Systems Engineering

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Class 3: Getting Started with SysML

Getting Started with SysML

- OMG SysML specification was adopted in 2006 by the Object Management Group (OMG) as a general-purpose graphical systems modelling language that extends the UML
- SysML is a general-purpose graphical modelling language that supports the analysis, specification, design, verification and validation of complex systems (Friedenthal et al., 2015)

  - These systems may include hardware and equipment, software, data, personnel, procedures, facilities, and other elements of human-made and natural systems
  - The language is intended to help specify and architect systems and to specify components that can then be designed using other domain-specific languages, such as UML for software design and VHDL for electrical design

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- SysML is intended to facilitate the application of an MBSE approach to create a cohesive and consistent model of the system
- SysML can represent the following aspects of the systems, components, and other entities:

  - Structural composition, interconnection, and classification
  - Flow-based, message-based, and state-based behaviour
  - Constraints on the physical and performance properties
  - Allocations between behaviour, structure, and constraints
  - Requirements and their relationships to other requirements, design elements, and test cases

Getting Started with SysML

- SysML diagram overview (version 1.7)

  - Package diagram (same as UML)
  - Requirements diagram (not in UML)
  - Activity diagram (modification of UML)
  - Sequence diagram (same as UML)
  - State machine diagram (same as UML)
  - Use case diagram (same as UML)
  - Block definition diagram (modification of UML class diagram)
  - Internal block diagram (modification of UML)
  - Parametric diagram (not in UML)

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- SysML diagram overview (version 1.7)

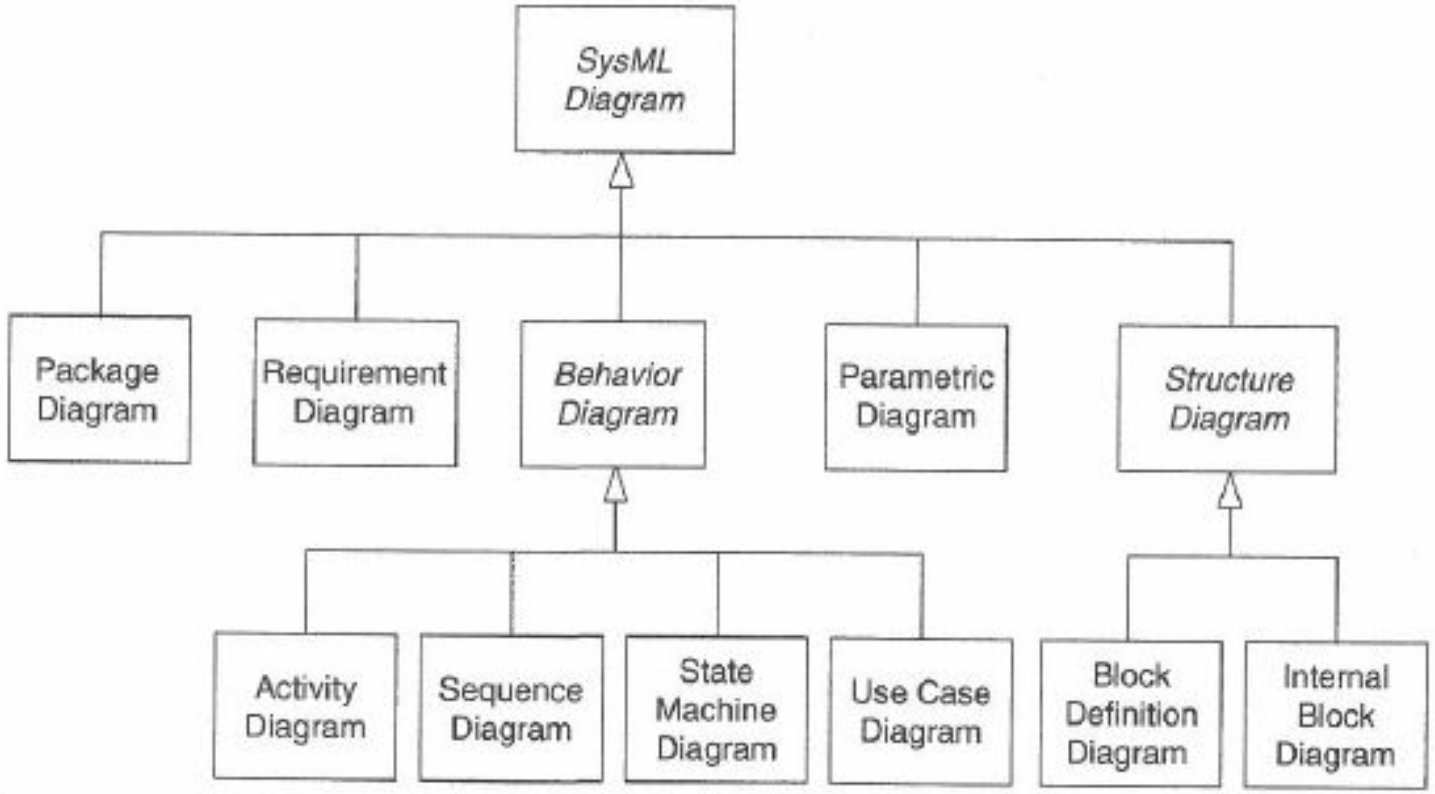

FIGURE 3.1

SysML diagram taxonomy.

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- SysML-Lite Diagrams

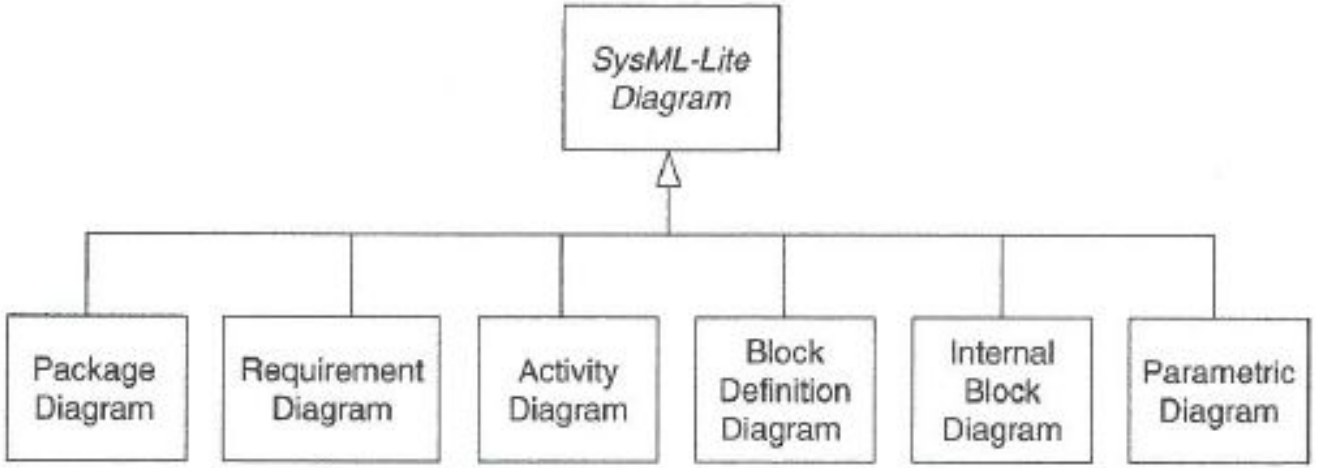

FIGURE 3.2

SysML-Lite includes six of the nine SysML diagrams and a subset of the language features. It is intended to introduce new modelers to SysML while providing substantial modeling capabilities.

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- Relationship among the diagrams

