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Real Time Systems
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Automated Commuter Train System

Analysis Phase

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1. Scope

1.1. Identification and System Overview

The Automated Commuter Train System is a fully automated commuter train system which operates throughout the metropolitan area (Reference to the MEMORANDUM in appendix A). Each train is equipped with its own control system to direct and monitor on-train systems such as doors, temperature, brakes, engine, etc. Also, each train runs according to a precise itinerary data coming from the central computer. Overall, the design focuses only on the automation process of the on-train system. The requirements of the On-Train Control System include:

- Control system to direct and monitor on-train components and devices.
- Allow the control system to be override by the operator in case of an emergency.
- The system should be able to communicate with the central computer to get data on operation modes, obstacles, repair requests, and itineraries.
- The system should maintain to apply the four break modes according to specific situations.
- The system should response to different stop requests weather according to the itineraries or passengers on board or at stations.
- The system must keep records about each run including failures or repair requests.

1.2. Document Overview

The document provides analysis to the different requirements of the Automated Commuter Train System, specifically the requirements of the automation process of the on-train system.

The document consists of the following types of requirements analysis:

- Context Diagram of the system
- Data-Flow Diagrams (DFD)
- State-transition diagrams (STD)
- Processes Specifications (C-Specs)
- Controls Specifications (C-Specs)

2. Requirements

2.1. Required States and Modes

Figure 1 is the STD 0 Control Specifications for the Automated Commuter Train that illustrate the states and mode of the system.

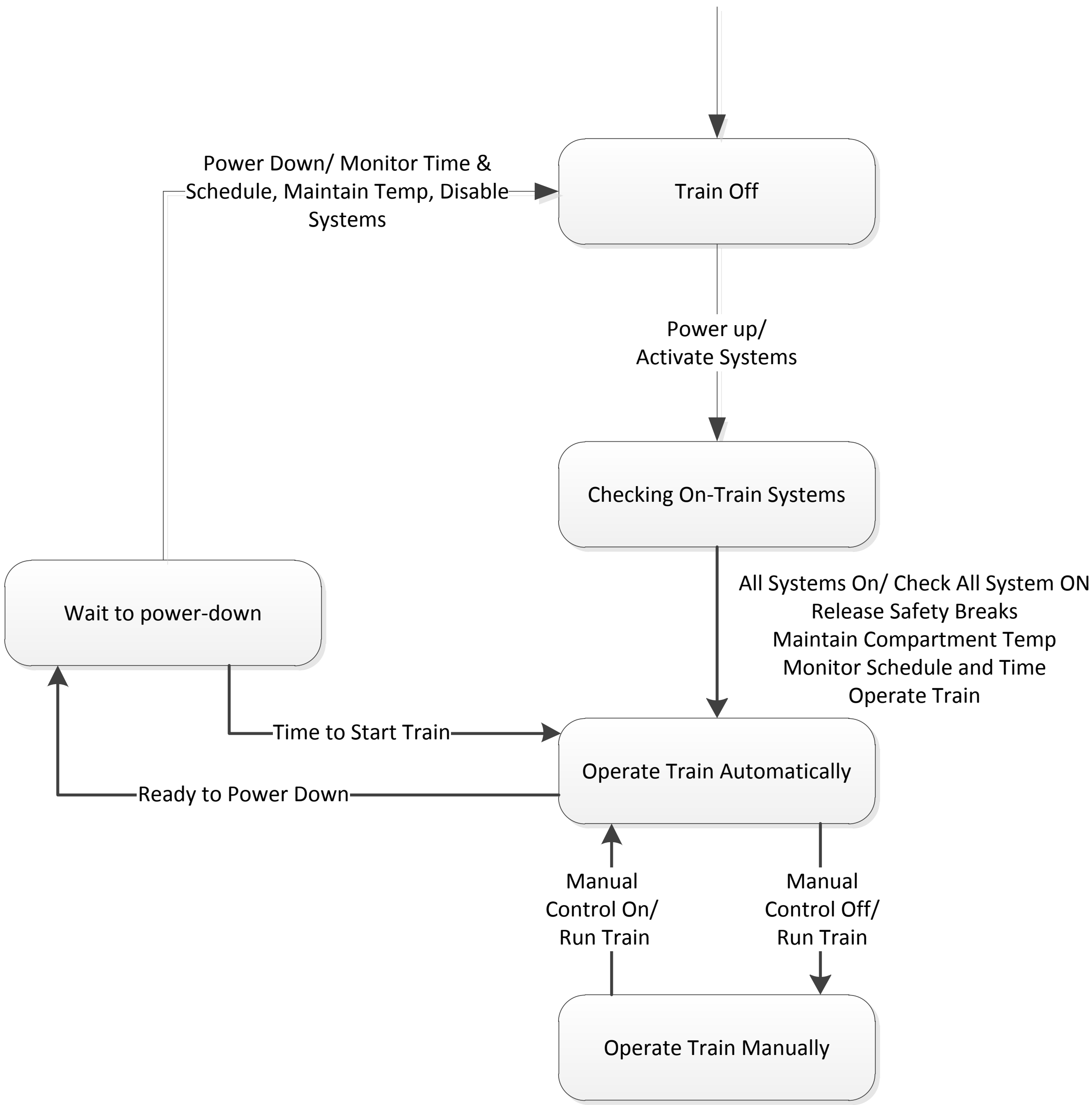

Figure 1: STD 0 - Control Specifications for the Automated Commuter Train

2.2. CSCI Capability Requirements – DFD 0

Figure 2 is the DFD 0 Data Flow Diagram for the Automated Commuter Train is illustrated by four functions that are briefly shown in detailed levels in the following sections of this document. But, the STD 0 that illustrate the states and mode of the system is identified above in Figure 1.

