Cruise Control

EMGT 587 Systems Engineering

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Introduction

The report explains the systems approach taken to analyze the structure and function of a modern-cruise control system used in automobiles.

The cruise control system interacts with the driver, the speed control device (throttle) and the external environment despite various interfaces in order to keep the speed of the car as desired by the driver. These interactions may be one way or both ways. Different kinds of signals may be needed to build this system. The user requests activation of the cruise control. The cruise control system accepts inputs from the sensor and gives a signal to the throttle mechanism for adjustment in the desired position. After the throttle is set, the cruise control system gives the user a feedback that it is now active and set.

Various commonly occurring operating scenarios are described in words first, and then translated into an external systems diagram after identifying the main functional blocks. The external systems diagram fulfills all interactions between the functional blocks as stated in the scenarios. Based on the external systems diagram, written requirements, including those for cost and performance trade-offs are generated for the understanding of all stakeholders involved. Then, the first level functional level decomposition is used to analyze the functioning of the main functional block – 'Provide Cruise Control Services'. Then, the physical architecture is explained in its general and instantiated form and interactions are shown using interfaces. Finally, there is a risk analysis done along with an integration and qualification plan.

Operational Scenarios

1. User sets and cancels cruise control:

- User requests an activation of the cruise control.
- Cruise control provides visual feedback that it is ready for activation.
- User requests the cruise control be set to the current speed.
- Cruise control requests values from sensors.
- Sensors provide values for approval to set cruise control at current speed.
- Cruise control requests the throttle to be set at current position for desired speed.
- Throttle is set at current position.
- Cruise control provides visual feedback to the user that the cruise control is set and working.
- Sensors provide the changing environmental information to the cruise control unit.
- Cruise control unit detects the changes from the sensors and adjusts the throttle accordingly.
- Throttle position is continuously set to new values to ensure that the speed remains constant.
- Throttle position is continuously reported to cruise control unit.
- User requests that the cruise control be deactivated.
- Cruise control requests the throttle be unset.
- Throttle unsets from the cruise control unit.
- Cruise control provides feedback to user that the unit is now deactivated.

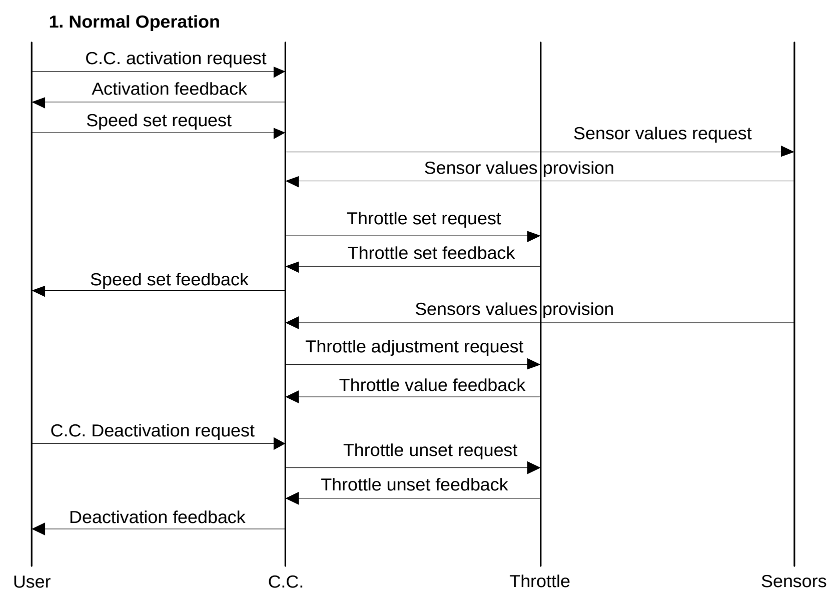

Figure 1: Visio diagram of operational scenario 1

2. User cancels cruise control via brake and then turns it back on:

- User requests an activation of the cruise control.
- Cruise control provides visual feedback that it is ready for activation.
- User requests the cruise control be set to the current speed.
- Cruise control requests values from sensors.
- Sensors provide values for approval to set cruise control at current speed.
- Cruise control requests the throttle to be set at current position for desired speed.
- Throttle is set at current position.
- Cruise control provides visual feedback to the user that the cruise control is set and working.
- User applies the brake, which sends a signal to the sensors.
- Sensors provide cruise control with a brake application signal.
- Cruise control requests the throttle be unset.
- Throttle unsets from the cruise control unit.
- Cruise control provides visual feedback to the user that the system is unset.
- User requests the cruise control be reset to the previous speed.
- Cruise control requests for approval from sensors.
- Sensors give approval to set cruise control at current speed.
- Cruise control requests the throttle to be set at current position for desired speed.
- Throttle is set at current position.
- Cruise control provides visual feedback to the user that the cruise control is set and working.

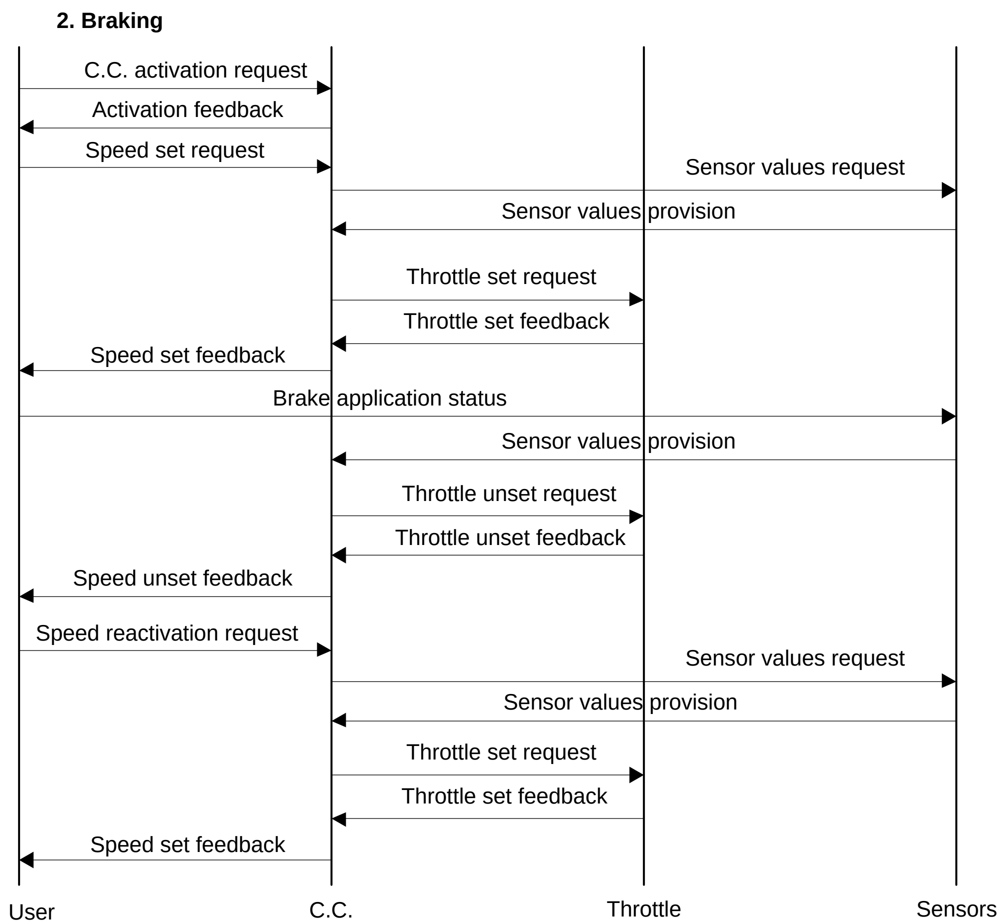

Figure 2: Visio diagram of operational scenario 2

3. Cruise control system changes due to an incline or decline in the road:

- User requests an activation of the cruise control.
- Cruise control provides visual feedback that it is ready for activation.
- User requests the cruise control be set to the current speed.
- Cruise control requests values from sensors.
- Sensors provide values for approval to set cruise control at current speed.
- Cruise control requests the throttle to be set at current position for desired speed.
- Throttle is set at current position.
- Cruise control provides visual feedback to the user that the cruise control is set and working.
- Sensors provide information to the cruise control that alerts of a change in actual speed.
- Throttle position is continuously set to new values to ensure that the speed remains constant.
- Throttle position is continuously reported to cruise control unit.