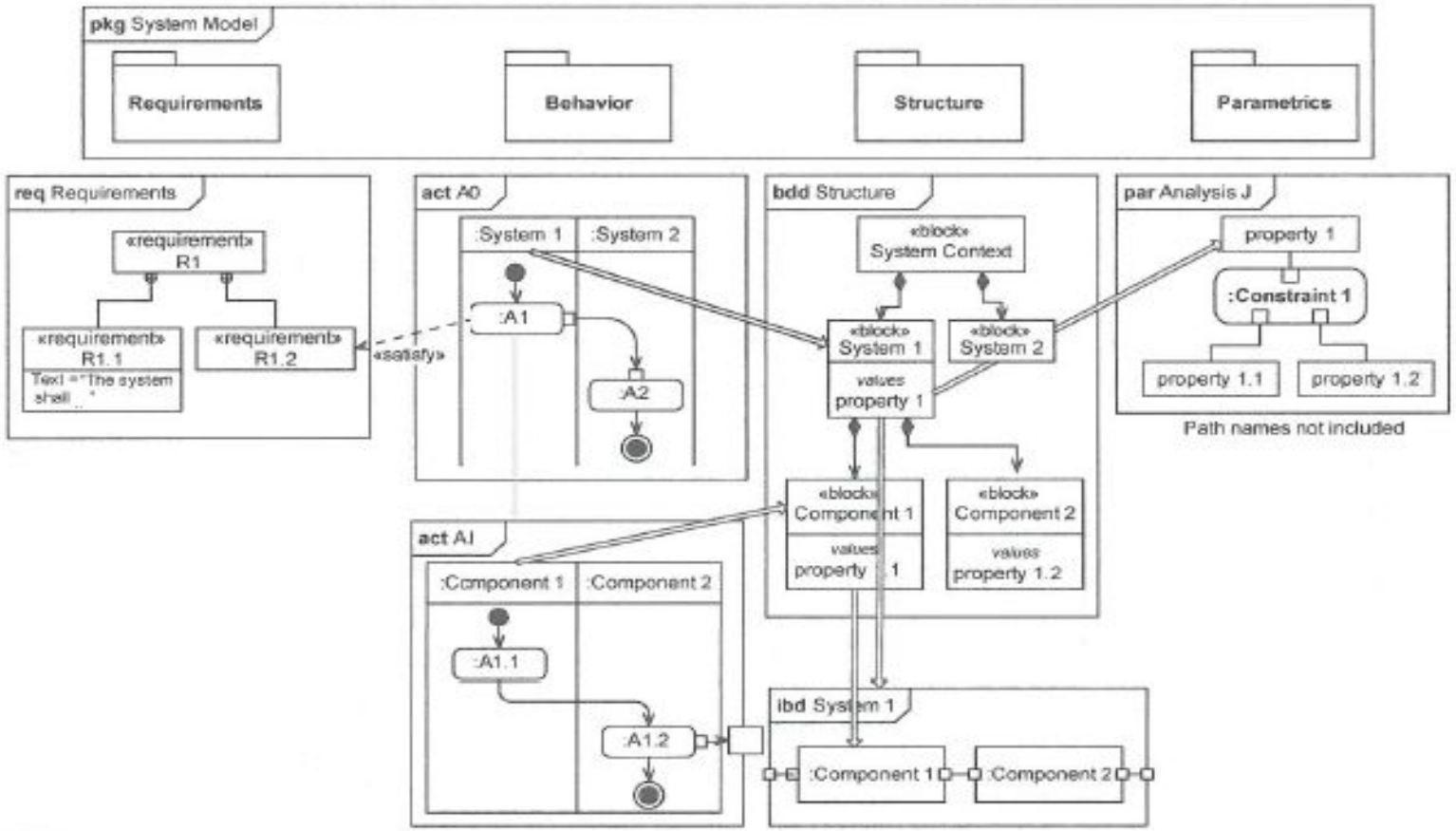

FIGURE 3.3

Simplified diagrams highlighting some of the language features for each kind of diagram in SysML-Lite.

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- An Automobile Example Using the SysML Basic Feature Set

4.2.1 PROBLEM SUMMARY

This example describes the use of SysML to specify and design an automobile system. As mentioned earlier, the modeling artifacts included in this example are representative of the kinds of modeling artifacts that are generated from a typical MBSE method similar to the one described in Chapter 3, Section 3.4. Only a small subset of the system requirements and design are addressed in this example to highlight the use of the language. The diagrams used in this example are shown in Table 4.1.

A marketing analysis that was conducted indicated the need to increase the automobile's acceleration and fuel efficiency from its current capability. In this simplified example, selected aspects of the design are considered to support an initial trade-off analysis. The trade-off analysis includes an evaluation of alternative vehicle configurations that included a 4-cylinder engine and a 6-cylinder engine to determine if they can satisfy the acceleration and fuel efficiency requirement.

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- An Automobile Example Using the SysML Basic Feature Set

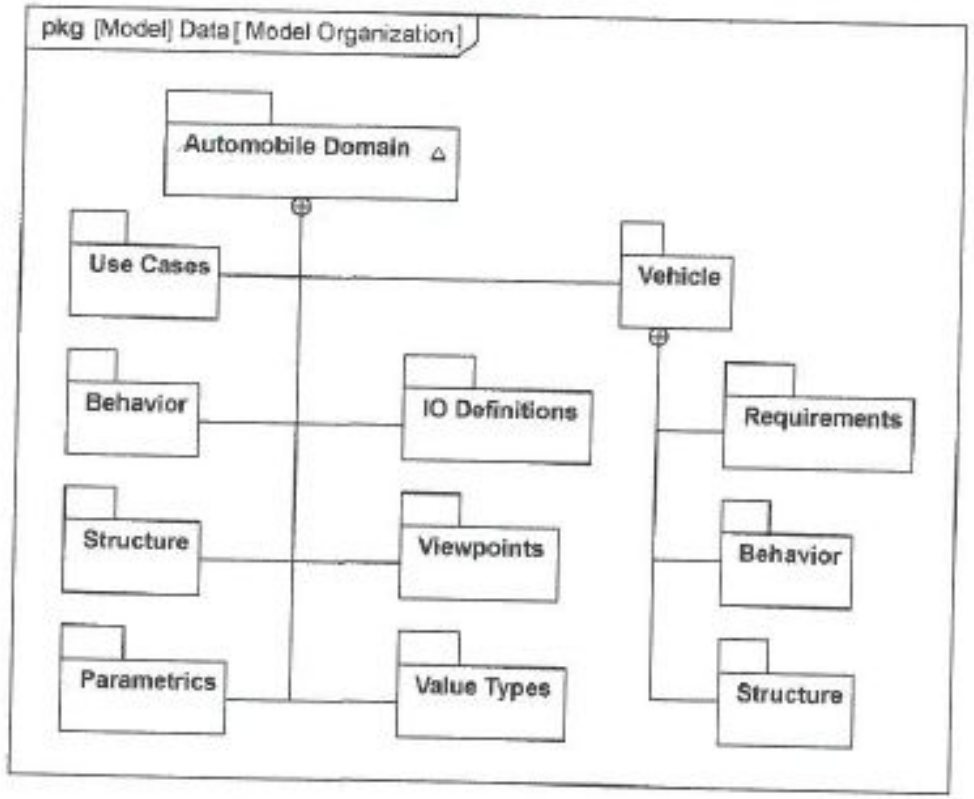

FIGURE 4.1

Package diagram showing how the model is organized into packages that contain the model elements that comprise the *Automobile Domain*.

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- An Automobile Example Using the SysML Basic Feature Set

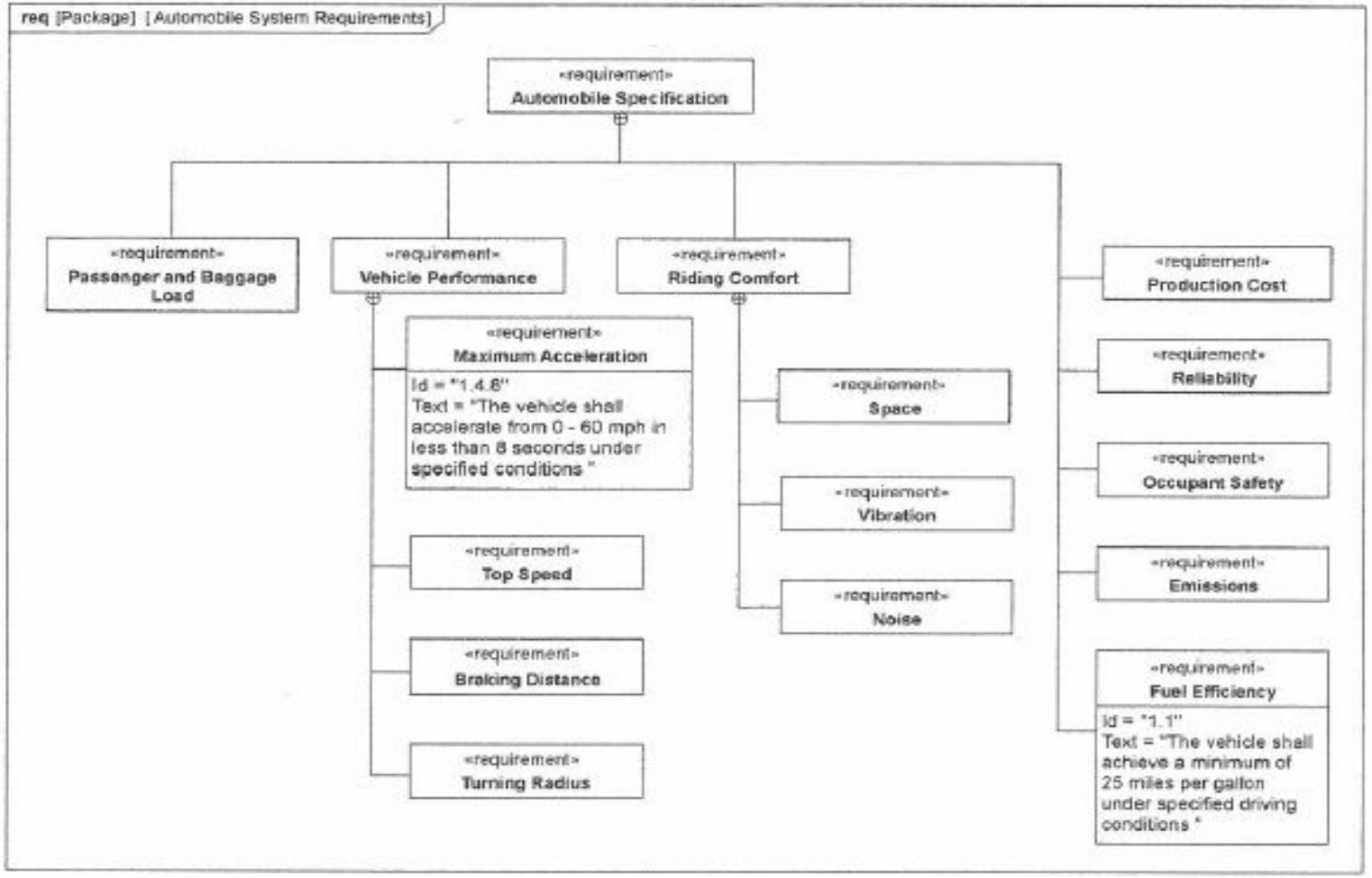

FIGURE 4.2

Requirement diagram showing the system requirements contained in the *Automobile Specification*.