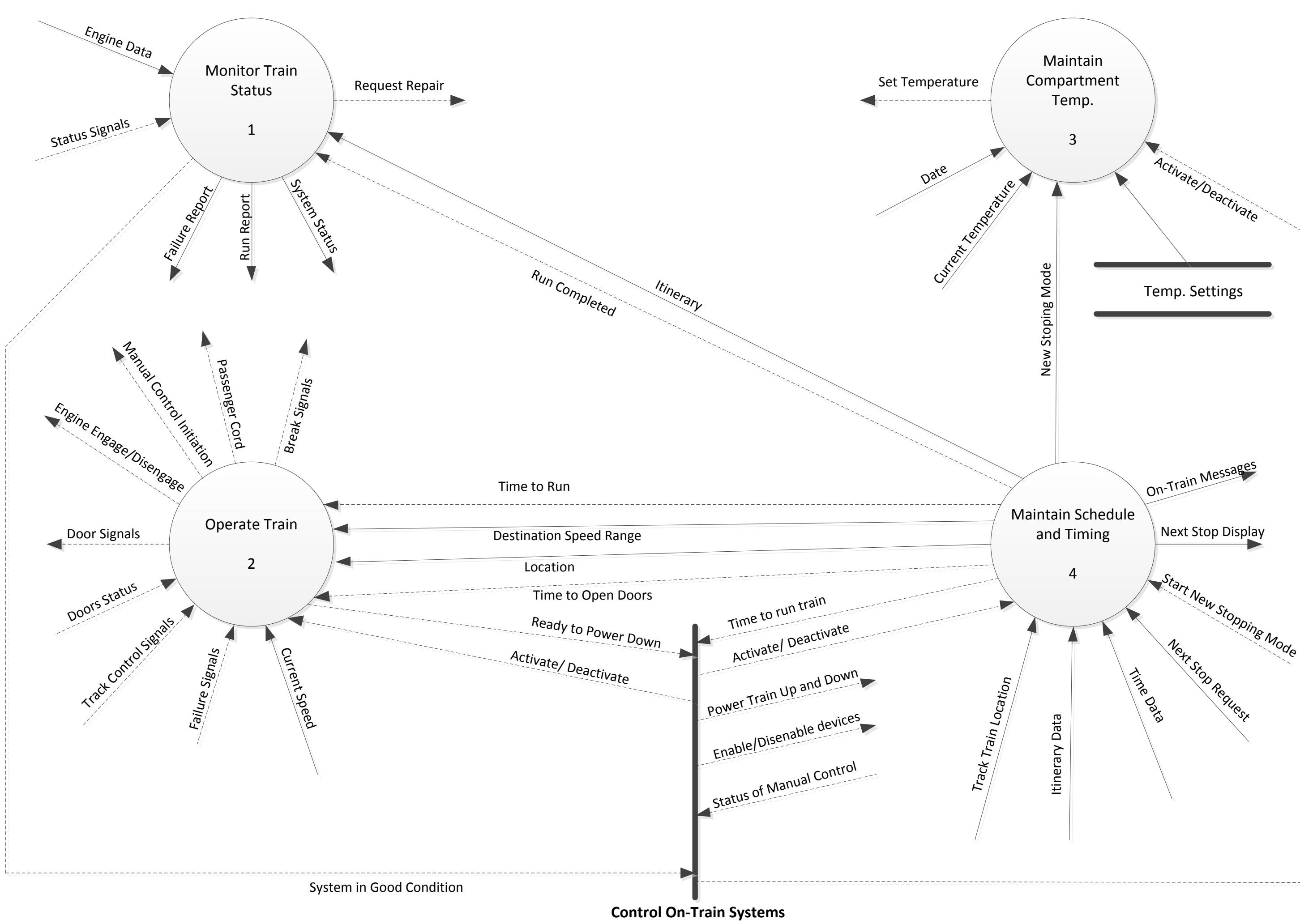

Figure 2: DFD 0 – Data Flow Diagram for the Automated Commuter Train

2.3.CSCI Capability Requirements – DFD 1

Figure 3 is the DFD 1 Diagram for Monitor Train Status is illustrated by two primitive functions that are briefly described in the (P-Specs) section.

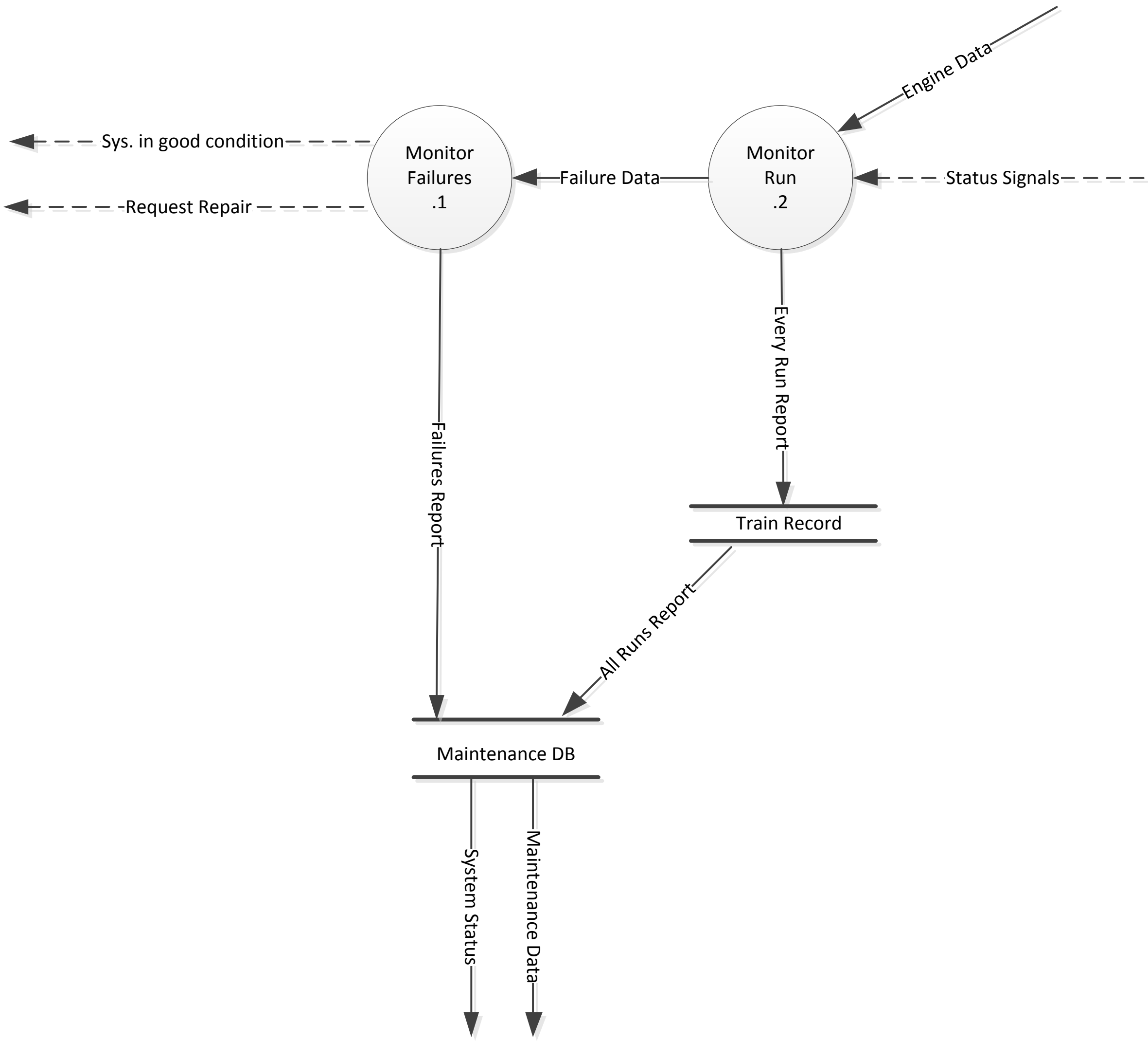

Figure 3: DFD 1 - Data Flow Diagram for the Monitor Train Status

2.4.CSCI Capability Requirements – DFD 2

Figure 4 is the DFD 2 Diagram for Operate Train is illustrated by two primitive functions that are briefly described in the (P-Specs) section, and two control nodes that also briefly described in (C-Specs) section.

