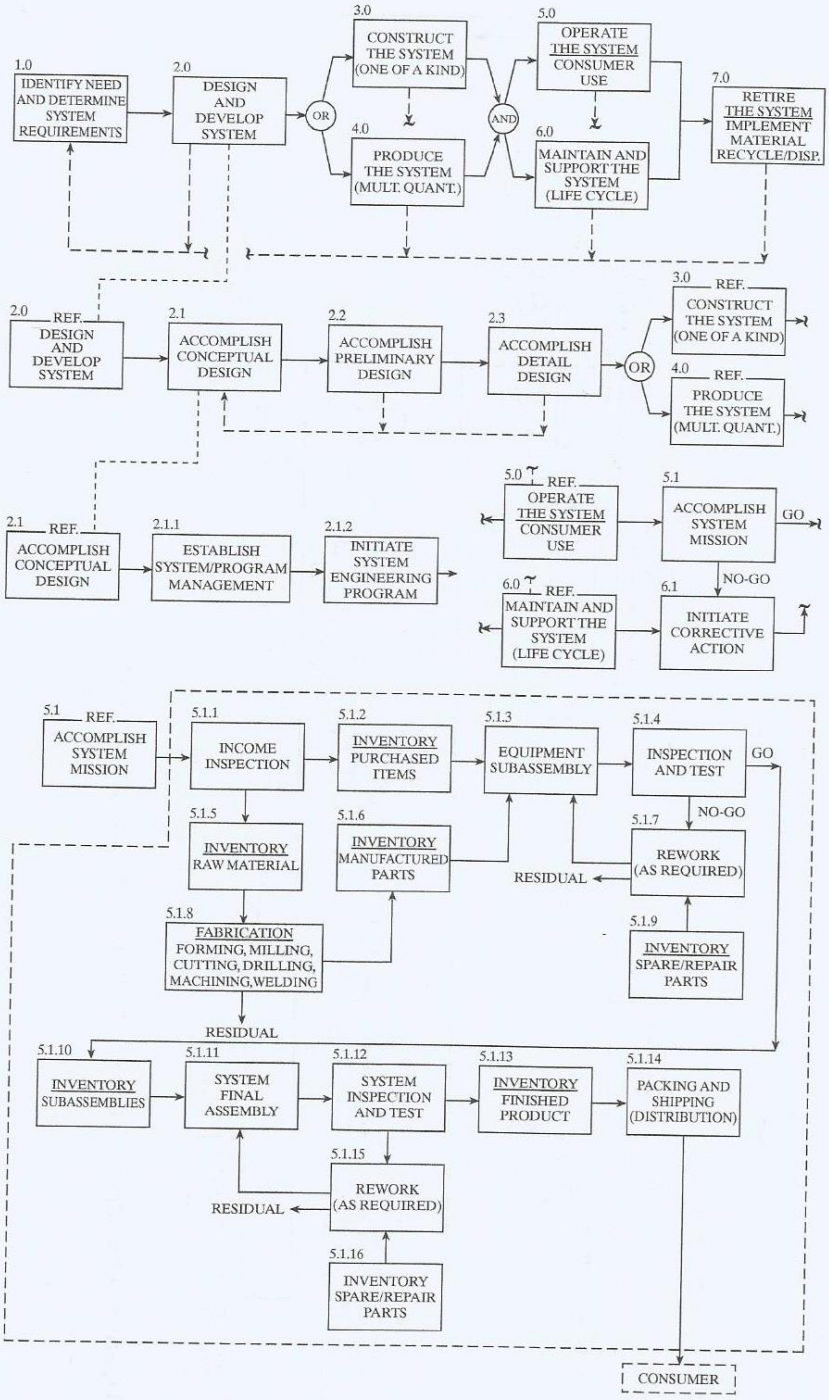

Figure 2 A manufacturing functional flow block diagram.