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- An Automobile Example Using the SysML Basic Feature Set

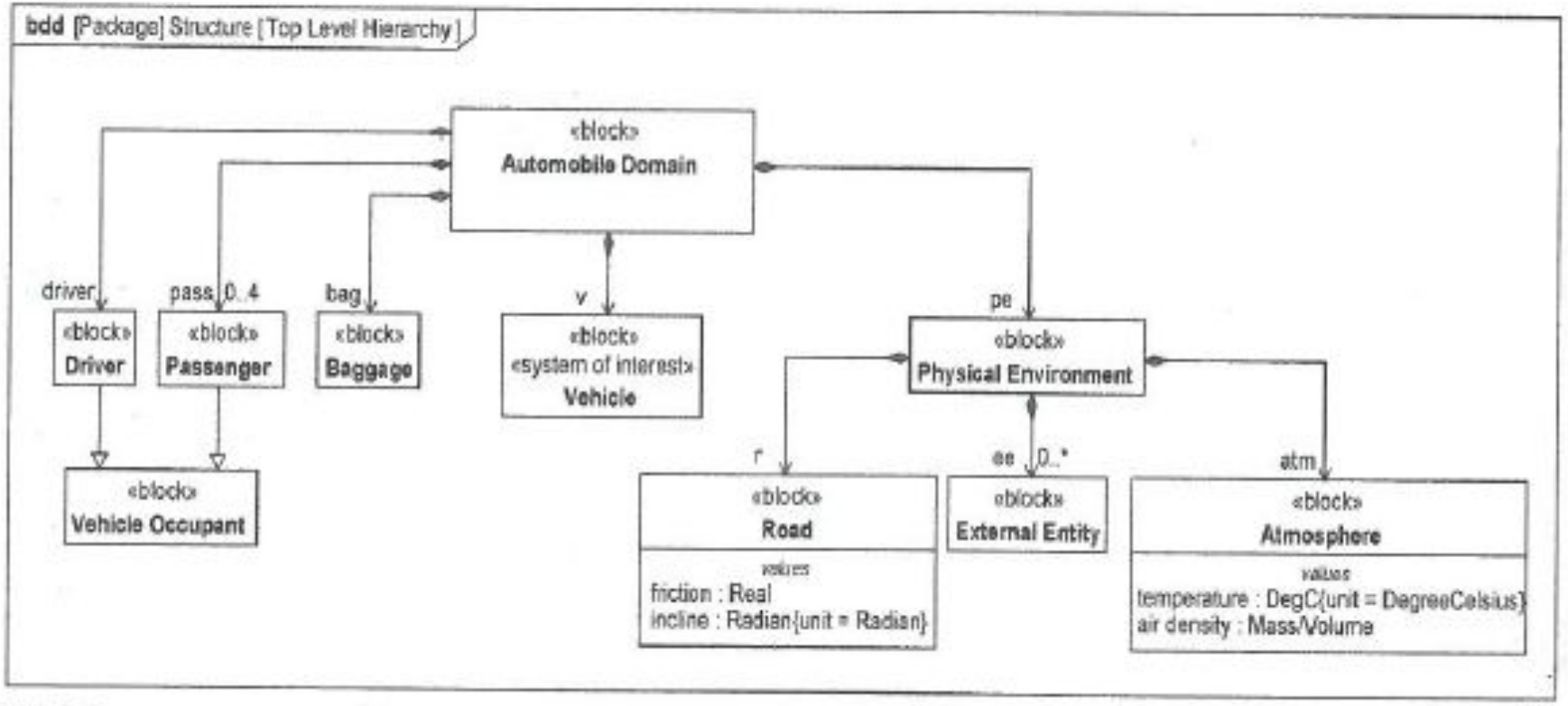

FIGURE 4.3

Block definition diagram of the *Automobile Domain* showing the *Vehicle* as the *system of interest*, along with the *Vehicle Occupants* and the Environment. Selected value properties for the *Road* and *Atmosphere* are also shown.

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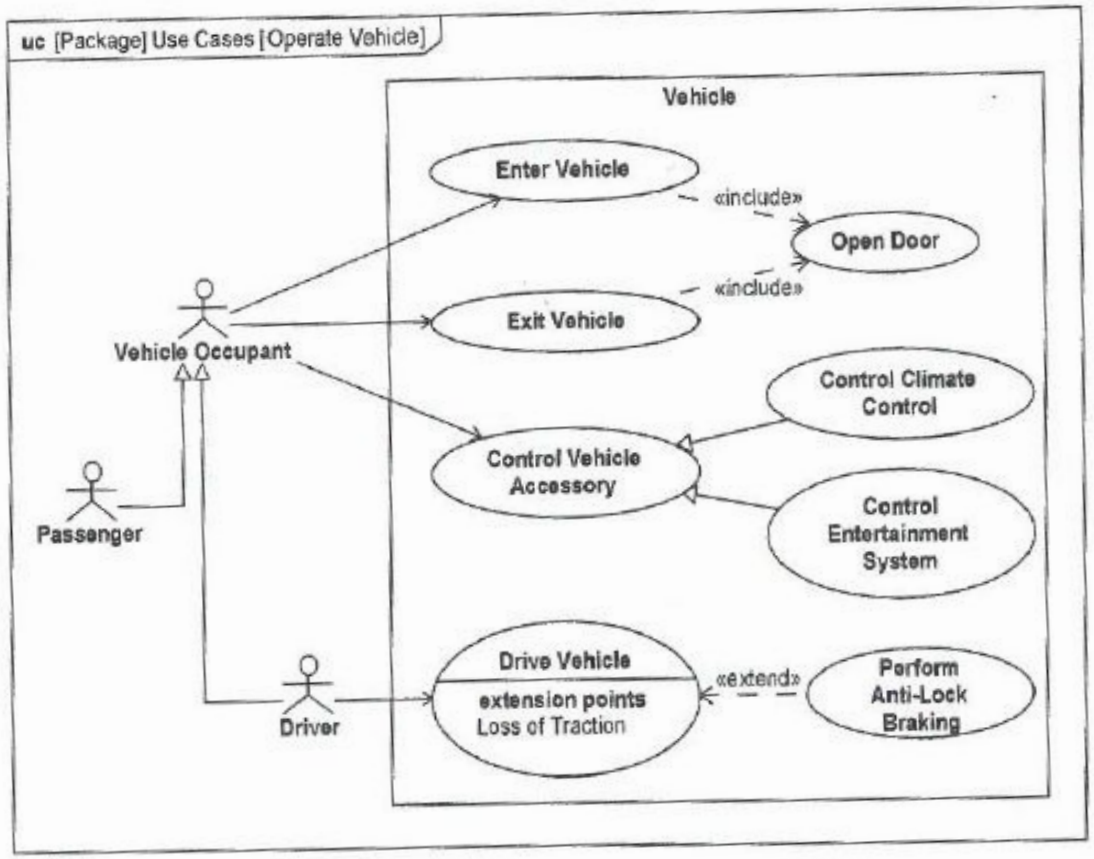

FIGURE 4.4

The use case diagram describes the major functionality in terms of how the *Vehicle* is used by the *Vehicle Occupants* to *Operate Vehicle*. The *Vehicle* and *Vehicle Occupants* are defined on the block definition diagram in Figure 4.3.

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- An Automobile Example Using the SysML Basic Feature Set

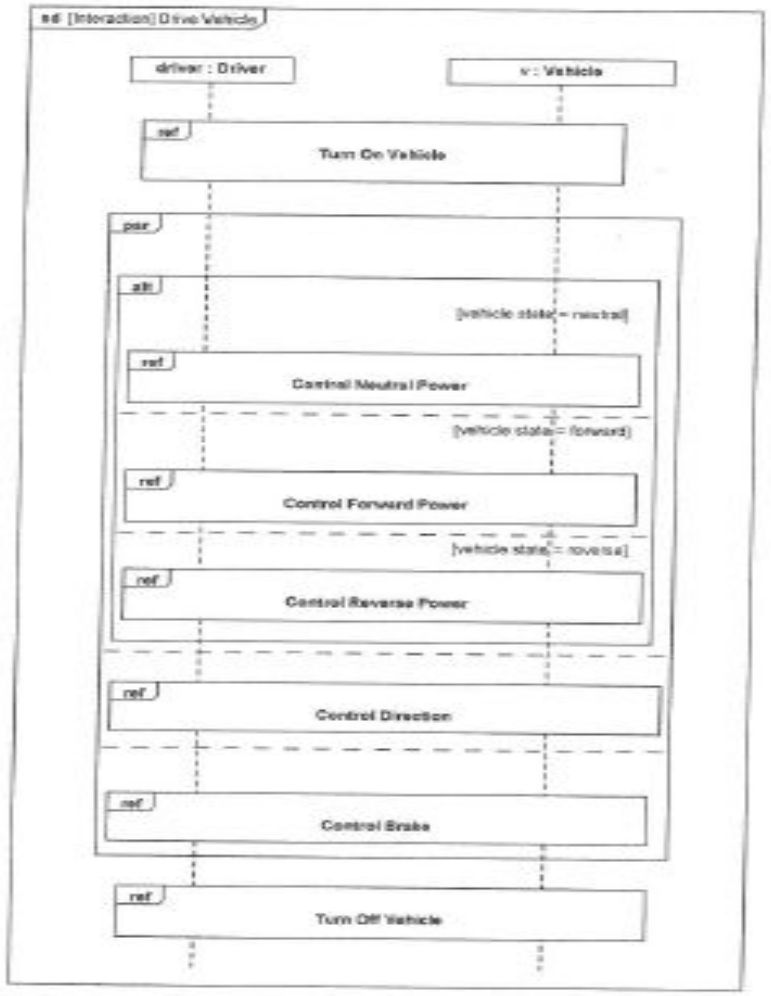

FIGURE 4.5

The *Drive Vehicle* sequence diagram describes the interaction between the *Driver* and the *Vehicle* to realize the *Drive Vehicle* use case in Figure 4.4.