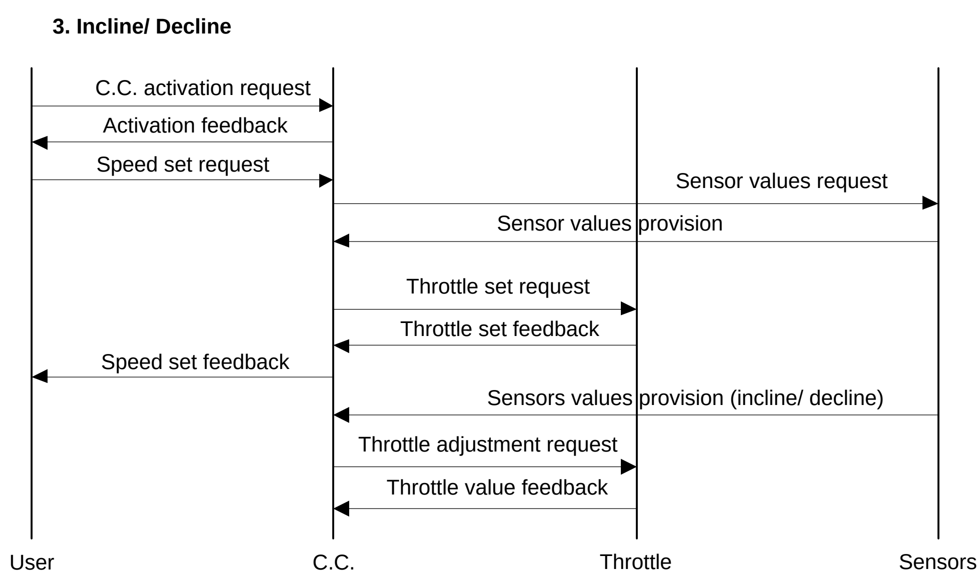

Figure 3: Visio diagram of operational scenario 3

4. Cruise control system cancels due to a flat tire:

- User requests an activation of the cruise control.
- Cruise control provides visual feedback that it is ready for activation.
- User requests the cruise control be set to the current speed.
- Cruise control requests values from sensors.
- Sensors provide values for approval to set cruise control at current speed.
- Cruise control requests the throttle to be set at current position for desired speed.
- Throttle is set at current position.
- Cruise control provides visual feedback to the user that the cruise control is set and working.
- Sensors provide information to the cruise control that alerts of a tire pressure change.
- Cruise control requests the throttle unset.
- Throttle is unset.
- Cruise control provides visual feedback to user that the unit is now deactivated.

