# CruiseAuto Project – Milestone 3

**INSTRUCTIONS:** Algorithm Evaluation & Improvements

## Introduction

### General Instructions

Read this document carefully. It provides you with all the requirements needed to complete the M3 Answer Sheet and any coding tasks. You are responsible for following all instructions in this document to complete your work. Use professional language in all written responses. See EPS01 for guidelines [link]. Format all plots for technical presentation. See EPSO2 for guidelines [link]. You will submit all deliverables to Gradescope.

### Using & Citing External Resources

When external sources are used, each must be properly cited with (1) an in-text citation referenced in the body of the text and (2) a full citation in *Part 7. References* of the M3 Answer Sheet for each part of this milestone document. Use APA 7th style [help link].

### Milestone 3 Context

This project can be completed using only MATLAB commands that have been taught or used in class materials; however, MATLAB has a huge library of built-in functions not necessarily taught in class that can be very useful. **Beginning in this milestone**, you may begin to refine your algorithm utilizing these built-in functions. **If you decide to use a function that was not taught in class, you must document the function name and how it works.** Write several sentences to thoroughly explain the function, how it operates, and the reason you chose to use it. **Replicating the MATLAB help documentation is neither appropriate nor sufficient.** Failure to demonstrate full understanding of a built-in function that you use in your algorithm will result in point deductions.

# Milestone 3 Instructions

## Part 1: Assignment Header

Complete the following on Page 2 of the M3 Answer Sheet.

### *Team Information*

The assignment header must contain the section number and team ID, team member names, Purdue career account username, and programmer number for each team member in Part 1. *If you are in section 001 and team 3, your section and team ID (SSS_TT) would be 001_03.*

### *Milestone Work Report*

**For this milestone, there will be a need to adapt earlier code and to add new code.** Your team will need to ensure that the coding workload is spread out across the team. The tasks are defined here:

- → Part 3: Update M2 algorithm files based on feedback from M2.
- → Part 4a: Write a new program that analyzes benchmark data.
- → Part 4b: Adapt a new version of your main function to use the benchmark data.
- → Part 5: Write a new program that will plot data and model(s) with the CruiseAuto performance boundaries.

Read the remaining instructions in this document to understand what is expected for each task. Fill in the task assignment column in Part 1 of the M3 Answer Sheet with which task (3, 4a, 4b, or 5) is assigned to each team member.

In the Detailed Description of Work, each person on the team should write their own description of how they contributed to this milestone. Be very detailed here. Then in the last column, your team should estimate the percentage of the work that each team member did on this milestone. **This column needs to add up to 100%.** We know this will vary on any given milestone, but one person in the team should not be doing significantly more than the others throughout the whole project. Use this column as a way for you to make sure your workload is balanced throughout the project.

## Part 2. Milestone 2 Feedback and Reflection

Based on your feedback from M2, identify at least one strength and one limitation of your team's algorithm created in M2. Consider how the feedback from M1 & M2 could lead to improvements in your work. Your reflection should provide a clear, useful summary of your M2 feedback and provide a practical plan to address the issues. Use professional written language to record your answers in Part 2 of the M3 Answer Sheet. Document any references in Part 7 of the M3 Answer Sheet.

## Part 3. Improve your Algorithm

Incorporate any improvements to your algorithm based on the feedback you received on M2. Be sure to fill out Part 8 on the M3 Answer Sheet if you used any MATLAB built-in functions not explicitly taught in class (see Milestone 3 Context for more information). Save any changes to your functions using the naming convention

provided below, where SSS is your section number (e.g., 001 for section 001) and TT is your team number (e.g., 07 for team 7) and login is your Purdue career account username.

→ M3_main_SSS_TT_login.m
→ M3_sub2_SSS_TT_login.m
→ M3_sub3_SSS_TT_login.m
→ M3_sub4_SSS_TT_login.m

Follow this pattern if you made extra subfunctions, appending a short descriptor after "sub#" to differentiate the subfunctions while also indicating which part of the algorithm it represents.

## Part 4. Parameter Output Comparison

Examine the benchmark data and parameters provided to you by CruiseAuto in their recent client memo. You will use this information to determine how well your algorithm performs. There are two main error sources in your output. One is error inherent in the data due to the noise. The other is due to processes in your algorithm. Using CruiseAuto's benchmark data with your algorithm will help you understand how much error is associated with the data and with the parameter identification of your algorithm.