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- An Automobile Example Using the SysML Basic Feature Set

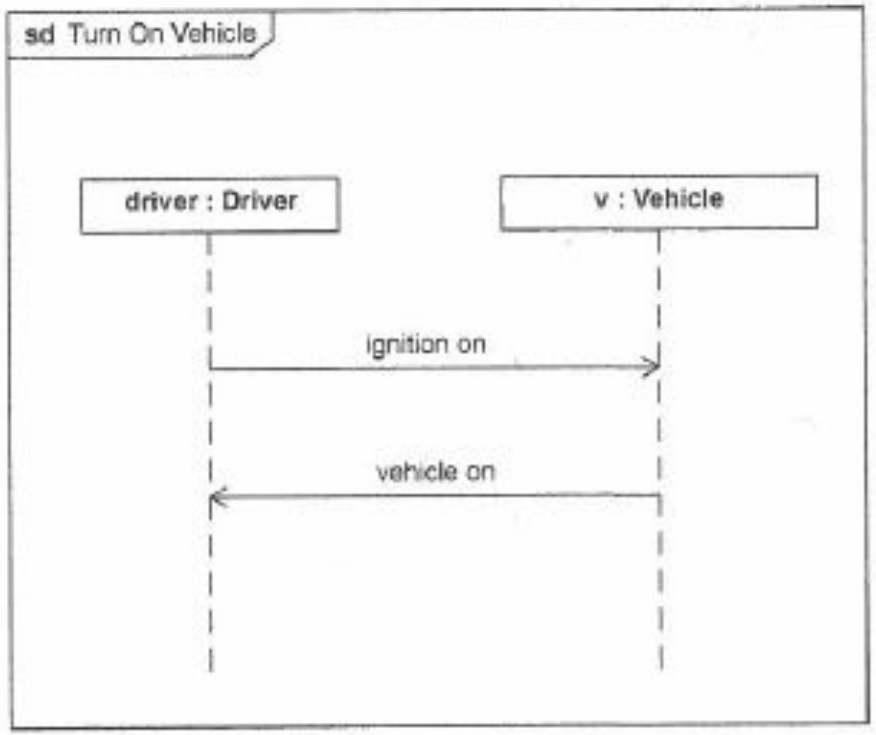

FIGURE 4.6

Sequence diagram for the *Turn On Vehicle* interaction that was referenced in the *Drive Vehicle* sequence diagram in Figure 4.5, showing the message from the *Driver* requesting *Vehicle* to start, and the *Vehicle* responding with the *vehicle on* reply.

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- An Automobile Example Using the SysML Basic Feature Set

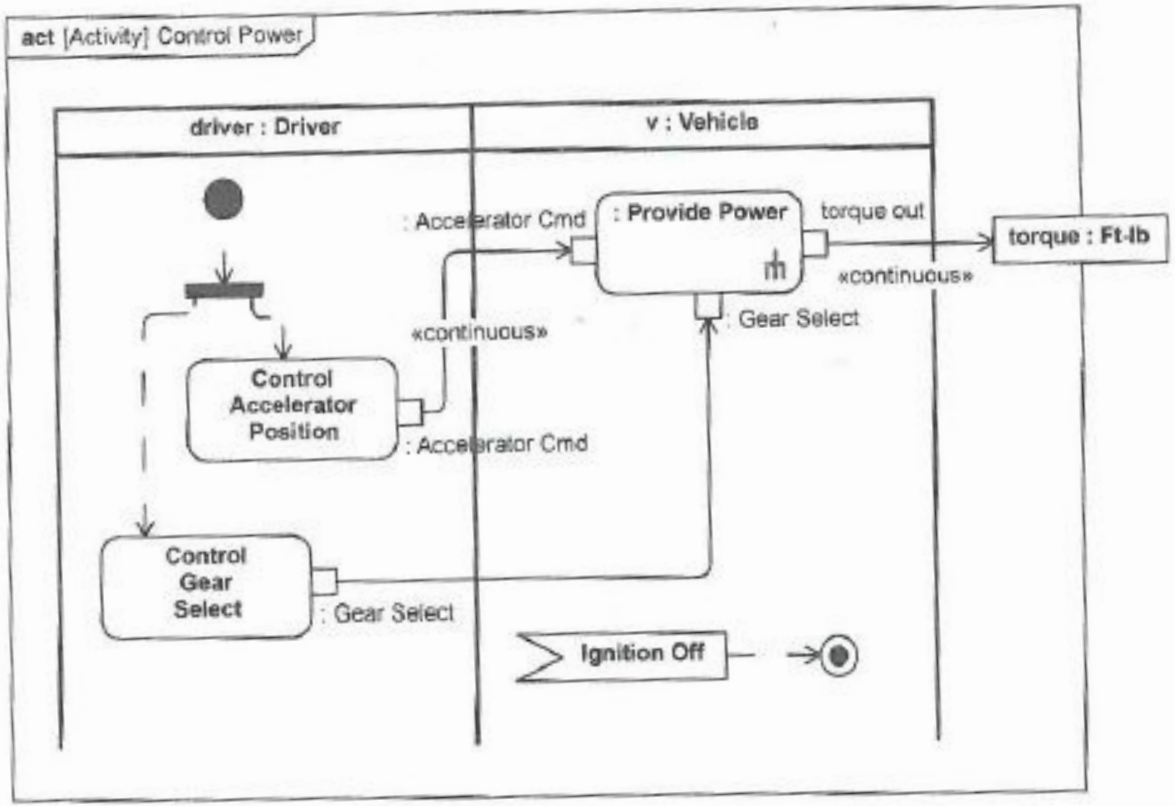

FIGURE 4.7

Activity diagram allocated from the *Control Neutral, Forward,* and *Reverse Power* interaction uses that are referenced in the *Drive Vehicle* sequence diagram in Figure 4.5. It shows the continuous *Accelerator Cmd* input and the *Gear Select* input from the *Driver* to the *Provide Power* action that the *Vehicle* must perform.

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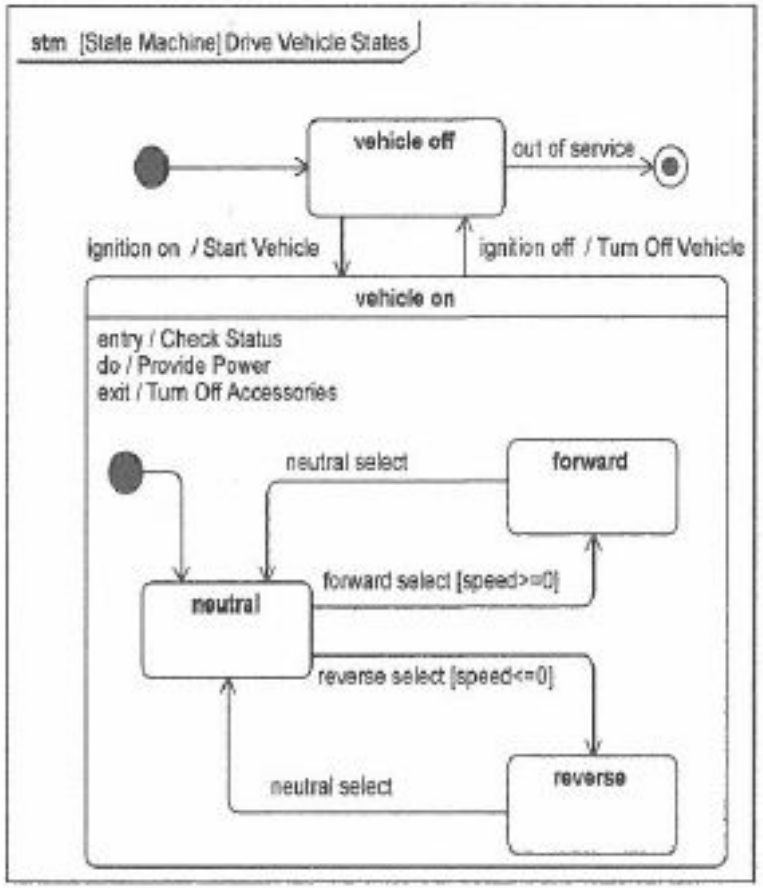

FIGURE 4.8

A state machine diagram that shows the *Drive Vehicle States* and the transitions between them.