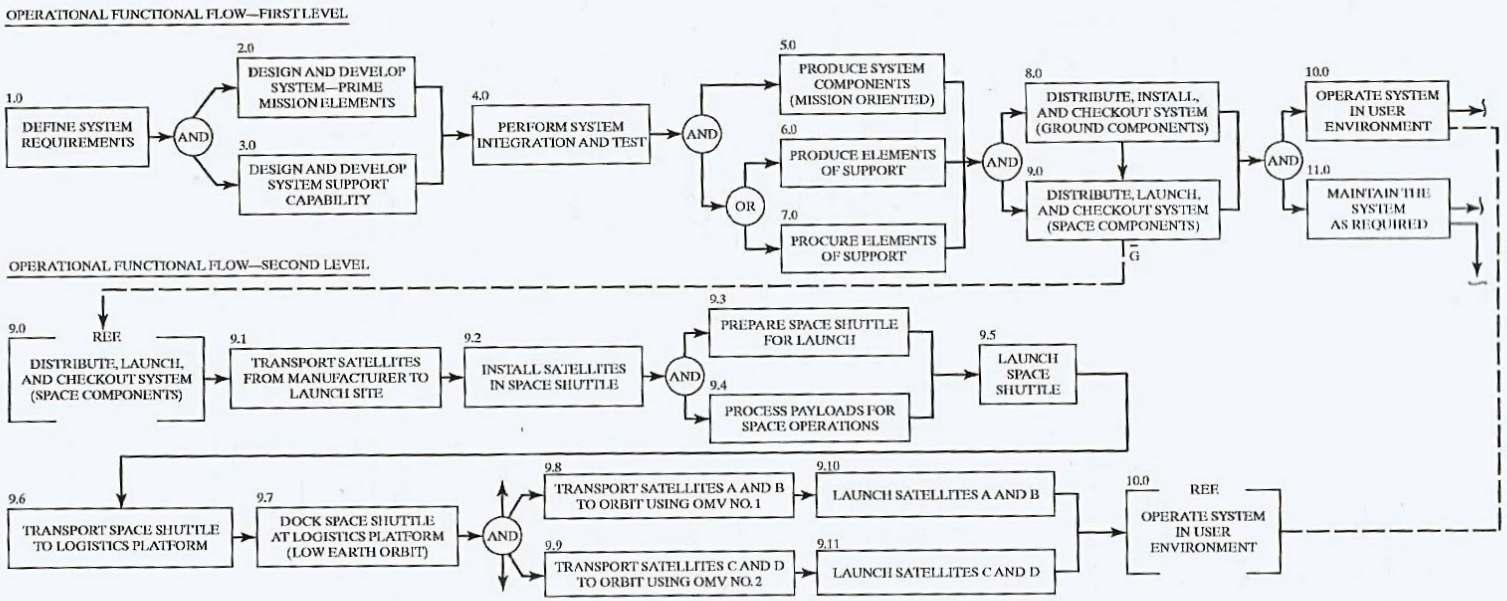

Figure 3 Operational functional flow diagram for a space system.