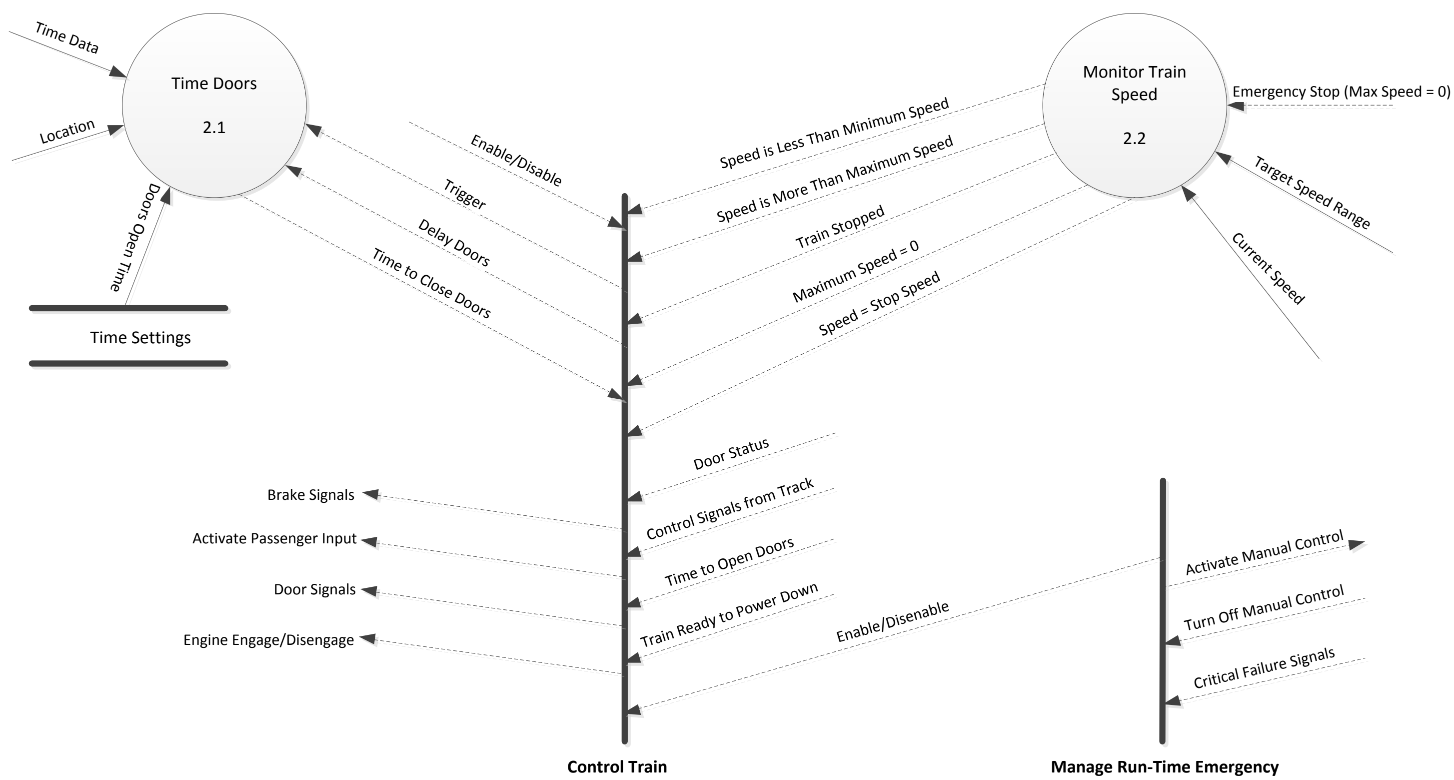

Figure 4: DFD 2 - Data Flow Diagram for the Operate Train

2.5.CSCI Capability Requirements – DFD 3

Figure 5 is the DFD 3 Diagram for Maintain Compartment Temperature in is illustrated by three primitive functions that are briefly described in the (P-Specs) section, and one control node that is also briefly described in the (C-Specs) section.

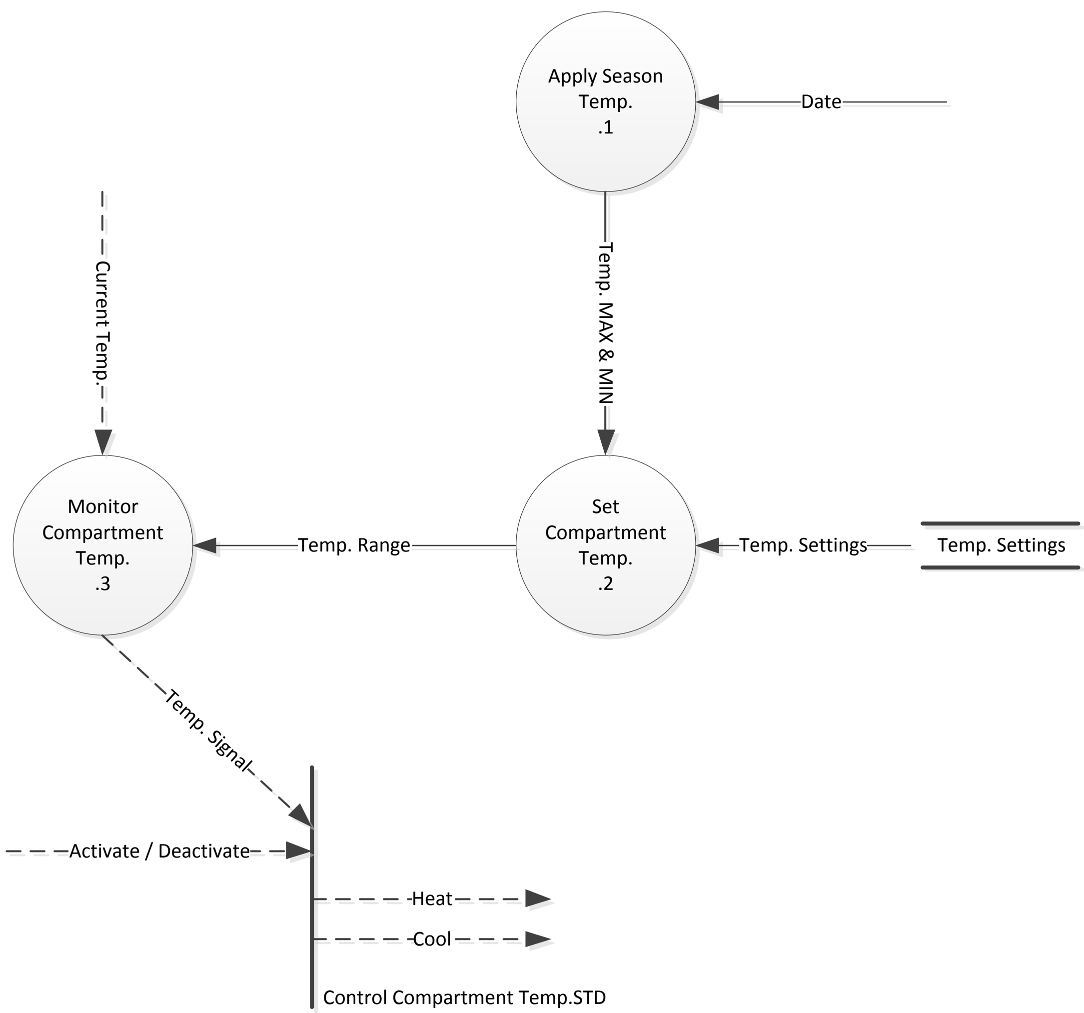

Figure 5: DFD 3 - Data Flow Diagram for Maintain Compartment Temperature

2.6.CSCI Capability Requirements – DFD 4

Figure 6 is the DFD 4 Diagram for Maintain Compartment Temperature in is illustrated by two primitive functions that are briefly described in the (P-Specs) section, and one control node that is also briefly described in the (C-Specs) section.