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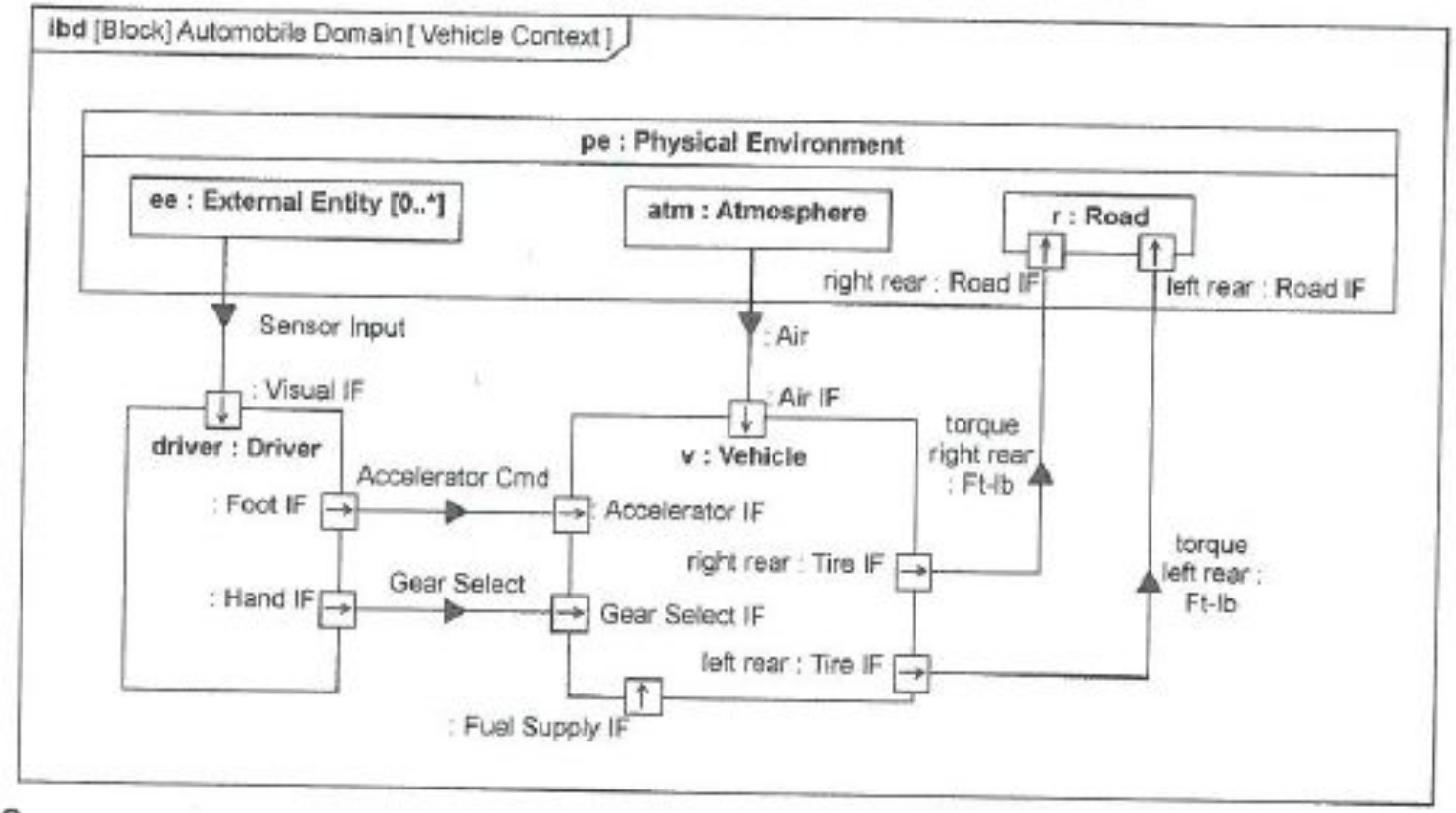

FIGURE 4.9

The internal block diagram for the *Automobile Domain* describes the *Vehicle Context*, which shows the *Vehicle* and its external interfaces with the *Driver* and the *Physical Environment* that were defined in Figure 4.3.

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- An Automobile Example Using the SysML Basic Feature Set

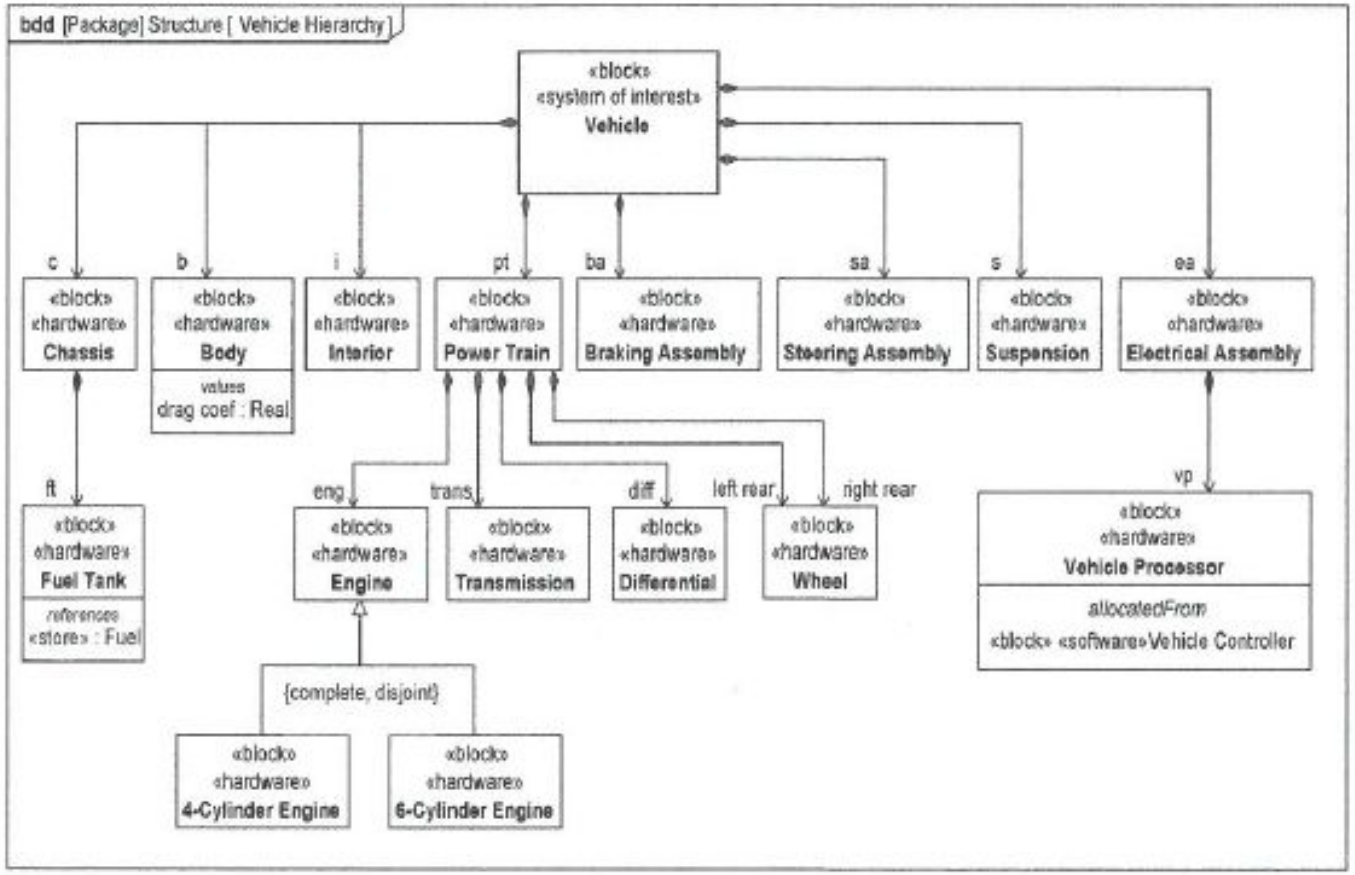

FIGURE 4.10

A block definition diagram of the *Vehicle Hierarchy* that shows the *Vehicle* and its components. The *Power Train* is further decomposed into its components, and the *Vehicle Processor* includes the *Vehicle Controller* software.

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- An Automobile Example Using the SysML Basic Feature Set