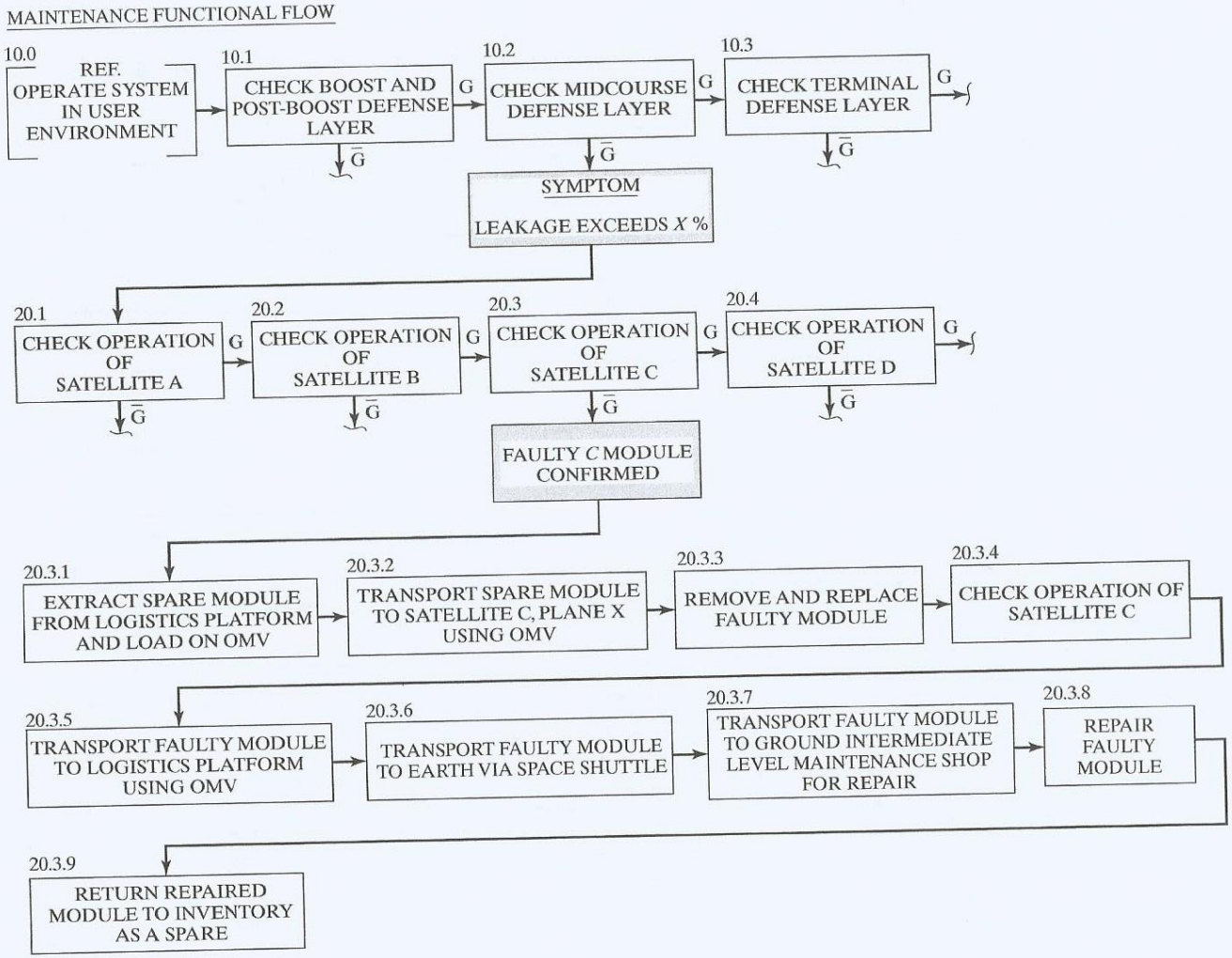

Figure 4 Space system maintenance functional flow diagram (example).