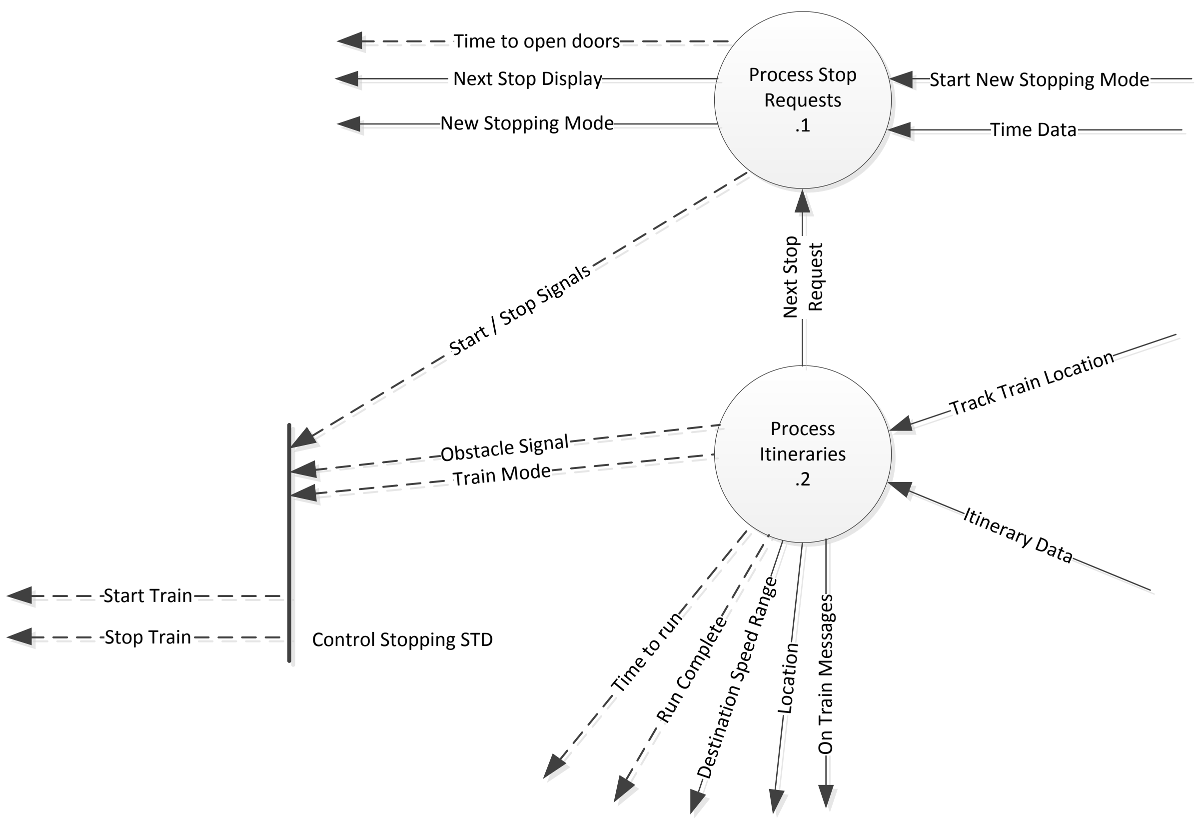

Figure 6: DFD 4 - Data Flow Diagram for Maintain Schedule and Timing

3. CSCI External Interface Requirements

3.1. Interface Identification and Context Diagram

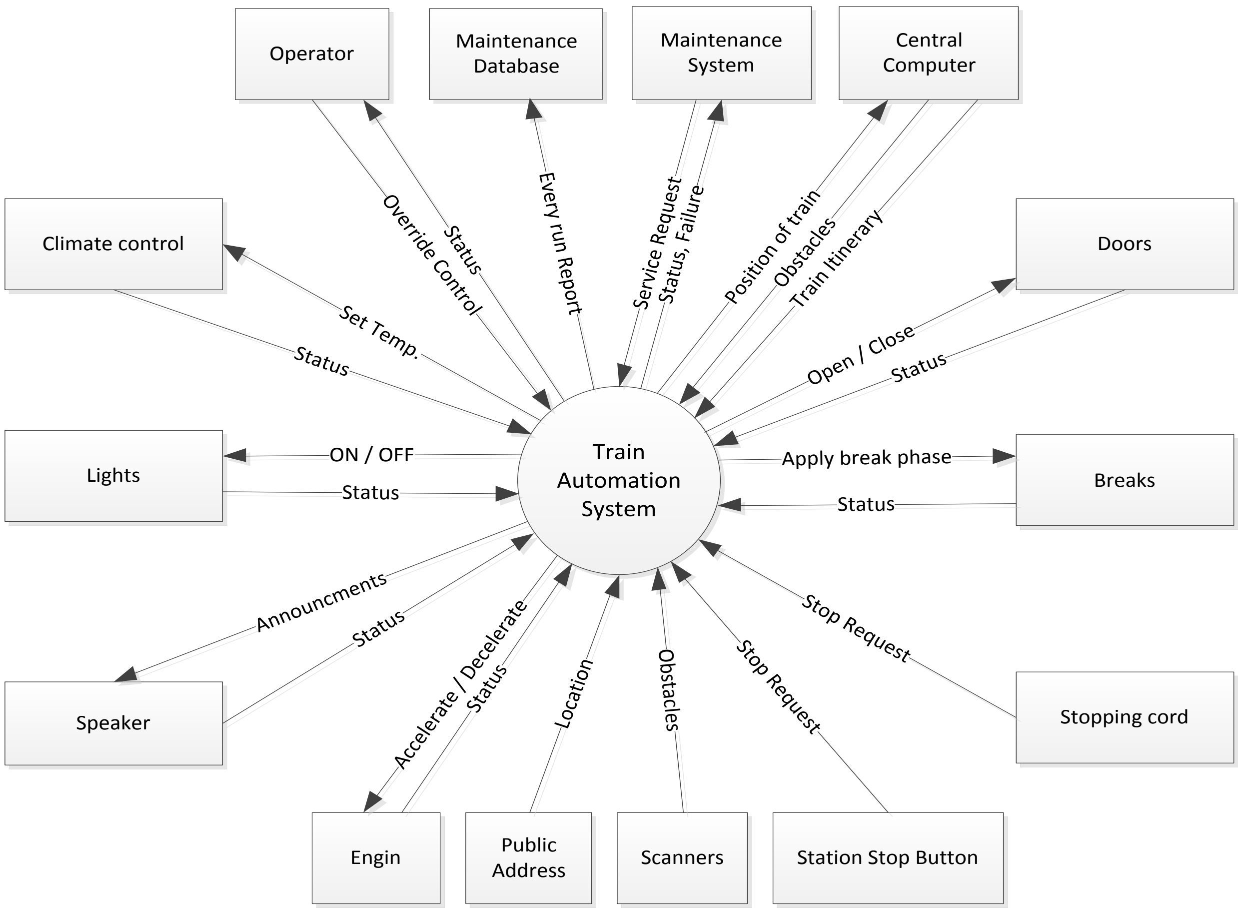

Figure 7: Context Diagram Automated Commuter Train System

3.2. External Interface Data Definitions

- Control Climate

  Set Temp.: Control output of the system to set the temperature

  Status: Data input to the system contains the current temperature reading

- Lights

  ON / OFF: Control output of the system to set the light status on or off

  Status: Data input to the system contains the current status of lights

- Speakers

  Announcements: Control output of the system to select the appropriate announcement to the passengers

  Status: Data input to the system contains the current status of the speakers if they are working or not.

- Engine

  Accelerate / Decelerate: Control output of the system to set the speed

  Status: Data input to the system contains the current speed

- Public Address

  Status: Data input to the system contains the current location

- Scanners

  Obstacles: Data input to the system contains if the scanners sense any obstacles in the train's path

- Station Stop Button

  Stop Request: Control output of the system to stop the train by passengers at the station

- Stopping Cord

  Stop Request: Control output of the system to stop the train by passengers inside the train

- Breaks

  Apply Break Phase: Control output of the system to set the appropriate break phase

  Status: Data input to the system contains the status of breaks if they work or not

- Doors

  Open / Close: Control output of the system to open or close doors based on itinerary or obstacles

  Status: Data input to the system contains the status of doors if they are opend or closed or obstructed

- Control Climate

  Set Temp.: Control output of the system to set the temperature

  Status: Data input to the system contains the current temperature reading

4. CSCI Interface Requirements

4.1. Process Specifications (P-Specs)

4.1.1. P-specs for Primitive of Monitor Train Status

NAME: 1.1

TITLE: Monitor Failures

INPUT/OUTPUT:

system_status: data_in

failures_report: data_out

request_repair: control_out

System_in_good_condition: control_out

BODY: This function monitor the system for failures, and in case of failure, it generate a request repair and failure report

NAME: 1.2

TITLE: Monitor Run

INPUT/OUTPUT:

Engine_data: data_in

Status_signals: control_in

Every_run_report: data_out

BODY: This function monitor each run the train operate, it receives engine data and controls for each run then execute only if the system of the train is in good condition, lastly at end of each run it keep report in the train record which will be transmitted to the maintenance database.

4.1.2. P-Specs for Primitive Functions of Operate Train

NAME: 2.1

TITLE: Time Train

INPUT/OUTPUT:

Time_Data: data_in

Location: data_in

Trigger: control_out