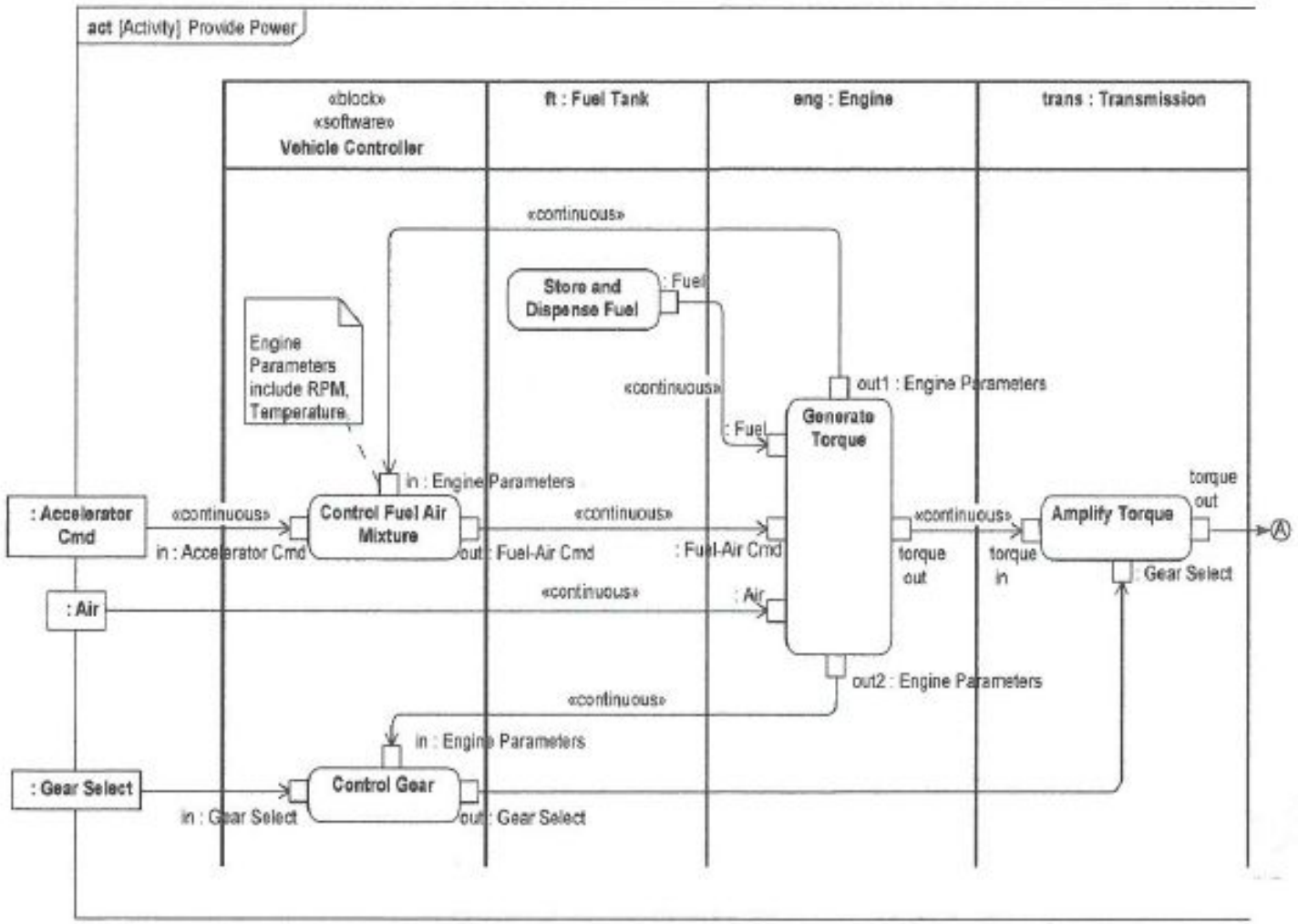

FIGURE 4.11 Cont'd

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- An Automobile Example Using the SysML Basic Feature Set

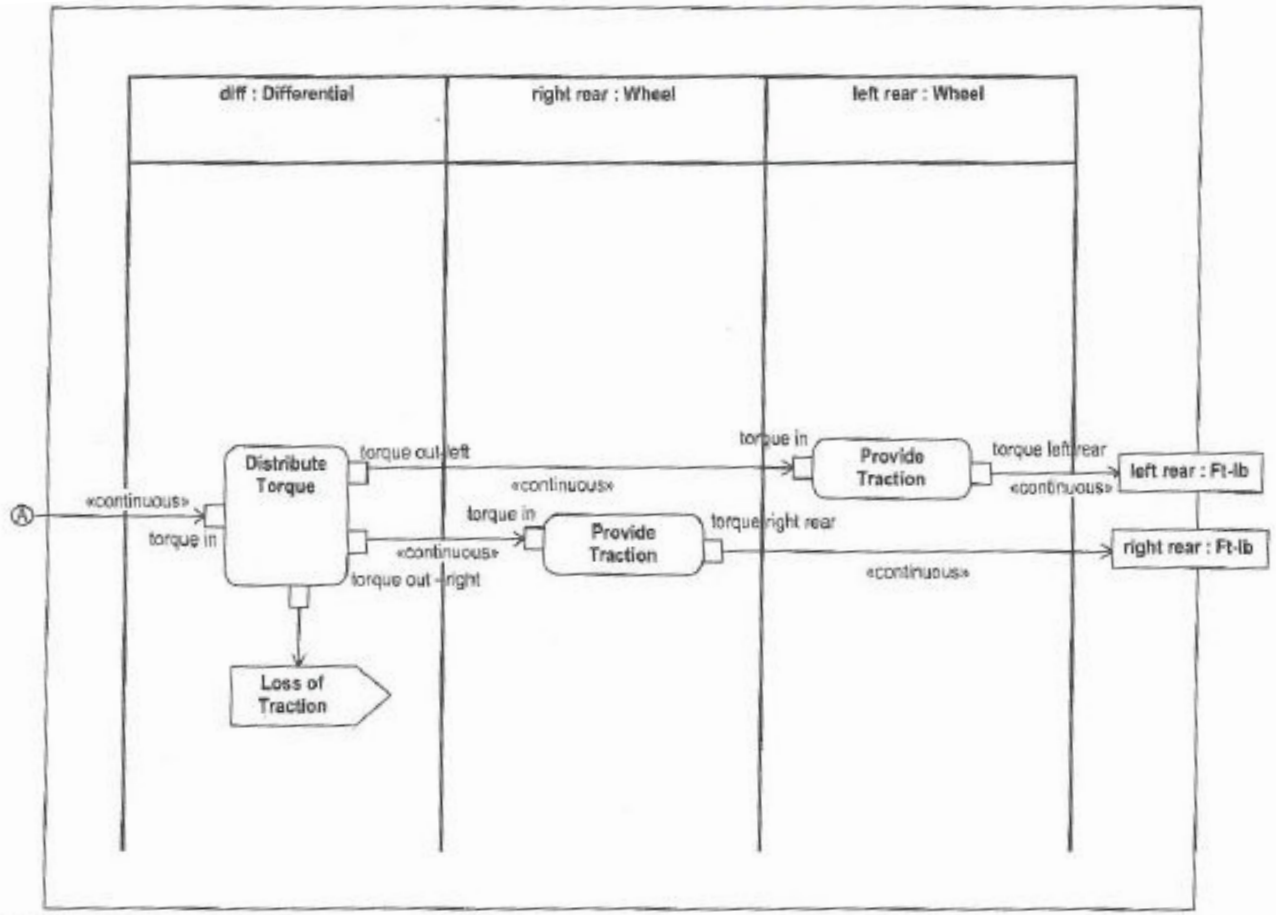

FIGURE 4.11

The activity diagram for *Provide Power* shows how the *Vehicle* components generate the torque to move the vehicle. This activity diagram realizes the *Provide Power* action in Figure 4.7 with activity partitions that correspond to the components in Figure 4.10.

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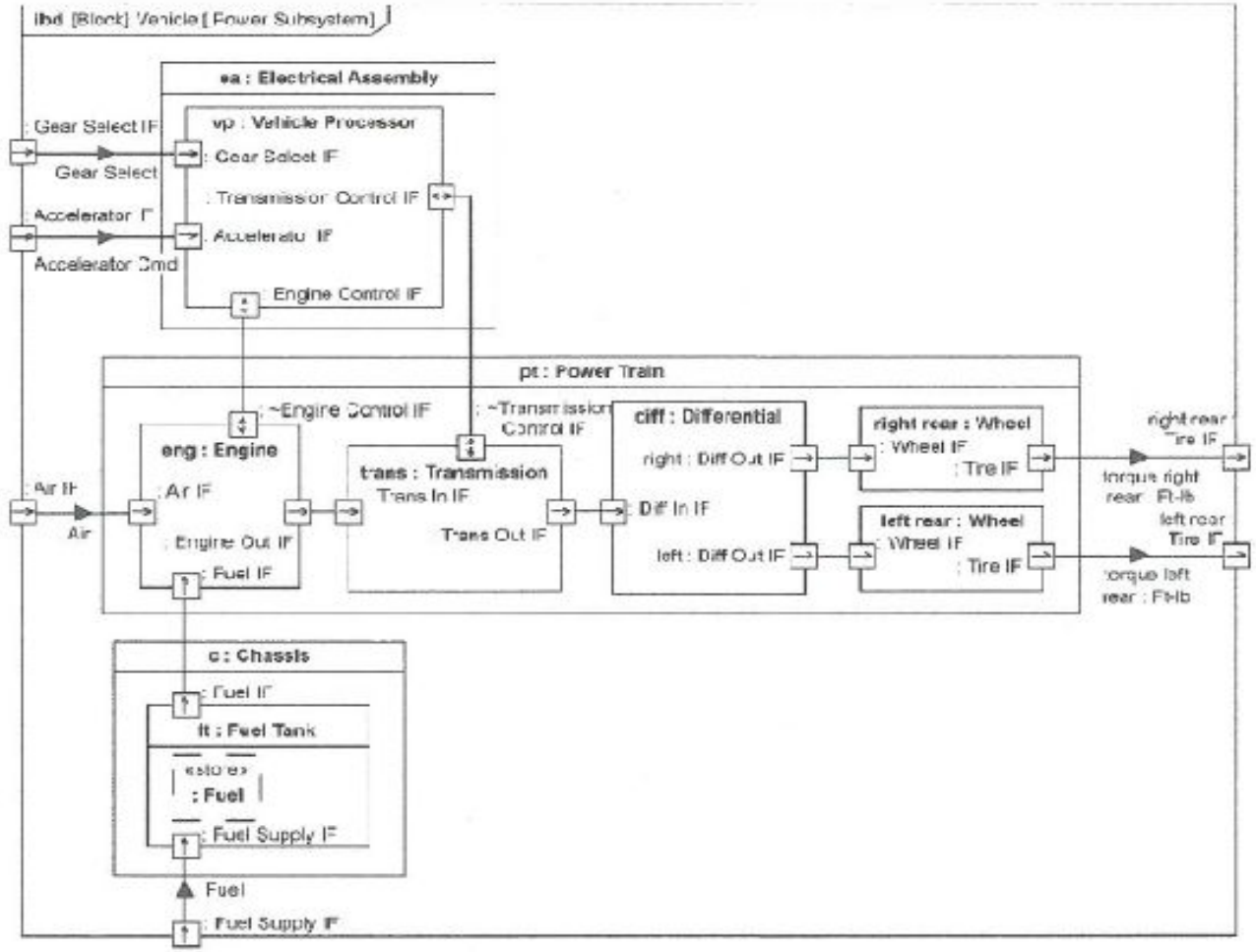

FIGURE 4.12

The internal block diagram for the *Power Subsystem* shows how the parts of the *Vehicle* that *Provide Power* are interconnected. The parts interact as specified by the activity diagram in Figure 4.11.