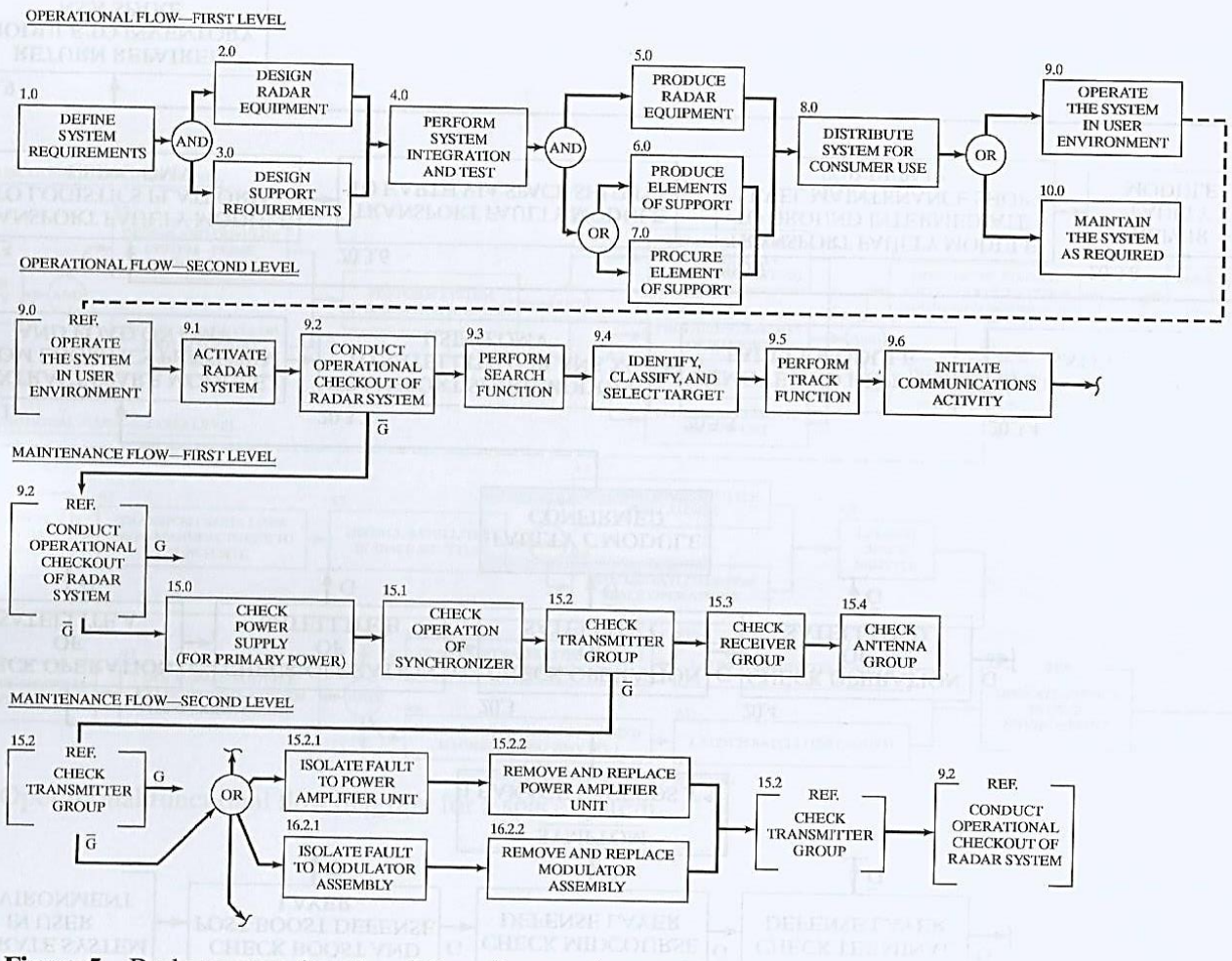

Figure 5 Radar system functional flow diagram (example).

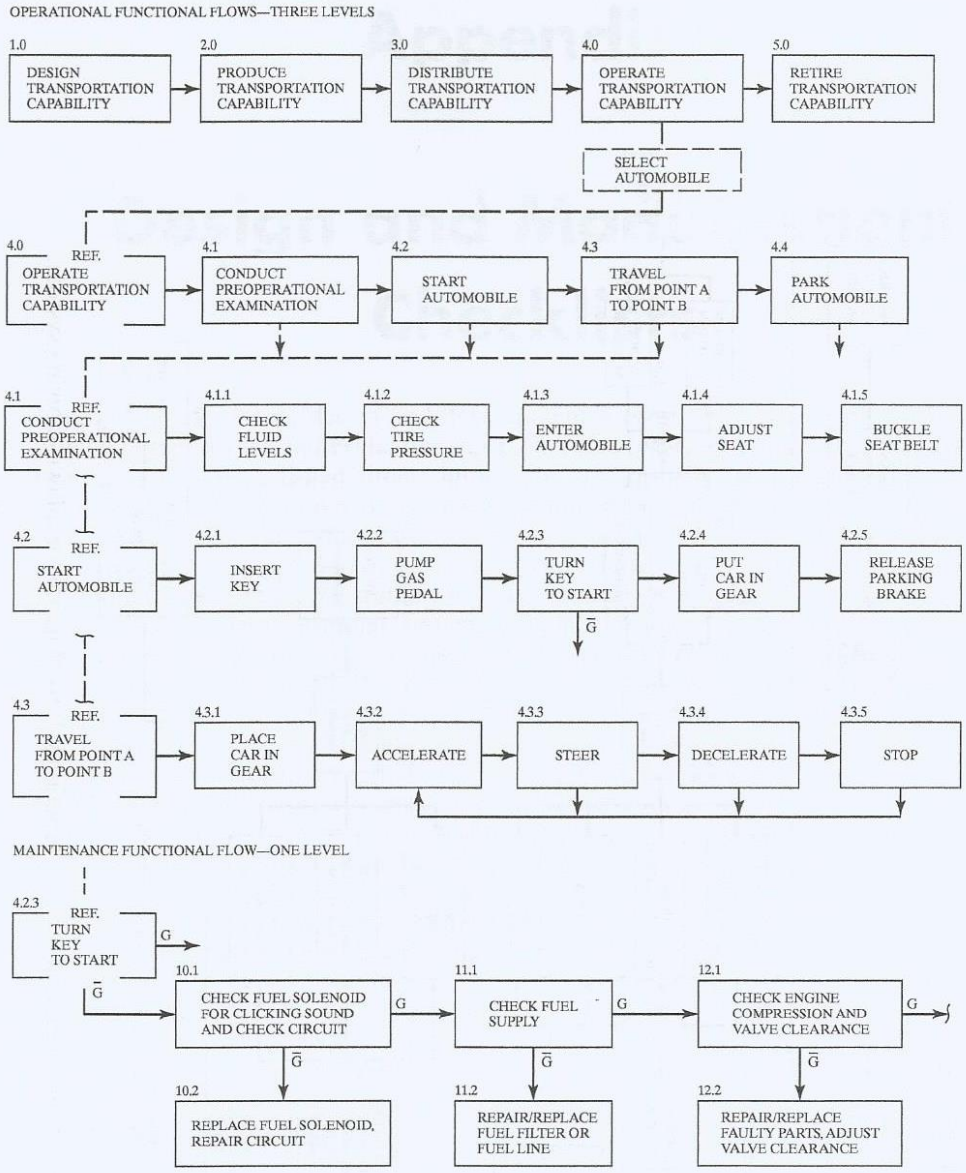

Figure 6 Operational and maintenance functional flow diagram for an automobile.