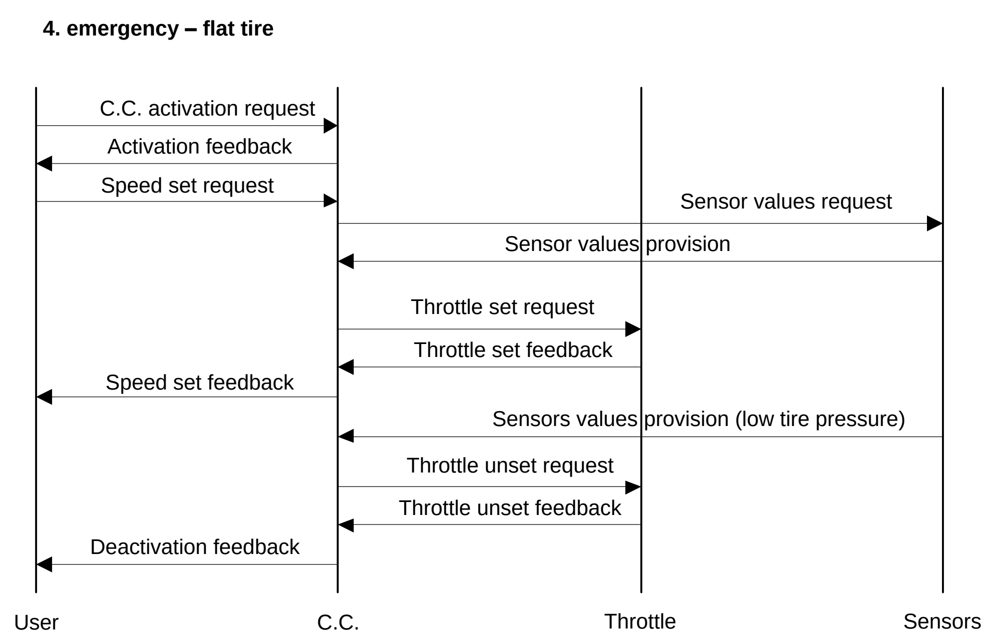

Figure 4: Visio diagram of operational scenario 4

External Systems Diagram

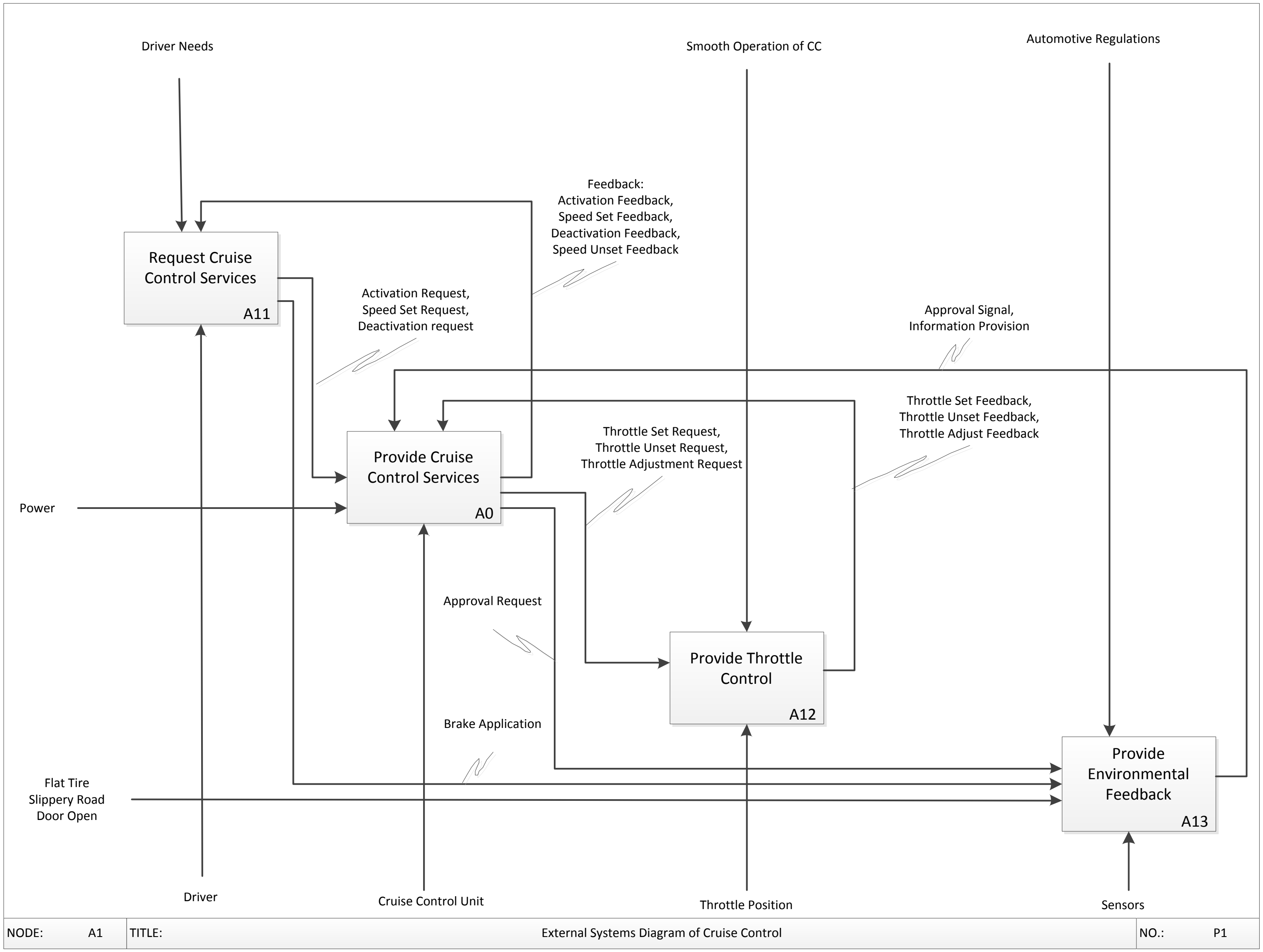

Figure 5: External Systems Diagram

Requirements

1. Input Requirements

1.1 General Requirements for Input

1.1.1 The C.C. system shall accept all inputs within 2 seconds after engine starts. Design goal is 0.5 second.

1.1.2 The C.C. system shall accept electric power from the alternator.

1.1.3 The C.C system shall accept 12V direct current from the car battery.

1.2 Requirements for Input from Driver

1.2.1 The C.C. system shall accept the driver's activation of the system.

1.2.2 The C.C. system shall accept the driver's deactivation of the system.

1.2.3 The C.C. system shall accept every setting of speed by the driver.

1.2.4 The C.C. system shall accept driver's increase of the set speed.

1.2.5 The C.C. system shall accept driver's decrease of the set speed.

1.3 Requirements for Input from Sensors

1.3.1 The C.C. system shall receive information from sensors about tire pressure continuously every 0.5 seconds.

1.3.2 The C.C. system shall receive information from sensors about low traction continuously every 0.5 seconds.

1.3.3 The C.C. system shall receive information from sensors about open doors continuously every 0.5 seconds.

1.3.4 The C.C. system shall receive information from sensors about brake application when requested continuously every 0.5 seconds.

1.3.5 The C.C. system shall accept signal for approval of the sensors.

1.3.6 The C.C. system shall accept values of sensor about tire pressure.

1.3.7 The C.C. system shall accept values of sensor about low traction.

1.3.8 The C.C. system shall accept values of sensor about open doors.

1.3.9 The C.C. system shall accept values of sensor about brake application.

1.4 Requirements for Input from Throttle Control

1.4.1 The C.C. system shall receive feedback about throttle set from throttle unit when requested.

1.4.2 The C.C. system shall receive feedback about throttle set from throttle unit continuously every 1 second.

1.4.3 The C.C. system shall receive feedback about throttle unset from throttle unit when requested.

1.4.4 The C.C. system shall receive feedback about throttle unset from throttle unit continuously every 1 second.

1.4.5 The C.C. system shall receive feedback about throttle adjusted from throttle unit when requested.

1.4.6 The C.C. system shall receive feedback about throttle adjusted from throttle unit continuously every 1 second.

1.4.7 The C.C. system shall accept the throttle set feedback from throttle unit.

1.4.8 The C.C. system shall accept the throttle unset feedback from throttle unit.

1.4.9 The C.C. system shall accept the throttle adjust feedback from throttle unit.

2. Output Requirements

2.1 User Feedback

2.1.1 The C.C. system shall provide visual feedback to the user about activation.

2.1.2 The C.C .system shall provide visual feedback to the user about deactivation.

2.1.3 The C.C. system shall provide visual feedback to the user about setting of speed.

2.1.4 The C.C. system shall provide visual feedback to the user about unsetting of speed.

2.1.5 The C.C. system shall provide a 6V DC supply to power the user interface.

2.2 Throttle Control

2.2.1 The C.C. system shall provide a set request to the throttle.

2.2.2 The C.C. system shall provide an unset request to the throttle.

2.2.3 The C.C. system shall provide an adjustment request to the throttle up to the allowable positions of the throttle.

2.2.4 The C.C. system shall provide no control to the throttle incase of ‘emergency condition’ of the sensors.

2.3 Sensor Control

2.3.1 The C.C. system shall provide an approval request to the sensors before activation.

3. Technology and System-Wide Requirements

3.1 The C.C. system MTBF is 15 years. The design goal is 20 years.

3.2 The C.C. manufacturing cost shall be less than $150. The design goal is $125.

3.3 The C.C. purchasing cost shall be less than $275. The design goal is $225.

3.4 The annual maintenance cost shall be less than $20.

3.5 The average repair cost over the entire life of the vehicle shall be less than $100.

3.6 The C.C. system shall be able to communicate with the sensors.

3.7 The C.C. system shall be able to communicate with the throttle unit.

3.8 The C.C. system shall require prior training of less than 10 minutes. The design goal is 5 minutes.

3.9 The C.C. system shall operate between the speeds of 25 – 120 mph.

3.10 The C.C. system shall be able to operate within environmental temperatures ranging from -30 to 140 degrees Fahrenheit.

3.11 The C.C. system shall use the SAND algorithm based on sensor values to determine the throttle position[1].

3.12 The C.C. system interface shall be accessible on the steering wheel face.

3.13 The C.C. system interface shall have less than 5 buttons. The design goal is 3 buttons.

3.14 The C.C. system shall have an accuracy range of ±1 mph of the set speed. The design goal is ±0.5 mph.

3.15 The C.C. system shall activate within 0.5 second after the activation signal has been sent by the user. The design goal is 0.25 second.

3.16 The C.C. system shall deactivate within 0.5 second after the activation signal has been sent by the user. The design goal is 0.25 second.

3.17 The throttle shall be set within 0.5 second after the set signal has been sent by the C.C. system. The design goal is 0.25 second.

3.18 The throttle shall be unset within 0.5 second after the set signal has been sent by the C.C. system. The design goal is 0.25 second.

3.19 The C.C. system shall adhere to corresponding federal, state, and other applicable automotive industry regulations.

3.20 The C.C. system shall adhere to corresponding SAE safety standards.

4. Qualification Requirements

4.1 Verification

4.1.1 The C.C. system verification shall be conducted by inspection, analysis and simulation, instrumented tests, and demonstration.

4.1.2 The C.C. system shall verify the following requirements using inspection: 3.19, 3.20

[1] The SAND algorithm has been designed and patented by our company for use within the C.C. system.

4.1.3 The C.C. system shall verify the following requirements using analysis and simulation: 3.1-3.5,

4.1.4 The C.C. system shall verify the following requirements using instrumented tests: 1.1.1, 1.1.3, 1.3.1-1.3.4, 1.4.2, 1.4.4, 1.4.6, 2.1.5, 3.8-3.10, 3.14-3.18

4.1.5 The C.C. system shall verify the following requirements using demonstration: 1.1.2, 1.2.1-1.2.5, 1.3.5-1.3.9, 1.4.1, 1.4.3, 1.4.5, 1.4.7-1.4.9, 2.1.1-2.1.4, 2.2.1-2.2.4, 2.3, 3.6, 3.7, 3.11-3.13

4.2 Validation

4.2.1 The C.C. system shall address every operational scenario using primarily instrumented tests and demonstration.

4.3 Acceptance

4.3.1 The C.C. system acceptance tests shall demonstrate all functional inputs and outputs.

5. Trade-Off Requirements

5.1 Performance Trade-offs

5.1.1 The system shall adhere to the weighted performance scores as assigned by the right side of the objectives hierarchy. The value curves for the performance requirements are to be determined.

5.2 Cost Trade-offs

5.2.1 The system shall adhere to the weighted cost scores as assigned by the left side of the objectives hierarchy. The value curve for the cost requirement is to be determined.

5.3 Cost-Performance Trade-offs

5.3.1 The system shall attain the highest weighted score combining the weighted performance and weighted cost as shown in the objectives hierarchy. The relative weights of the performance and cost requirements are 0.7 and 0.3, respectively.