Delay_Doors: control_out

Doors_Open_Time: data_in

Time_to_Close_Doors: control_out

BODY: This function monitor doors opening and closing. Location and Time_Data will indicate which side to open at each stop. When doors open at a stop, a timer will be activated. The timer will tell it is appropriate to close the doors. Delay_Doors closing if obstructed.

NAME: 2.2

TITLE: Monitor Train Speed

INPUT/OUTPUT:

Emergency_Stop : data_in

Target_Speed_Range : data_in

Current_Speed: data_in

Speed_is_Less_Than_Minimum_Speed: control_out

Speed_is_More_Than_Maximum_Speed: control_out

Train_Stopped: control_out

Maximum_Speed=0: control_out

Speed=Stop_Speed: control_out

BODY: This function monitors and regulates train speed. Based on the current speed and target speed range, it provides the following threshold control signals: Speed_is_Less_Than_Minimum_Speed, Speed_is_More_Than_Maximum_Speed, Train_Stopped, Maximum_Speed=0, and/or Speed=Stop_Speed to the controller.

4.1.3. P-specs for Primitive of Maintain Compartment Temperature

NAME: 3.1

TITLE: Apply Season Temp.

INPUT/OUTPUT:

date: data_in

temp_max_min: data_out

BODY: This function checks the temperature according to the current season and applies it by sending out the max & min temperature.

NAME: 3.2

TITLE: Set Compartment Temp

INPUT/OUTPUT:

temp_max_min: data_in

temp_settings: data_in

temp_range: data_out

BODY: This function takes the temperature MAX & MIN and the setting of how to set the temperature then send out the range to monitor it.

NAME: 3.3

TITLE: Monitor Compartment Temp

INPUT/OUTPUT:

temp_range: data_in

Current_temp: control_in

temp_signal: contorl_out

BODY: This function takes the temperature range and the current temperature to specify the appropriate temperature & send control signal to the controller.

4.1.4. P-specs for Primitive Functions of Maintain Compartment Temperature

NAME: 4.1

TITLE: Process Stop Requests

INPUT/OUTPUT:

Start_New_Stopping_Mode: data_in

Time_Data: data_in

Next_Stop_Request: data_in

Time_to_open_doors: control_out

Next_Stop_Display: data_out

New_Stopping_Mode: data_out

Start_/_Stop_Signals: control_out

BODY: This function process stop requests based on the itinerary and the mode.

NAME: 4.2

TITLE: Process Itineraries

INPUT/OUTPUT:

Track_Train_Location: data_in

Itinerary_Data: data_in

On_Train_Messages: data_out

Location: data_out

Destination_Speed_Range: data_out

Next_Stop_Request: data_out

Run_Complete: control_out

Time_to_run: control_out

Train_Mode: control_out

Obstacle_Signal: control_out

BODY: This function process the itinerary and by applying it based on the deferent modes of operations and based on the obstacles provided by the central computer, also it receive data from scanners of the train to track the current location where it also take care of announcing each stop to the passengers.

4.2.Control Specifications (C-Specs)

4.2.1. C-Specs for Operate Train

Figure 8 is the state-transition diagram for the Operate Train STD control in DFD2.