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- An Automobile Example Using the SysML Basic Feature Set

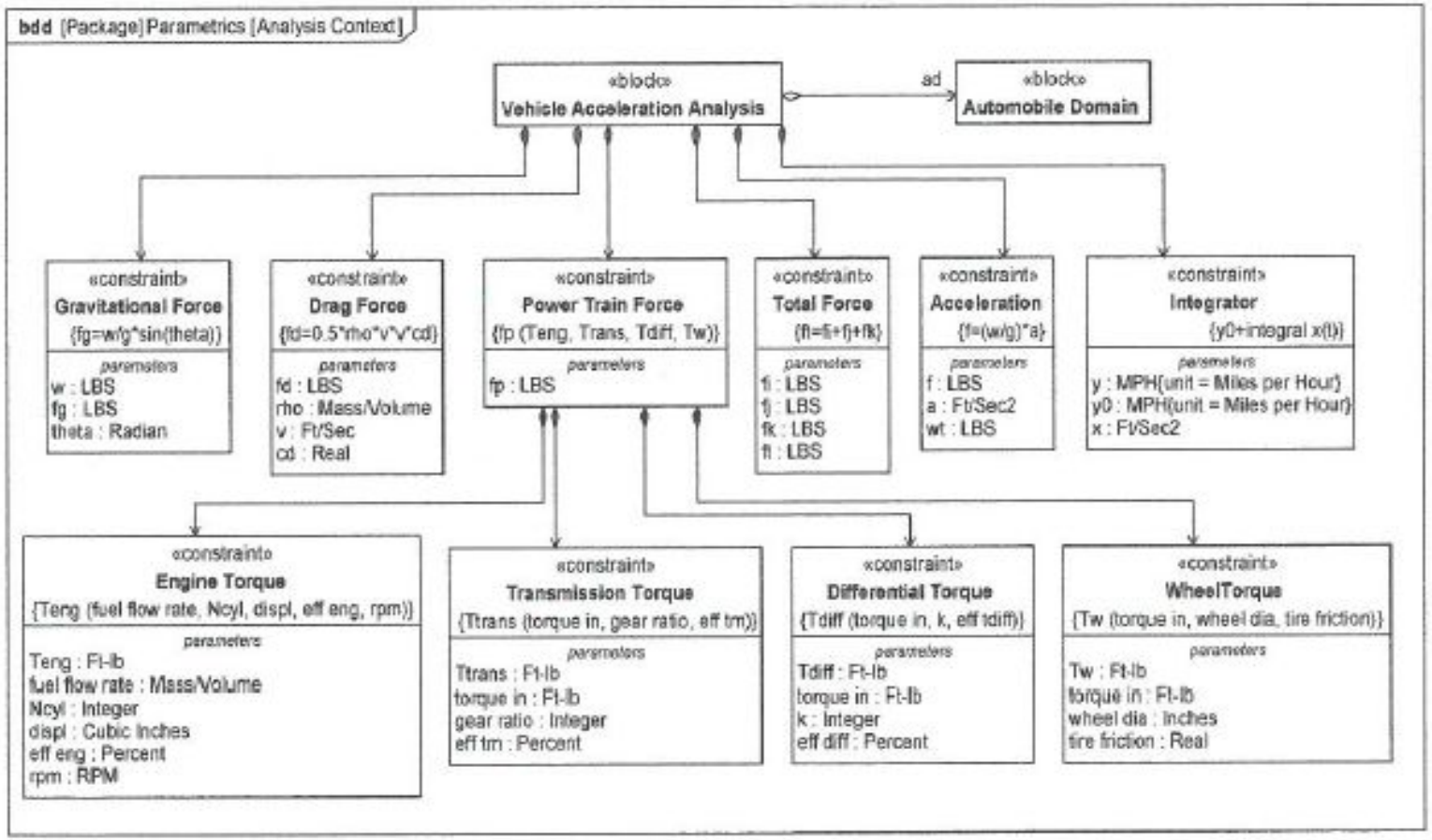

FIGURE 4.13

The block definition diagram for the *Analysis Context* that defines the equations for analyzing the vehicle acceleration requirement. The equations and their parameters are specified using constraint blocks. The *Automobile Domain* block from Figure 4.3 is referenced since it is the subject of the analysis.

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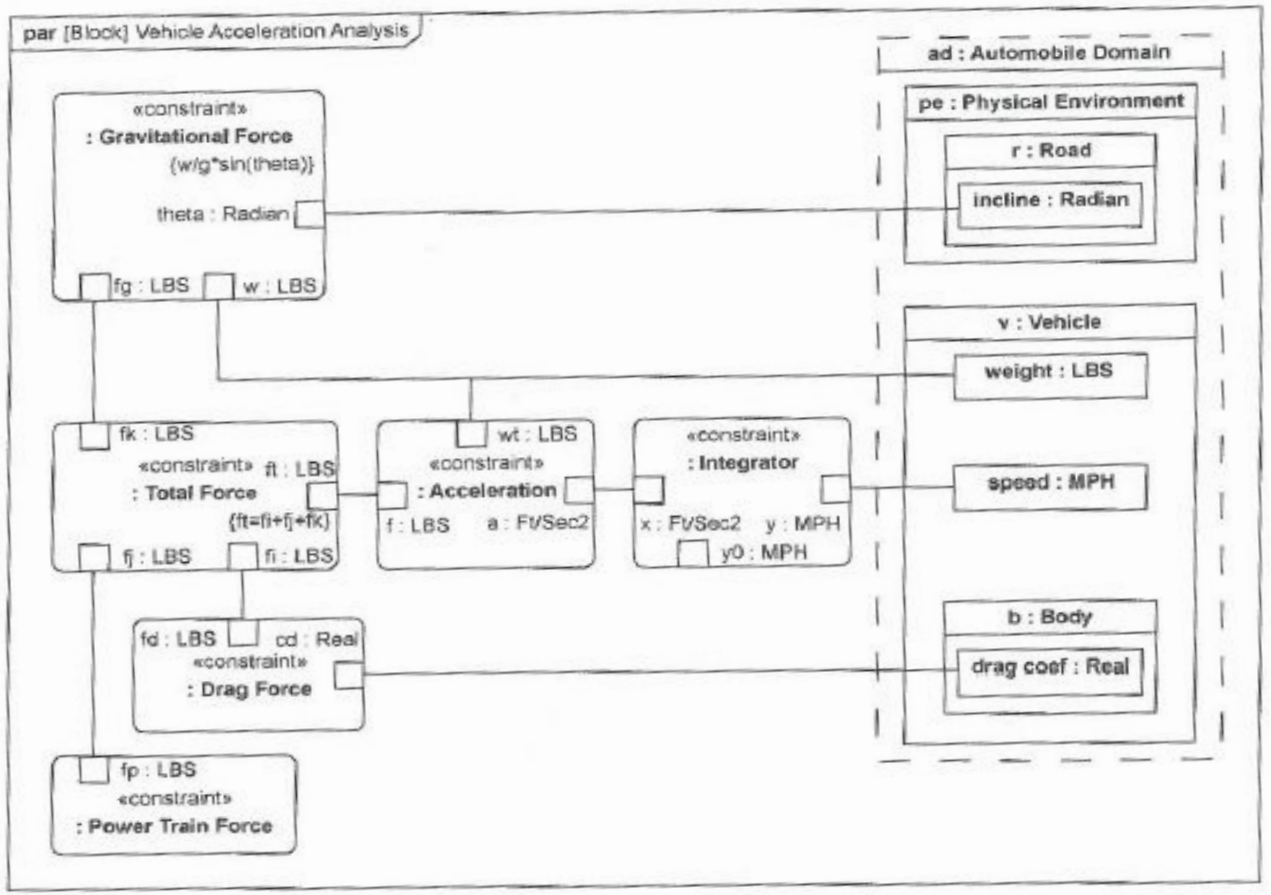

FIGURE 4.14

The parametric diagram that uses the equations defined in Figure 4.13 to analyze vehicle acceleration. The parameters of the equations are bound to other parameters and to value properties of the *Vehicle* and its *Physical Environment*, some of which were defined in Figure 4.3.

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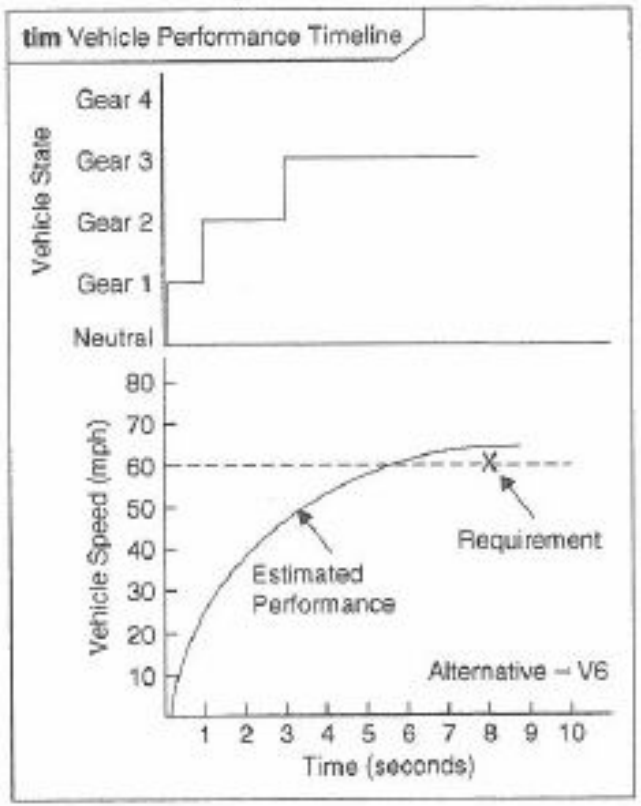

FIGURE 4.15

Analysis results from executing the constraints in the parametric diagram in Figure 4.14, showing the *Vehicle Speed* and *Vehicle State* as a function of time. This is captured in a UML timing diagram.