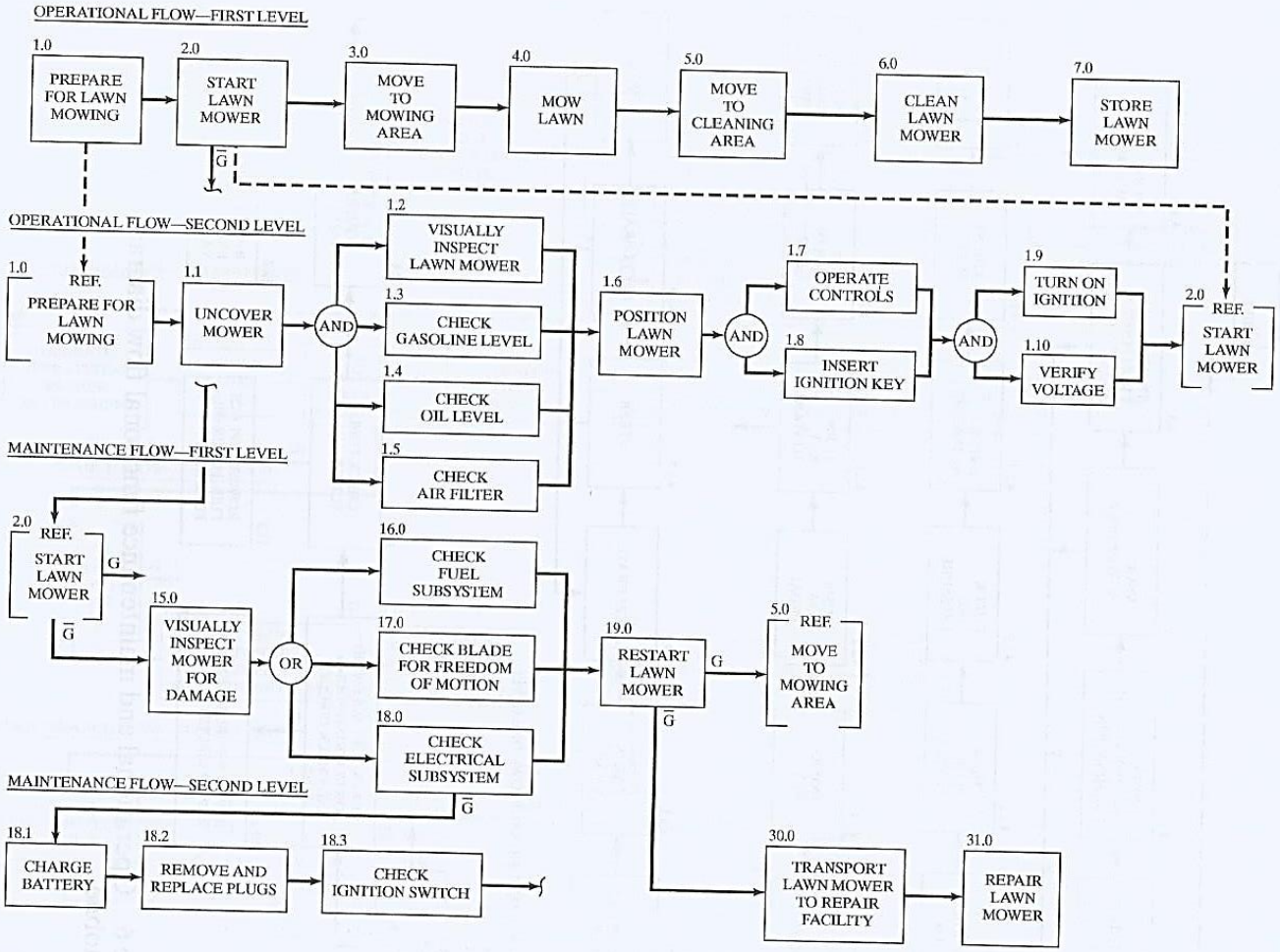

Figure 7 Operational and maintenance functional flow diagram for a lawn-mowing system.