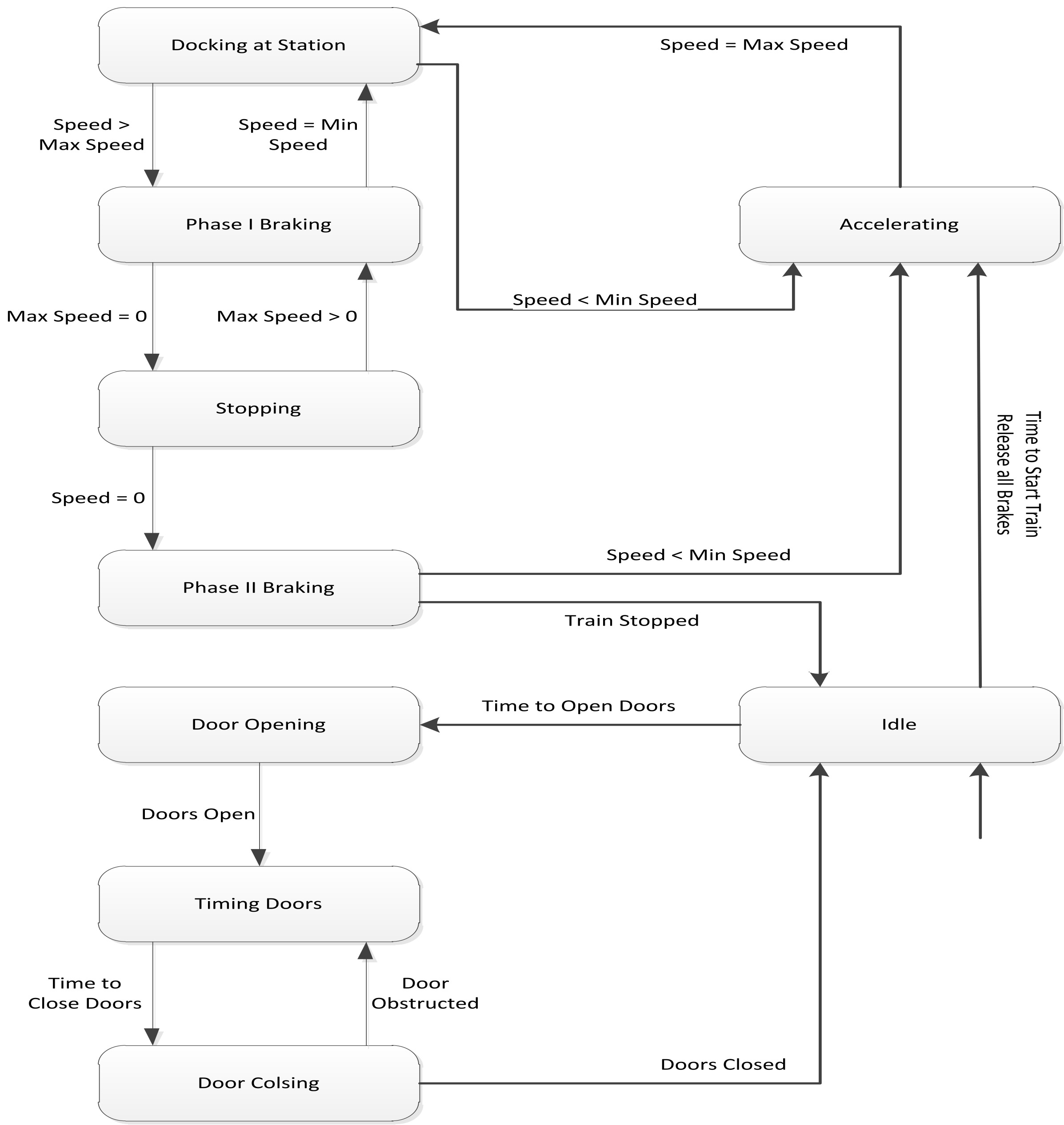

Figure 8: STD 2 - Control Specifications for the Operate Train

4.2.2. C-Specs for Maintain Compartment Temperature

Figure 9 is the state-transition diagram for the Control Compartment Temperature STD control in DFD3. This figure shows how controlling the heater and the cooler procedure work according to the different season temperature settings based on the current date.

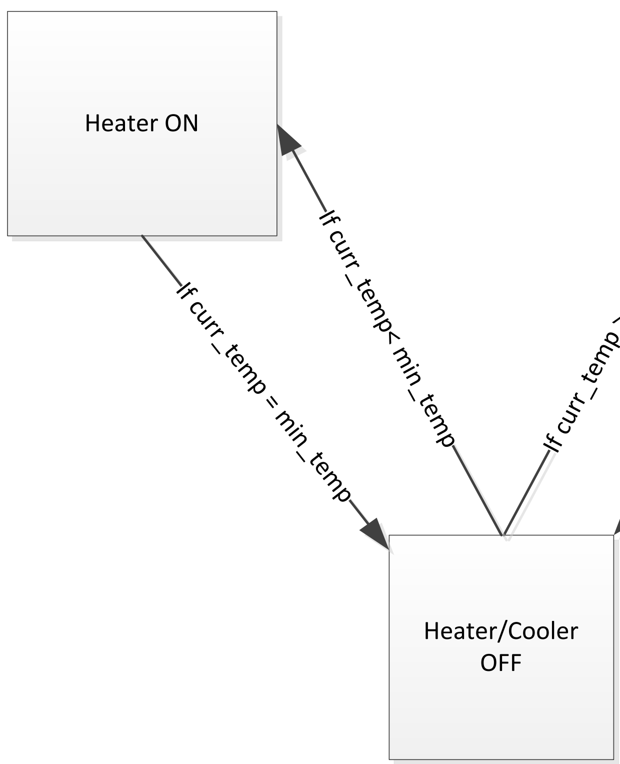

Figure 9: STD 3 - Control Specifications for Maintain Compartment Temperature

4.2.3. C-Specs for Maintain Schedule and Timing

Figure 10 is the state-transition diagram for the Control Stopping STD control in DFD4. This figure shows how stopping procedure work according to the different modes that the train runs at, which are: Local, Express, and Request only mode with regard to the obstacles data that comes from the central computer.