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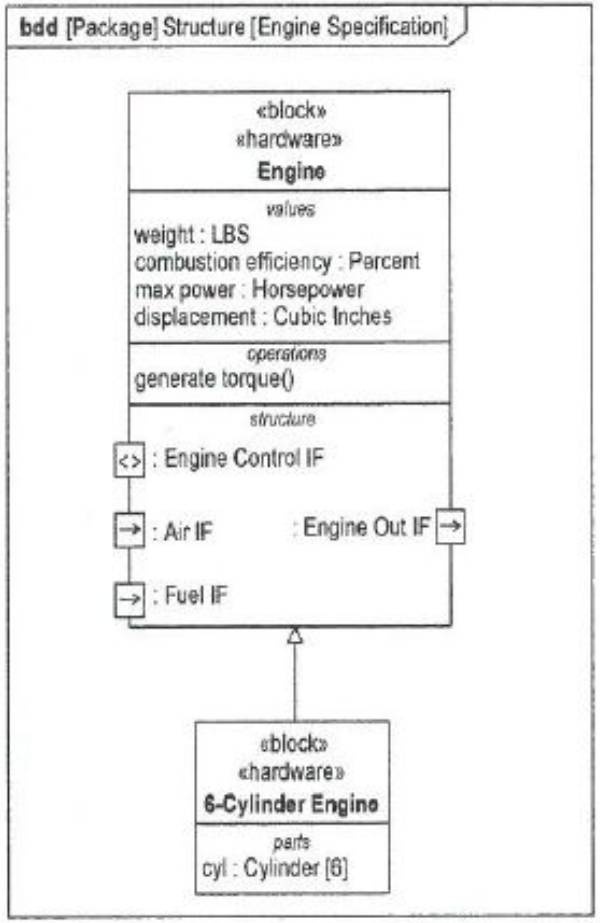

FIGURE 4.16

A block definition diagram that shows the *Engine* block and the features used to specify the block. This block was previously shown in the *Vehicle Hierarchy* block definition diagram in Figure 4.10.

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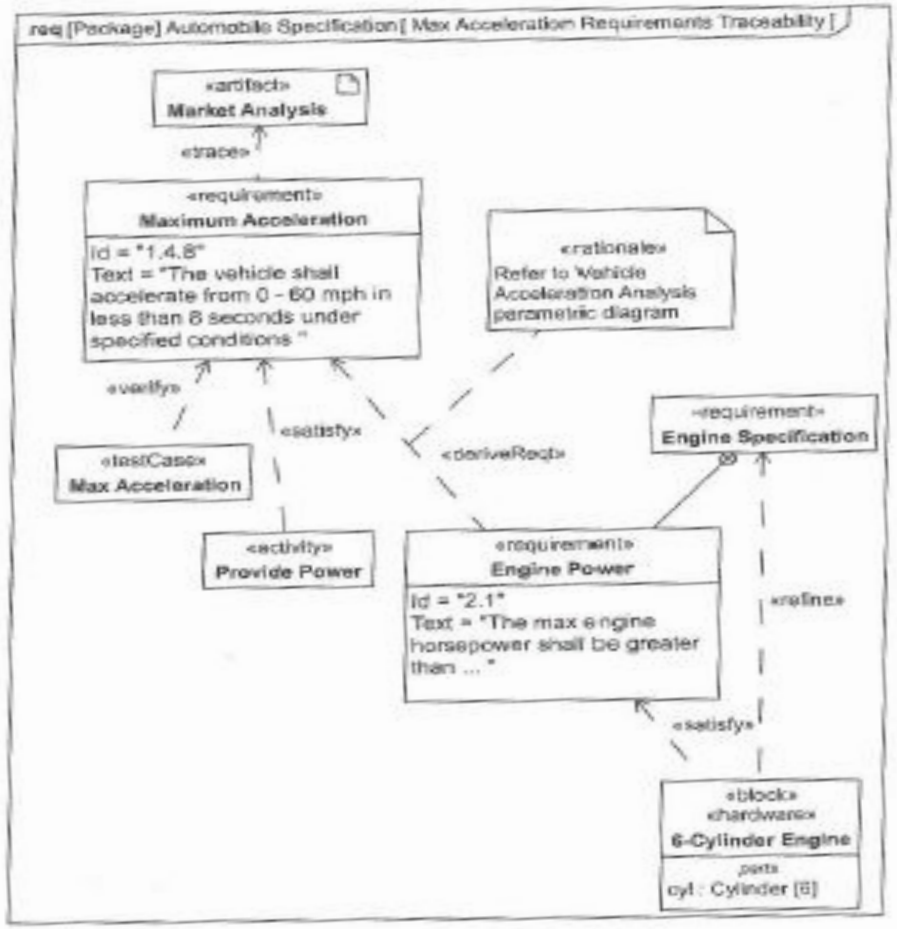

FIGURE 4.17

The requirement diagram showing the traceability of the *Maximum Acceleration* requirement that was displayed in the *Automobile Specification* in Figure 4.2. The traceability to a text-based requirement includes the design elements to satisfy it, other requirements derived from it, and a test case to verify it. Rationale for the deriveReqt relationship based on parametric analysis is also shown.

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- An Automobile Example Using the SysML Basic Feature Set

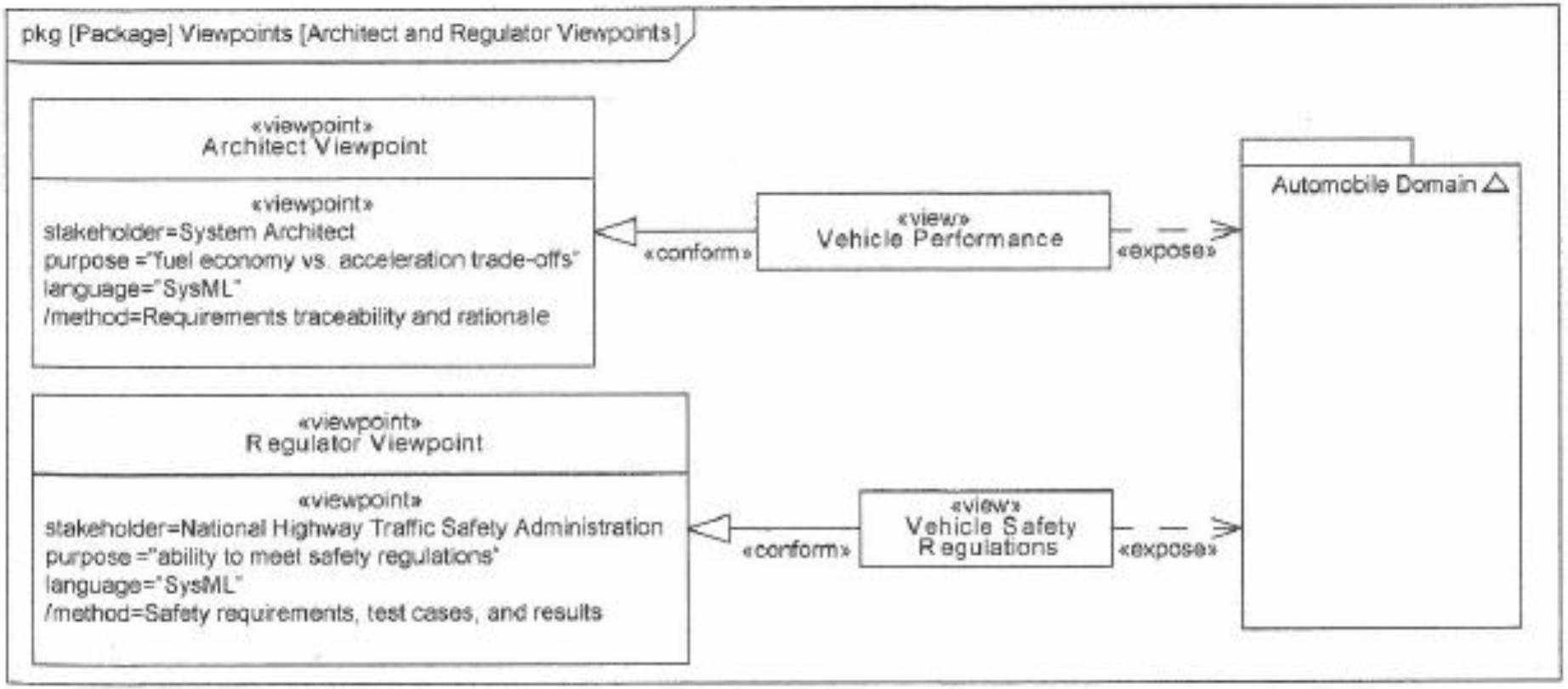

FIGURE 4.18

The package diagram showing the *Architect* viewpoint to address concerns related to fuel economy versus acceleration trade-offs, and a *Regulator* viewpoint to address concerns related to meeting safety requirements.

References

- Friedenthal, S. et al. “A Practical Guide to SysML: The Systems Modeling Language”. Elsevier, 3rd Edition, 2015.