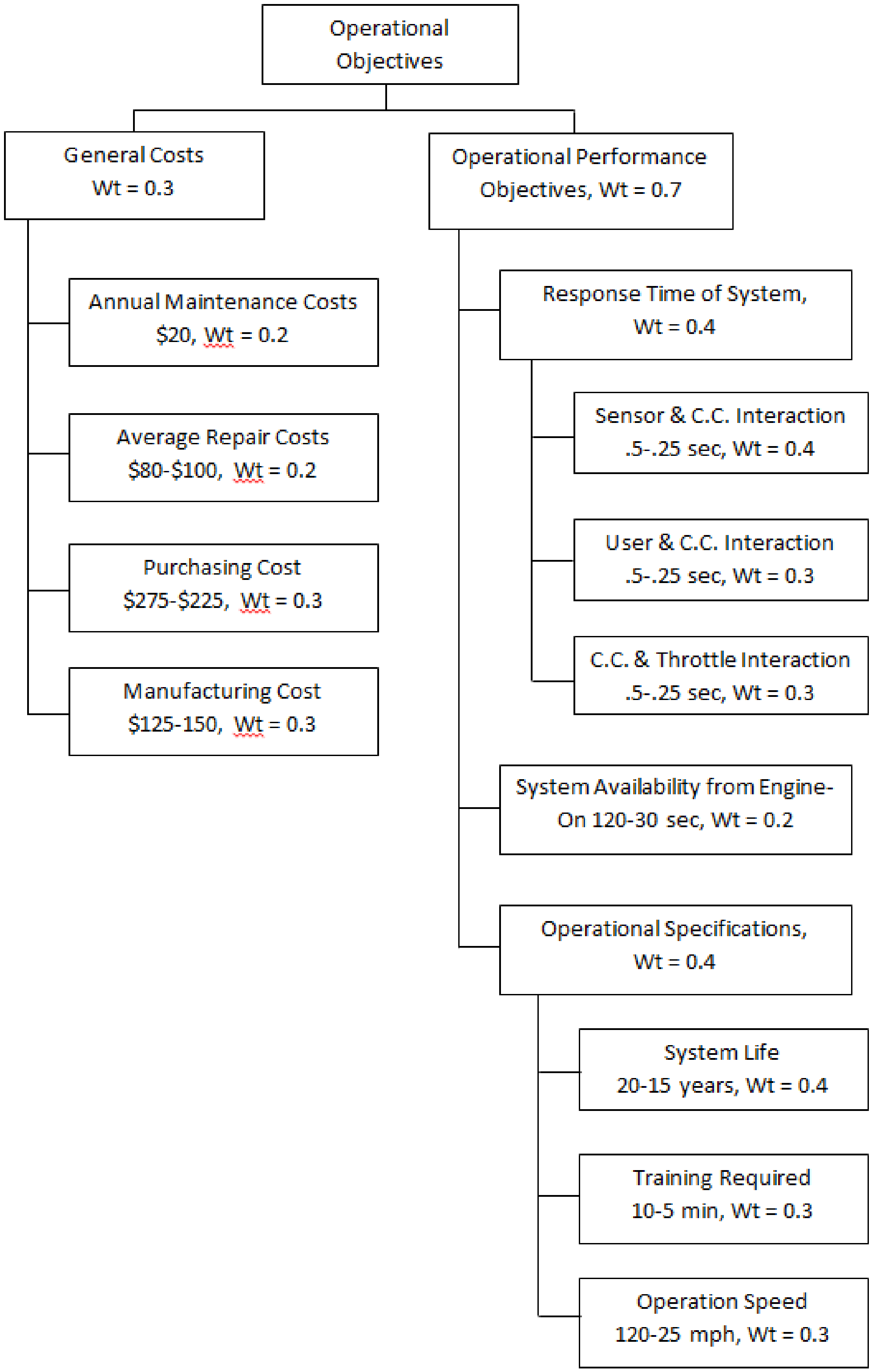

Figure 6: Objectives Hierarchy

Functional Architecture

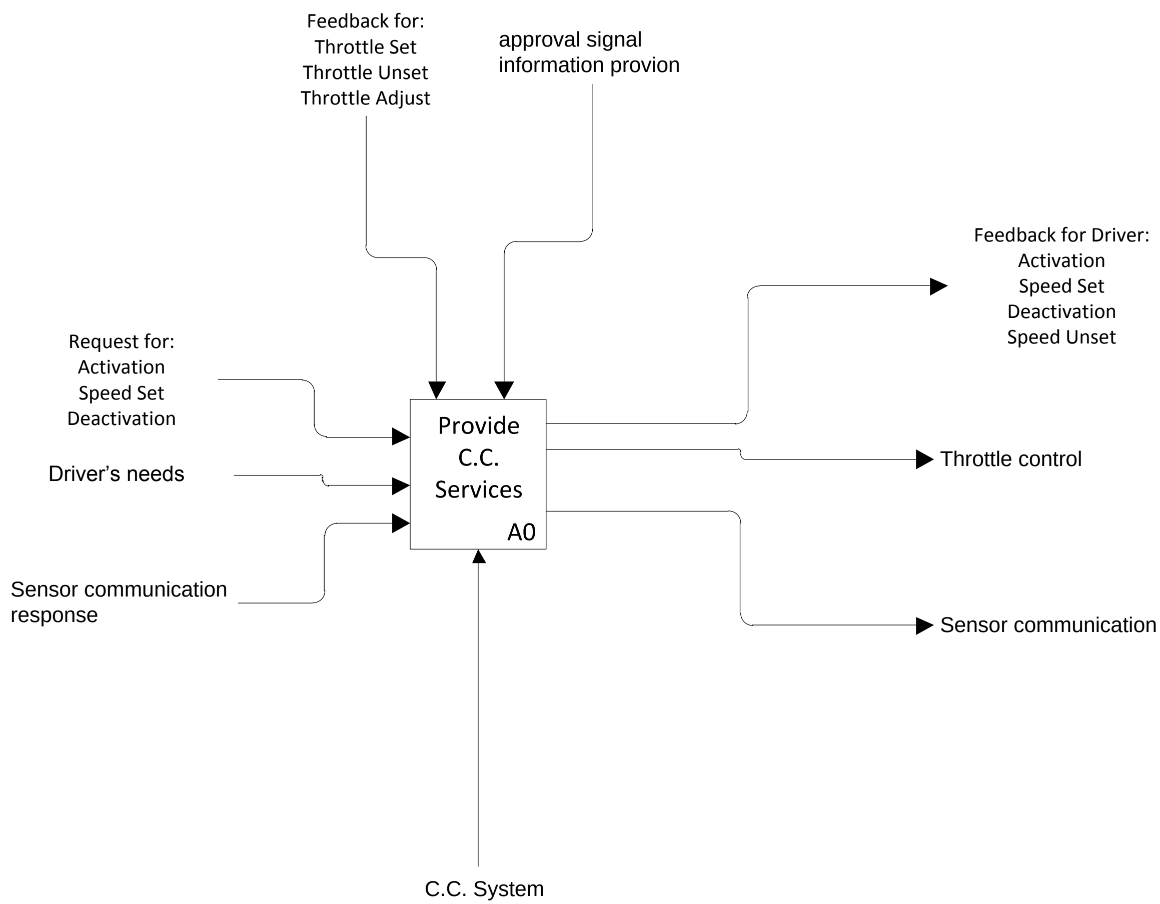

Figure 7: Functional Architecture of C.C. System

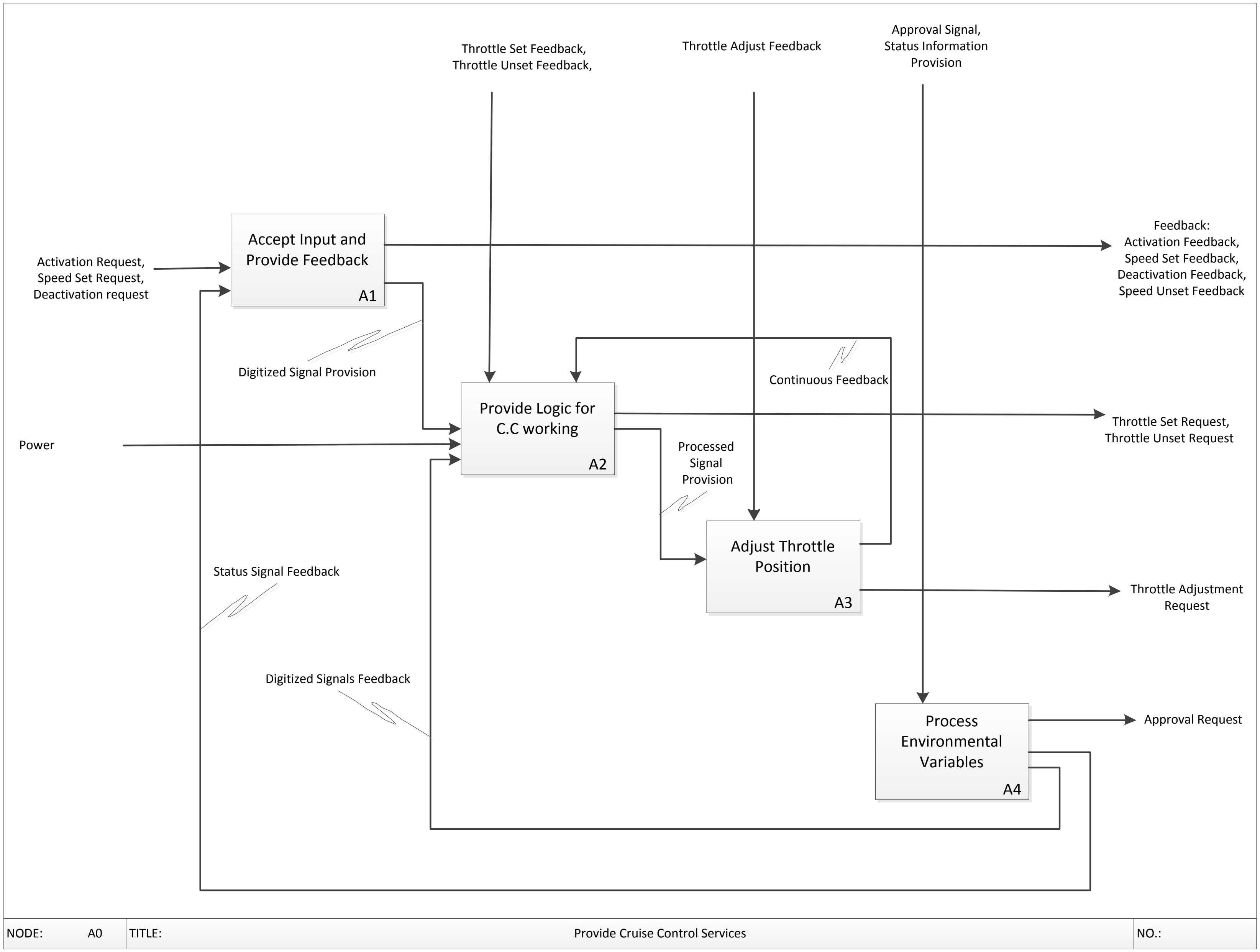

Figure 8: Functional Architecture Diagram for C.C. System

Physical Architecture

1. Generic Physical Architecture for Cruise Control System

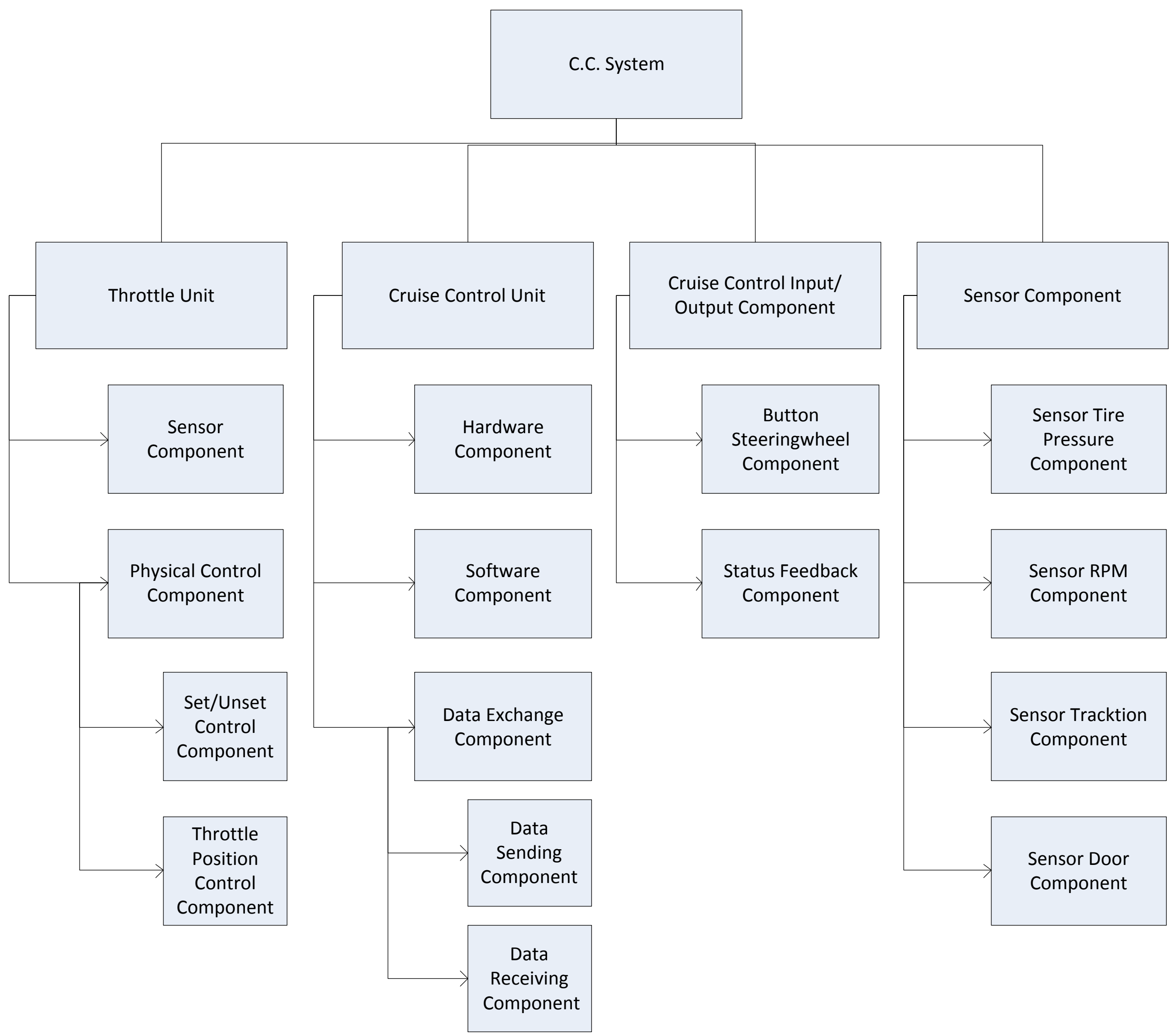

Figure 9: Physical Architecture for C.C. System

2. Instantiated Physical Architecture for Cruise Control System

Options		Features			
		Sensor Component	**Output component**	**Input component**	**Cruise Control Unit**
	Standard	Tire pressure, RPM, traction	Single visible feedback	Two Buttons on steering wheel	AMD Athlon II
	Sport	Tire pressure, RPM, traction; door, airbag	Multiple visible feedback	Four Buttons + wheel on steering wheel	Intel Pentium 4
	Premium	Tire pressure, RPM, traction, door, airbag, distance, permitted speed limit	Multiple visible feedback, acoustic feedback	Lever next to steering wheel	Inter Duo core II