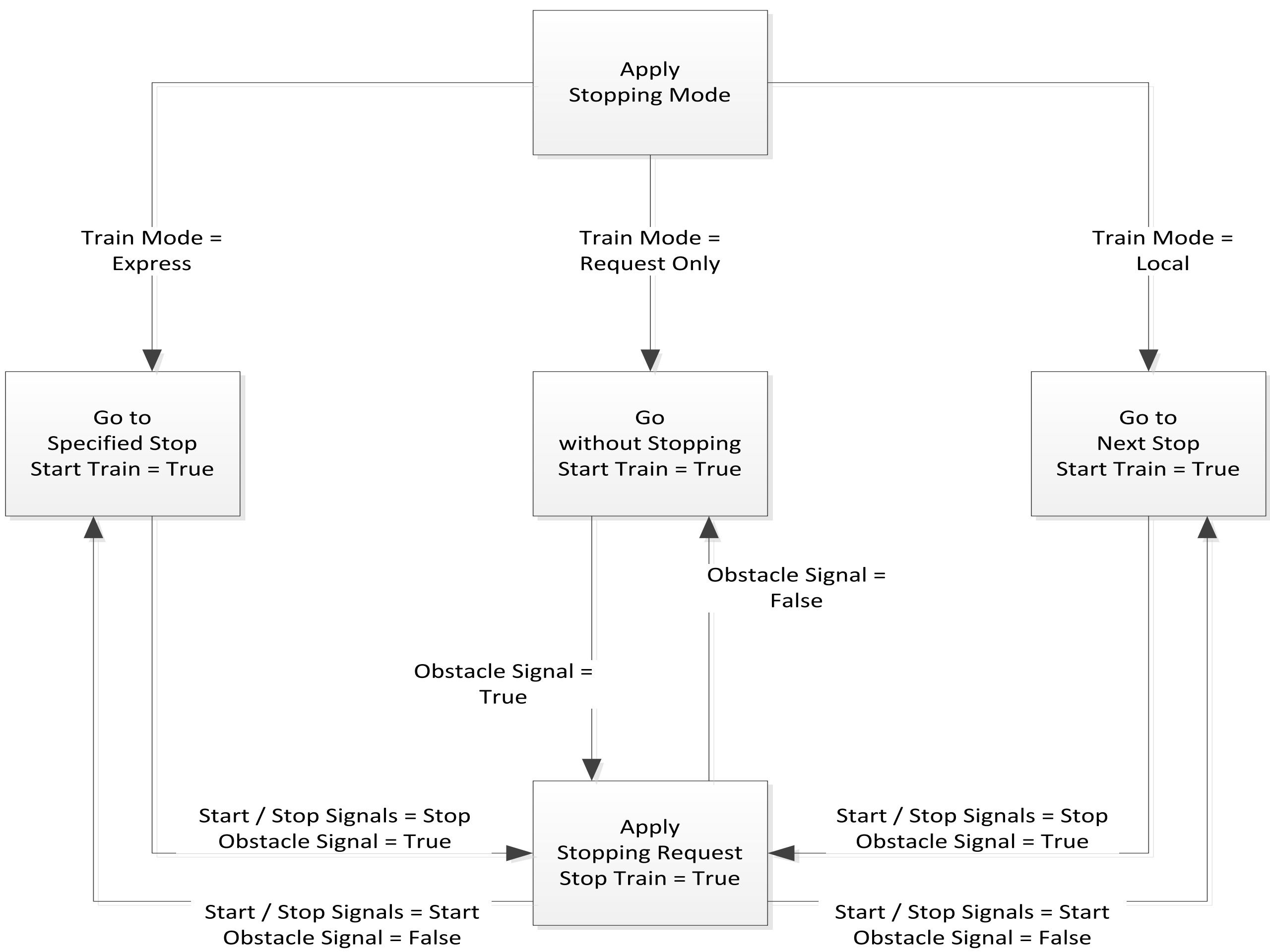

Figure 10: STD 4 - Control Specifications for Maintain Schedule and Timing

5. CSCS Internal Data Requirement

- Temp. Settings Database:

  Purpose: Stores range of temperature settings based on seasons

  Location: DFD 0 - Data Flow Diagram for the Automated Commuter Train

  Inputs/outputs: Temp._Set

- Train Record Database:

  Purpose: Stores each run information to be transferred later to the maintenance database

  Location: DFD 1 - Monitor Train Status

  Inputs/outputs: every_run_report

- Maintenance Database:

  Purpose: Stores all reports of each run of trains

  Location: DFD 1 - Monitor Train Status

  Inputs/outputs: all_run_reports

- Time Settings

  Purpose: Stores doors opening time and delay times

  Location: DFD 2 - Operate Train

  Inputs/outputs: Doors_Open_Time

6. Data Dictionary Entries

1. accelerate_decelerate_signal(control,primitive)
   a. //signal sent to engine to accelerate or decelerate

2. announcments(data,compound)
   a. = train_Next_Stop + itinerary_data

3. apply_break_phase_signal(control, primitive)
   a. [“PHASE1”||”PHASE2”||”SAFETY”||”EMERGENCY”]

4. avery_run_report(data,primitive)
   a. //carry each run information

5. status_failure(data,primitive)
   a. //carry data about train devices status or failure messages

6. location(data,primitive)
   a. //carry data about train current location

7. Obstacles_in_path(data,primitive)
   a. //carry data about obstacles in the path of the train coming from Central Computer

8. Obstacles_from_scanners(data,primitive)
   a. //carry data about obstacles in the path of the train coming from scanners

9. on_off_lights_signal(control,primitive)
   a. [“ON”||”OFF”]

10. open_close_doors_signal(control,primitive)
    a. [“OPEN”||”CLOSE”]

11. override_control_signal(control,primitive)
    a. [“TRUE”||”FALSE”]

12. position_of_train(data,primitive)
    a. //carry data about train current location

13. service_request_signal(control,primitive)
    a. [“TRUE”||”FALSE”]

14. set_temp._signal(control,primitive)
    a. [“AC”||”HEAT”||”NONE”]

15. status_announcement_trigger(control,primitive)
    a. [“ON”||”OFF”]

16. status_climate_control_signal(control,primitive)
    a. [“ON”||”OFF”]

17. status_lights_signal(control,primitive)
    a. [“ON”||”OFF”]

18. status_speakers_signal(control,primitive)
    a. [“ON”||”OFF”]

19. status_engine_signal(control,primitive)
    a. [“ON”||”OFF” ||”Speed”]

20. status_breaks_signal(control,primitive)
    a. [“OK”||”FAILED”]

21. status_doors_signal(control,primitive)
    a. [“OK”||”FAILED”]

22. stop_request_from_station_button(control,primitive)
    a. [“TRUE”||”FALSE”]

23. stop_request_from_stopping_cord(control,primitive)
    a. [“TRUE”||”FALSE”]

24. train_itinerary(data,compound)
    a. //carry data about current itinerary of the train

7. Conclusion

The system requirements analysis for the on-train control system was developed using the specification of SWRA phase in the DOD standard MIL-STD-498 and the structured analysis for real-time systems. The requirement analysis was then realized using Data Flow and Control Flow Diagrams (DFDs/CFDs), Control specifications (C-specs), and Process specifications (P-specs). That includes developing some State Transition Diagrams (STDs) and Data Dictionary for the Train Control System. Furthermore, Data Dictionary Entries was listed.

8. Team Performance

Our group consisted of two members. For the requirements analysis phase, three meetings were held by the team besides communicating via email and online collaboration using Dropbox tool. The first meeting was held in the class after class time and all members were present. The team prepared the system requirements in-class presentation and split the work up into parts. Each member was responsible for developing a different part of the requirements analysis. Then, a meeting was held on February 26th in the Evansdale library. The group communicated using email to develop the initial presentation. After the presentation, the group made updates to their respective diagrams. Finally, a meeting was held on March 14th in the Engineering Sciences Building. All members were present at this meeting. The group discussed the overall report on the system requirements. Overall, the group worked together quite well, and no problems were encountered.

9. Appendix A

9.1. Memorandum of proposal request

The following three memos compose the RFP for the Automated Commuter Train System.

MEMORANDUM

TO: All Bidders

FROM: The Office of the Mayor

SUBJECT: Proposed Automated Commuter Train DATE: October 1, 1999

The City hereby requests proposals for the design and construction of an automated commuter train system to operate throughout the metropolitan area beginning on October 1, 2005. The proposal must provide support for the following requirements.

1.0 The trains in this system will be powered via a third rail. At no point will pedestrians or auto- mobiles have access to the tracks.