Table 10: Instantiated Physical Architecture

State Transition Diagram

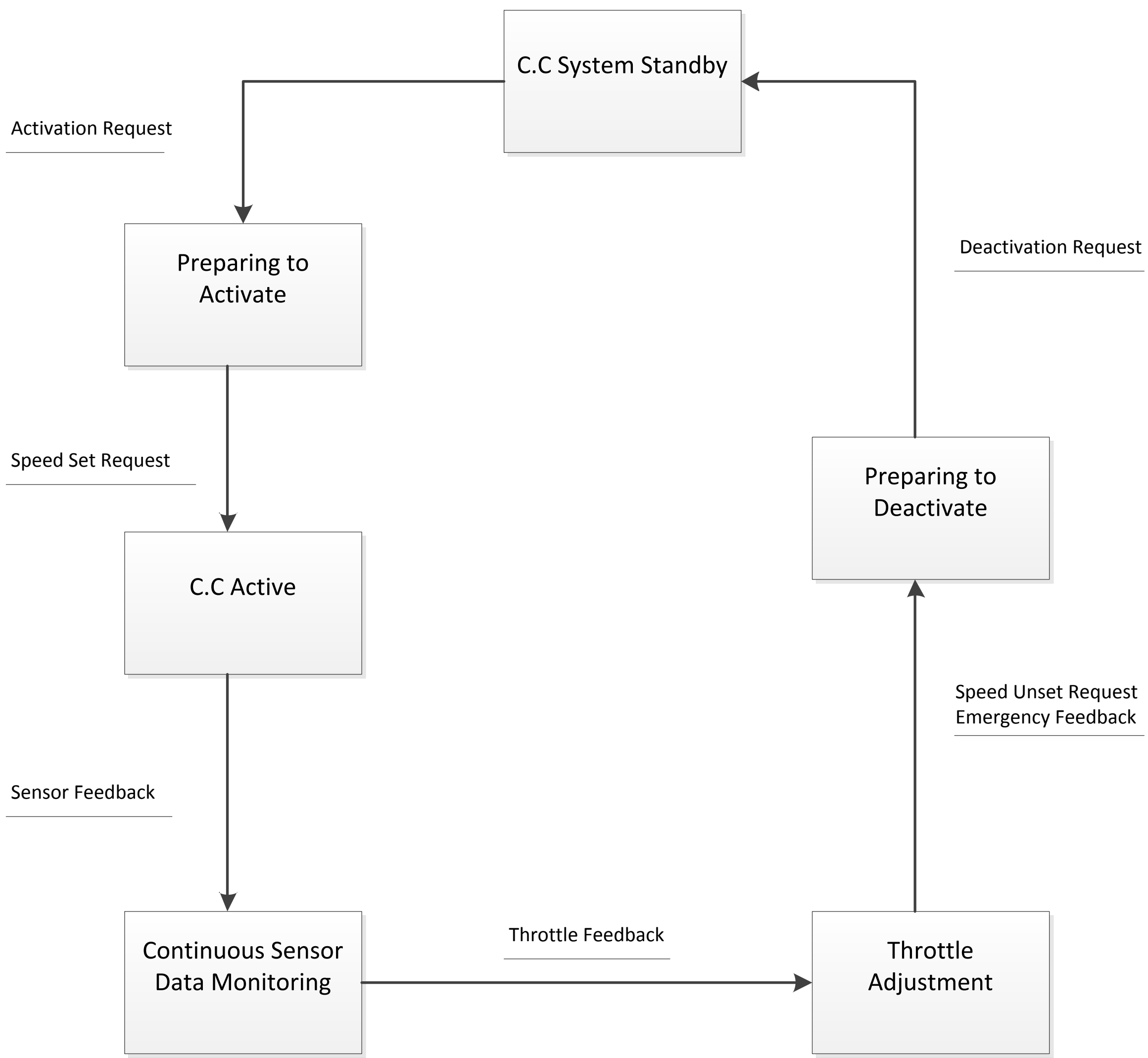

Figure 11: State Transition Diagram for C.C. System

Interface Description and Summary

The cruise control system interfaces are the locations at which the cruise control system interacts with other systems. Most of the system interactions are between the cruise control unit and the physical speed control, though interfaces exist between the cruise control unit and the driver, as well as the cruise control unit and sensors. The primary interface is a wired connection with the physical speed control. During normal operation, the sensors stay in continuous communication with the cruise control unit, which then relays information to the physical speed control. Additionally, the cruise control system has its own feedback interface through lights on the dashboard of the automobile. The cruise control unit also has a physical interface on the steering wheel in which the driver can interact with in order to set or unset desired speeds and activates or deactivates the system. The cruise control system must also interface with the battery of the car in order to receive operational power.

A summary of the system interfaces has been tabulated below.

Component		Signal	Interface type	Function, logical& physical	Physical interface type	Physical instantiations	Usage
A1	Accept Input and provide output	Feedback: Activation, speed set, deactivation, speed unset	Input	Accept feedback about status from sensor	Wired connector	All	Cont.
A1	Accept Input and provide output	Request: Activation, speed set, deactivation	Output	Sends operating parameters to logic	Wired connector	All	As needed
A2	Provide logic for C.C. working	Approval signal, information provision	Input	Accept signals for approval and sensor information	Wired connector	All	Cont.
A2	Provide logic for C.C. working	Feedback: Throttle set, throttle unset	Input	Accept feedback about status from throttle unit	Wired connector	All	As needed
A2	Provide logic for C.C. working	Power	Input	Accepts electrical power from battery	power connector	All	Cont.
A2	Provide logic for C.C. working	digitized signal provision	Input	Accept digital signals of Input interface	Wired connector	All	As needed
A2	Provide logic for C.C. working	Digitized signals feedback	Input	Accept digital signals for feedback about environment	Wired connector	All	Cont.
A2	Provide logic for C.C. working	Continuous feedback provision	Input	Accept feedback signals from throttle	Wired connector	All	Cont.
A2	Provide logic for C.C. working	Request: Throttle set, throttle unset	Output	Send request for throttle status to throttle unit	Wired connector	All	As needed

A3	Maintain constant speed	throttle adjust feedback	Input	Accept feedback signal from throttle unit	Wired connector	All	Cont.
A3	Maintain constant speed	Processed signal transmission	Input	Accept operating parameters form logic	Wired connector	All	Cont.
A3	Maintain constant speed	Continuous feedback provision	Output	Provision of feedback for logic	Wired connector	All	Cont.
A3	Maintain constant speed	Throttle adjustment	Output	Sends signals to throttle unit	Wired connector	All	Cont.
A4	Process environ. variables	Approval signal, information provision	Input	Accepts signals from signal	Wired connector	All	Cont.
A4	Process environ. variables	Status signal feedback	Output	Provide feedback signals for input	Wired connector	All	…
A4	Process environ. variables	Approval request	Output	Send request for approval signal to sensors	Wired connector	All	As needed
A4	Process environ. variables	Digitized signals feedback	Output	Provide signals about environ. Status for logic	Wired connector	All	Cont.

Table 1: Cruise Control Interfaces

Risk Analysis, Score, and Risk Plan

In every complex system there is the potential that something will go wrong as a result of one or a series of events. That situation is called risk. It is measured as the combined effect of the probability of occurrence and the assessed consequences of the occurrence. Typical areas of risk are technical, schedule, resources, personnel, budget, and political. An organized method, called risk management, supports in identifying and measuring this risk. It also helps to develop options and select alternatives. It includes the risk assessment which involves the ongoing review of technical design and/or program management decisions. Risk management also supports identifying potential areas of risk. The next step is the risk analysis. It determines the probability of events and the consequences associated with their occurrence. Finally, there is the risk abatement which includes techniques and methods to reduce or control the risk.

1. Risk Assessment

Since the cruise control system consists of different types of parts several factors have to be considered for assessing the risk:

- Hardware components such as the sensors or processor unit can be purchased off the shelf.
- The data exchange component is standardized and can be easily adapted to be suitable for the system.
- The highly sensitive sensors are more complex and sophisticated than other similar products.
- Corresponding software is not a "state of the art" and is similar to existing programs. However, the SAND algorithm is more complicated and essential for the system.
- Since cruise control systems have been established for several years much testing and refinement information is available.

2. Risk Analysis

There are several tools available to analyze risk. One is the quantitative risk model to determine a risk factor for several parts. The following tables were used to determine risks:

Magnitude	Maturity Factor (P_M) Hardware $PMhw$	Maturity Factor (P_M) Software $PMsw$	Complexity Factor (P_C) Hardware $PChw$	Complexity Factor (P_C) Software $PCsw$	Dependency Factor (P_D)
0.1	Existing	Existing	Simple design	Simple design	Independent of existing system, facility, or associate contractor
0.3	Minor redesign	Minor redesign	Minor increases in complexity	Minor increases in complexity	Schedule dependent on existing system, facility, or associate contractor
0.5	Major change feasible	Major change feasible	Moderate increase	Moderate increase	Performance dependent on existing system performance, facility, or associate contractor
0.7	Technology available, complex design	New software similar to existing	Significant increase	Significant increase/major increase in no. of modules	Schedule dependent on new system schedule, facility, or associate contractor
0.9	State of art some research complete	State of art never done before	Extremely complex	Extremely complex	Performance dependent on new system schedule, facility, or associate contractor

Magnitude	Technical Factor $(C_f) - (C_t)$	Cost Factor (C_C)	Schedule Factor (C_S)
0.1 (low)	Minimal or no consequences, unimportant	Budget estimates not exceeded, some transfer of money	Negligible impact on program, slight development schedule change compensated by available schedule slack
0.3 (minor)	Small reduction in technical performance	Cost estimates exceed budget by 1 to 5	Minor slip in schedule (less than 1 month), some adjustment in milestone required
0.5 (moderate)	Some reduction in technical performance	Cost estimates increased by 5% to 20%	Small slip in schedule
0.7 (significant)	Significant degradation in technical performance	Cost estimates increased by 20% to 50%	Development schedule slip in excess of 3 months
0.9 (high)	Technical goals cannot be achieved	Cost estimates increased in excess of 50 percent	Large schedule slip that affects segment milestones or has possible effect on system milestones

(1) Risk factor $= P_f + C_f - (P_f)(C_f)$

(2) $P_f = (a)(P_{Mhw}) + (b)(P_{Msw}) + (c)(P_{Chw}) + (d)(P_{Csw}) + (e)(P_D)$

where

P_{Mhw} = Probability of failure due to degree of hardware maturity

P_{Msw} = Probability of failure due to degree of software maturity

P_{Chw} = Probability of failure due to degree of hardware complexity

P_{Csw} = Probability of failure due to degree of software complexity

P_D = Probability of failure due to dependency on other items

and where: a, b, c, d, and e are weighing factors whose sum equals one.

(3) $C_f = (f)(C_t) + (g)(C_C) + (h)(C_S)$

where:

C_t = Consequence of failure because of technical factors

C_C = Consequence of failure because of changes in cost

C_S = Consequence of failure changes in schedule

and where: f to h are weighing factors whose sum equals one.

Tables 2 - 4: Risk Model Tables

	Factors		Weights
PMhw	0.3	**a**	0.1
PMsw	0.4	**b**	0.3
PChw	0.3	**c**	0.2
PCsw	0.4	**d**	0.2
Pd	0.5	**e**	0.2
Ct	0.4	**f**	0.3
Cc	0.2	**g**	0.3
Cs	0.2	**h**	0.4

	Project A
Pf	0.39
Cf	0.26
Risk Factor	0.5486

Table 5: Table Risk Calculation

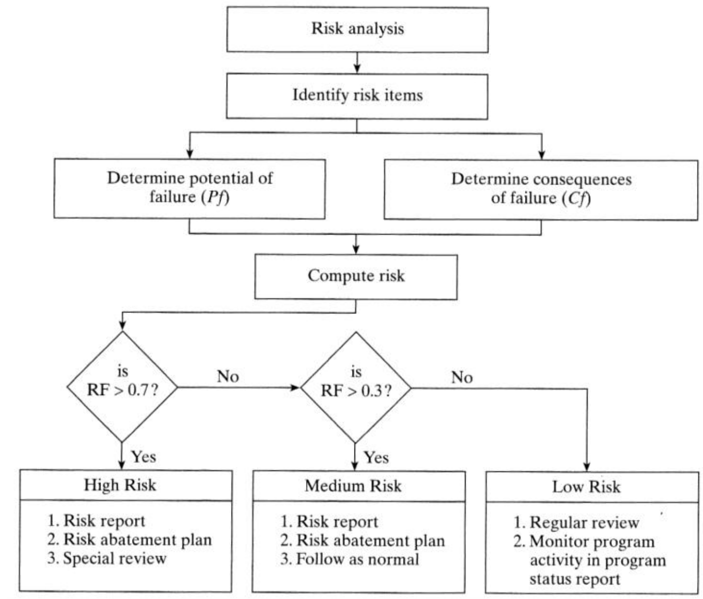

Table 6: Risk Model Process/Decision

3. Risk Abatement

Since the most physical components are existing and established parts we just have to modify and adjust them to meet our requirements. Also, the hardware components can be purchased from several suppliers and do not require dependency from a single vendor. Therefore, costs for hardware are not a large source of risk. Consequently, the risk is relatively low. However, since the focus is on the SAND algorithm the risk of the software part is a little greater. The algorithm has to be able to process and communicate with other parts very quickly. The operation times have to meet requirements for emergency situations. That increases the magnitude and weights for software components and pushes the risk factor into the medium range.

Software and components for the data exchange are also standardized and established products which are offered by several suppliers. The highly sensitive sensors must be able to identify changes in the operating parameters and environment in a very short time span. Products with such characteristics are also available on the marketplace and do not significantly increase the risk.

All hardware components have to be easy to replace as they wear down. Maintenance and repair processes will be easy too. Software should be able to function and operate together with the hardware as long as the hardware components are in working order.

Another important aspect of risk managing is to be flexible and responsive. To reach that, good preparation and planning is necessary. Financial resources have to be allocated carefully. The schedule and timeframe should be appropriate and sufficient. It makes sense to focus resources on the software development since it is the basis for the cruise control system. The design goal should be less complex to minimize software and hardware risks. A well-prepared and well-planned project should be able to manage all risks and upcoming problems.

Integration Plan

The cruise control system will be integrated using the bottom-up method. By using this method, the sensor, control, hardware/software, and throttle components can all be tested individually. As each component is produced, they will be tested to ensure a consistent and high quality. These components will also be tested at the final assembly stage when all of the parts interact as a complete system on the automobile. Although the individual components can be tested for defects, most of the errors may only be visible after the final assembly.

Qualification Plan

Operating Scenarios						Method			
User sets and cancels C.C.	Cancels C.C. via brake	C.C. system changes - incline/decline	Flat tire	The C.C. system shall…		Inspection	Simulation	Instrumented Tests	Demonstration
				Req.	Description				
X	X	X	X	1.1.1	The C.C. system shall accept all inputs within 2 seconds after engine starts. Design goal is 0.5 second.			X	
X	X	X	X	1.1.2	The C.C. system shall accept electric power from the alternator.				X
X	X	X	X	1.1.3	The C.C. system shall accept 12V direct current from the car battery.			X	
X	X	X	X	1.2.1	The C.C. system shall accept the driver’s activation of the system.				X
X				1.2.2	The C.C. system shall accept the driver’s deactivation of the system.				X
X	X	X	X	1.2.3	The C.C. system shall accept every setting of speed by the driver.				X
X	X	X	X	1.2.4	The C.C. system shall accept driver's increase of the set speed.				X
X	X	X	X	1.2.5	The C.C. system shall accept driver’s decrease of the set speed.				X
X	X	X	X	1.3.1	The C.C. system shall receive information from sensors about tire pressure continuously every 0.5 seconds.			X	
X	X	X	X	1.3.2	The C.C. system shall receive information from sensors about low traction continuously every 0.5 seconds.			X	

X	X	X	X	1.3.3	The C.C. system shall receive information from sensors about open doors continuously every 0.5 seconds.			X	
X	X	X	X	1.3.4	The C.C. system shall receive information from sensors about brake application when requested continuously every 0.5 seconds.			X	
X	X	X	X	1.3.5	The C.C. system shall accept signal for approval of the sensors.				X
X	X	X	X	1.3.6	The C.C. system shall accept values of sensor about tire pressure.				X
X	X	X	X	1.3.7	The C.C. system shall accept values of sensor about low traction.				X
X	X	X	X	1.3.8	The C.C. system shall accept values of sensor about open doors.				X
	X			1.3.9	The C.C. system shall accept values of sensor about brake application.				X
X	X	X	X	1.4.1	The C.C. system shall receive feedback about throttle set from throttle unit when requested.				X
X	X	X	X	1.4.2	The C.C. system shall receive feedback about throttle set from throttle unit continuously every 1 second.			X	
X	X	X	X	1.4.3	The C.C. system shall receive feedback about throttle unset from throttle unit when requested.				X
X	X	X	X	1.4.4	The C.C. system shall receive feedback about throttle unset from throttle unit continuously every 1 second.			X	
X	X	X	X	1.4.5	The C.C. system shall receive feedback about throttle adjusted from throttle unit when requested.				X
X	X	X	X	1.4.6	The C.C. system shall receive feedback about throttle adjusted from throttle unit continuously every 1 second.			X	
X	X	X	X	1.4.7	The C.C. system shall accept the throttle set feedback from throttle unit.				X
X	X	X	X	1.4.8	The C.C. system shall accept the throttle unset feedback from throttle unit.				X
X	X	X	X	1.4.9	The C.C. system shall accept the throttle adjust feedback from throttle unit.				X
X	X	X	X	2.1.1	The C.C. system shall provide visual feedback to the user about activation.				X