2.0 The trains will be fully automated. Each train will be equipped with its own control system to direct and monitor train acceleration, deceleration, stopping patterns, door opening and closing, lighting, climate control, and announcements to passengers. The operator's only charge will be to override the control system in the case of an emergency.

.3.0 Each train will run according to a precise itinerary. Trains will stop and start at the appropriate locations and times. Each train will record this information for every run. It will send this information in a report to the Maintenance Database at the end of each run.

4.0 Each train will be equipped with a self-monitoring engine and with the following automated on- train systems: doors, brakes, lights, public address, and climate control. In the event of a malfunction, manual controls will be enabled and monitored by the on-train control system.

4.1 Each train will have four separate brake systems: phase I brakes for general speed regulation, phase II brakes for stopping the train, emergency brakes for stopping the train in the event of failure by either phase l or II brakes, and safety brakes for extra security when the train stops to load and unload passengers.

4.2 Each train will have two separate door systems, left and right. Itineraries will indicate which side to open at each stop. When doors open at a stop, an on-train timer will be activated. The timer will tell the system when it is appropriate to close the doors, given the stop and the time of day. Doors will not close fully until they are unobstructed.

5.0 The Maintenance Computer System will keep complete and up-to-date records on all trains, communications hardware, and other components of the automated commuter train network. The Maintenance System Database will store service and repair histories for all these components.

6.0 In the event of equipment failure or accident, the on-train control system will notify the Maintenance System automatically, and will provide precise data about the problem. Appropriate data will be made available to maintenance crews before they make service calls.

7.0 Each train will be equipped with scanners to warn it of any obstacles in its path.

MEMORANDUM

TO: All Bidders

FROM: City Planning Department

SUBJECT: Off-Train Systems for Proposed Automated Commuter Train

DATE: October 5. 1999

This memo documents a change to paragraph 7.0 in the Mayor's October 1 memo.

7.1 Information about obstacles in the train's path will come from a Central Computer system. The Central Computer will monitor the positions of all vehicles on all track sections. The Central Computer system will provide information about obstacles in the train's path such as a service vehicle or another train. This system will also warn the train about traffic signals and track switches as well as turns and gradient changes in each section of track.

7.2 A communications network running parallel to the track will link the Central Computer to each train. Messages will pass from train to network {or network to train) via trackside devices located on each track section.

7.3 The Central Computer system will coordinate scheduling data for all trains. It will send an appropriate itinerary to each train in the automated commuter train network. The Central Computer system will be capable of changing the schedule at any time and will disseminate these changes throughout the system via the communications network.

MEMORANDUM

TO: All Bidders

FROM: City Planning Department

SUBJECT: Local, Express. and Request-Only Modes for Proposed Automated Commuter Train

DATE: October 7.1999

The Automated Commuter Train proposal will account for the following additional requirements:

8.0 The automated commuter train will operate in three modes: a Local mode in which it will stop at every stop an Express mode in which it will go directly to a designated stop and bypass all stops in between, and a Request-Only mode in which the train will stop only if prompted by a passenger.

9.0 In Request-Only mode, passengers on the train will prompt the train to stop using the Next Stop cord. Passengers waiting at the next stop will be able to stop an approaching train using a button located at the stop.

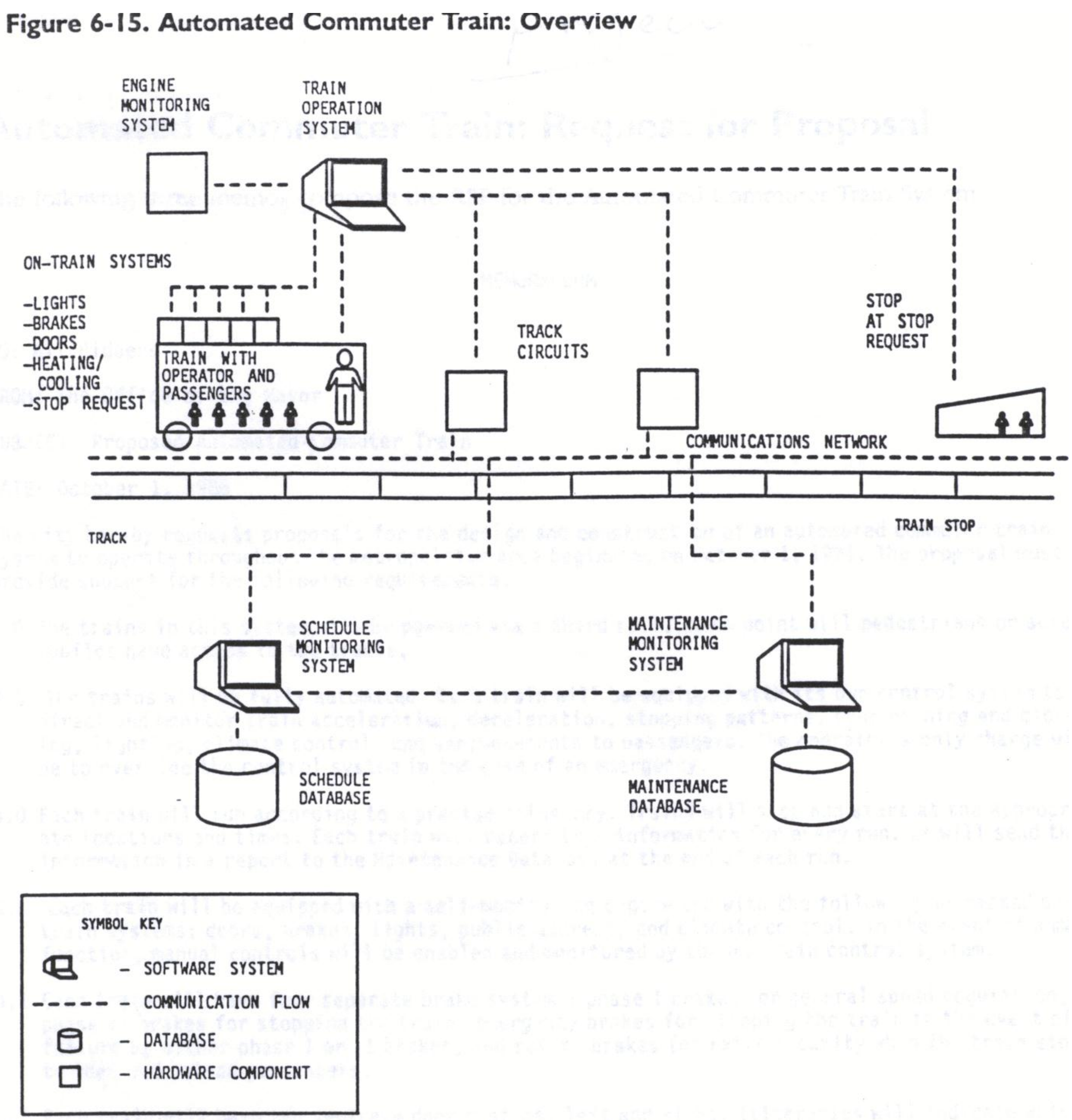

Figure 11: Automated Commuter Train Overview