X	X	X	X	2.1.2	The C.C .system shall provide visual feedback to the user about deactivation.				X
X	X	X	X	2.1.3	The C.C. system shall provide visual feedback to the user about setting of speed.				X
X	X	X	X	2.1.4	The C.C. system shall provide visual feedback to the user about unsetting of speed.				X
X	X	X	X	2.1.5	The C.C. system shall provide a 6V DC supply to power the user interface.			X	
X	X	X	X	2.2.1	The C.C. system shall provide a set request to the throttle.				X
X	X	X	X	2.2.2	The C.C. system shall provide an unset request to the throttle.				X
X	X	X	X	2.2.3	The C.C. system shall provide an adjustment request to the throttle up to the allowable positions of the throttle.				X
X	X	X	X	2.2.4	The C.C. system shall provide no control to the throttle in case of 'emergency condition' of the sensors.				X
X	X	X	X	2.3.1	The C.C. system shall provide an approval request to the sensors before activation.				X
X	X	X	X	3.1	The C.C. system shall be functional for 15 years. The design goal is 20 years.		X		
X	X	X	X	3.2	The C.C. manufacturing cost shall be less than $150. The design goal is $125.		X		
X	X	X	X	3.3	The C.C. purchasing cost shall be less than $275. The design goal is $225.		X		
X	X	X	X	3.4	The annual maintenance cost shall be less than $20.		X		
X	X	X	X	3.5	The average repair cost over the entire life of the vehicle shall be less than $100.		X		
X	X	X	X	3.6	The C.C. system shall be able to communicate with the sensors.				X
X	X	X	X	3.7	The C.C. system shall be able to communicate with the throttle unit.				X
X	X	X	X	3.8	The C.C. system shall require prior training of less than 10 minutes. The design goal is 5 minutes.			X	
X	X	X	X	3.9	The C.C. system shall operate between the speeds of 25 – 120 mph.			X	

X	X	X	X	3.10	The C.C. system shall be able to operate within environmental temperatures ranging from -30 to 140 degrees Fahrenheit.			X	
X	X	X	X	3.11	The C.C. system shall use the SAND algorithm based on sensor values to determine the throttle position.				X
X	X	X	X	3.12	The C.C. system interface shall be accessible on the steering wheel face.				X
X	X	X	X	3.13	The C.C. system interface shall have less than 5 buttons. The design goal is 3 buttons.				X
X	X	X	X	3.14	The C.C. system shall have an accuracy range of ±1 mph of the set speed. The design goal is ±0.5 mph.			X	
X	X	X	X	3.15	The C.C. system shall activate within 0.5 second after the activation signal has been sent by the user. The design goal is 0.25 second.			X	
X	X	X	X	3.16	The C.C. system shall deactivate within 0.5 second after the activation signal has been sent by the user. The design goal is 0.25 second.			X	
X	X	X	X	3.17	The throttle shall be set within 0.5 second after the set signal has been sent by the C.C. system. The design goal is 0.25 second.			X	
X	X	X	X	3.18	The throttle shall be unset within 0.5 second after the set signal has been sent by the C.C. system. The design goal is 0.25 second.			X	
X	X	X	X	3.19	The C.C. system shall adhere to all federal, state, and other applicable automotive industry regulations.	X			
X	X	X	X	3.20	The C.C. system shall adhere to all SAE safety standards.	X			

Table 7: Qualification Plan

Testing Equipment and Resources

Requirement ID	Requirement Description	Equipment Needed	Resources Needed	Time Table
1.1.1	The C.C. system shall accept all inputs within 2 seconds after engine starts. Design goal is 0.5 second	• Computerized Stopwatch • C.C. system • Engine	• Testing Personnel • Engine Lab • 1 week	Test Completed by March 2012
1.1.3	The C.C. system shall accept 12V direct current from the car battery	• C.C. system • Voltmeter • Car Battery	• Testing Personnel • 1 week	Test Completed by March 2012
1.3.1	The C.C. system shall receive information from sensors about tire pressure continuously every 0.5 seconds	• Tire pressure Sensor • Computerized Stopwatch • C.C. system • Tires	• Testing Personnel • 1 week • Inspection Area	Test Completed by March 2012
1.3.2	The C.C. system shall receive information from sensors about low traction continuously every 0.5 seconds	• C.C. system • Traction Control Sensors • Computerized Stopwatch	• Testing Personnel • 1 week • Test Course	Test Completed by March 2012
1.3.3	The C.C. system shall receive information from sensors about open doors continuously every 0.5 seconds	• C.C. system • Computerized Stopwatch • Door Sensors	• Testing Personnel • 1 week • Door Assembly	Test Completed by March 2012
1.3.4	The C.C. system shall receive information from sensors about brake application when requested continuously every 0.5 seconds.	• Computerized Stopwatch	• Testing personnel • 1 hour	Test completed by March 2012
1.4.2	The C.C. system shall receive feedback about throttle set from throttle unit continuously every 1 second.	• Computerized Stopwatch • Measuring instruments	• Testing personnel • 1 hour	Test completed by March 2012
1.4.4	The C.C. system shall receive feedback about throttle unset from throttle unit continuously every 1 second.	• Computerized Stopwatch • Measuring instruments	• Testing personnel • 1 day	Test completed by March 2012

1.4.6	The C.C. system shall receive feedback about throttle adjusted from throttle unit continuously every 1 second.	• Computerized Stopwatch • Measuring instruments	• Testing personnel • 1 day	Test completed by March 2012
2.1.5	The C.C. system shall provide a 6V DC supply to power the user interface.	• Measuring instruments	• Testing personnel • 1 day	Test completed by March 2012
3.8	The C.C. system shall require prior training of less than 10 minutes. The design goal is 5 minutes	• C.C. System • C.C. Interface • Computerized stopwatch	• Authorized trainer • Tester	Test Completed by Mar 2012
3.9	C.C. system shall operate between the speeds of 25 – 120 mph	• C.C. System • Vehicle • Dynamometer	• Tester • Maintenance Personnel	Test Completed by Mar 2012
3.10	The C.C. system shall be able to operate within environmental temperatures ranging from -30 to 140 degrees Fahrenheit.	• C.C. System • Engine • Thermocouple • Industrial Heat Generator	• Technician • Maintenance Personnel	Test Completed by Mar 2012
3.14	The C.C. system shall have an accuracy range of ±1 mph of the set speed. The design goal is ±0.5 mph	• C.C. System • Vehicle • Dynamometer	• Tester • Maintenance Personnel	Test Completed by Mar 2012
3.15	The C.C. system shall activate within 0.5 second after the activation signal has been sent by the user. The design goal is 0.25 second.	• Computerized Stopwatch • C.C. System	• Tester • 2 hours • Testing location	Test completed by March 2012
3.16	The C.C. system shall deactivate within 0.5 second after the activation signal has been sent by the user. The design goal is 0.25 second.	• Computerized Stopwatch • C.C. System	• Tester • 2 hours • Testing location	Test completed by March 2012
317	The throttle shall be set within 0.5 second after the set signal has been sent by the C.C. system. The design goal is 0.25 second.	• Computerized Stopwatch • C.C. System • Engine	• Tester • 2 hours • Testing location	Test completed by March 2012
3.18	The throttle shall be unset within 0.5 second after the set signal has been sent by the C.C. system. The design goal is 0.25 second.	• Computerized Stopwatch • C.C. System • Engine	• Tester • 2 hours • Testing location	Test completed by March 2012

Table 8: Testing Equipment and Resources