### *Part 4a. Noise Error Quantification*

To measure the error between the collected data and their models, you'll calculate a modified SSE (Sum of Squared Errors) for each vehicle's benchmark datasets. This modified SSE divides the standard SSE by the number of data points, *n*. This gives you the average error per data point.

The modified SSE equation is

$$SSE_{mod} = \frac{\sum_{i=1}^{n}[y_i - f(x_i)]^2}{n}$$

where $y_i$ are the data points from the benchmark data and $f(x_i)$ is the model, which is a piecewise equation that defines the first-order response (explained in more detail in *Addendum 1* of the *M0 – Client Memo & Addenda*).

The piecewise equation is:

$$y(t) = \begin{cases} y_L, & 0 \le t < t_s \\ y_L + (y_H - y_L)\left[1 - \exp\left(-\frac{t - t_s}{\tau}\right)\right], & t \ge t_s \end{cases}$$

Refer to *Table 1* of *M3 – Client Memo* for the benchmark parameters required for this task.

Using the benchmark data and parameters, your team will create a user-defined function named M3_benchmark_SSS_tt.m to measure how well the benchmark data matches the first-order model. In creating this function, you will:

1. Create a figure or set of figures showing each vehicle's benchmark data with its model overlaid. Consider your client when designing your display:
    a. *What is the best way to present the data to aid understanding and readability?*
    b. *How will you differentiate between data and models?*
    c. *Do lines or markers make sense for the data? Remember, you may use lines for data since it is sequential with a large number of data points.*
2. For each vehicle, calculate the $SSE_{mod}$ between the benchmark data and the ideal model using the benchmark parameters provided in the M3 Client Memo. List them in the appropriate column of Table 4b.4 in of the M3 Answer Sheet.
3. Analyze how well the benchmark data matches the first-order model using evidence-based rationales.

Provide all figures and solutions in Part 4a of the M3 Answer Sheet. Use professional written language. Be sure to fill out Part 8 on the M3 Answer Sheet if you used any MATLAB built-in functions not explicitly taught in class (see Milestone 3 Context for more information). Document any external references in Part 7 of the M3 Answer Sheet.

### *Part 4b. Evaluate your Algorithm using Benchmark Data*

Your team will need to update your main function to call and use the new sub-functions created in Part 3. This will help you compare your algorithm's parameter values with the benchmark parameters from the M3 Client Memo.

Save a new copy of your M2 main function and name the updated main function M3_main_SSS_tt.m. Remember, a main function has no input arguments and no output arguments. The new function must perform the following tasks:

1. Load the benchmark data provided with this milestone.
2. Call your subfunctions to find the parameters for the benchmark data.
3. Create plots displaying the benchmark data and the first-order models. *Make sure the plots are clear and useful for the client, following the same principles you used in Part 4a.*
4. Report the parameter values for each vehicle.
5. Calculate the $SSE_{mod}$ for the benchmark data using the parameters reported by your algorithm.
6. For each parameter, calculate the percent error between the benchmark values provided in the M3 Client Memo (reference values) and your algorithm's values (estimated values) using the formula:

$$\text{Percent Error} = \frac{|\text{reference} - \text{estimated}|}{\text{reference}}$$

Provide all figures and solutions in Part 4b of the M3 Answer Sheet. Use professional written language. Be sure to fill out Part 8 on the M3 Answer Sheet if you used any MATLAB built-in functions not explicitly taught in class (see Milestone 3 Context for more information). Document any external references in Part 7 of the M3 Answer Sheet.

## Part 5. Performance Boundaries

For your final project deliverable to the client, you need to justify whether the ACC system maintains its nominal performance with the new tires. To begin, revisit your work from the Project Introduction, where each team member plotted the performance boundaries defined in the initial *M0 - Client Memo and Addenda*. As a team, write a sub-function that generates one or more figures displaying each vehicle's benchmark data and models and the performance boundaries to visualize how the data and models fit within the boundaries. Include any relevant numeric results. Make sure the plots are clear and useful for the client, following the same principles you used in Part 4. Name the sub-function M3_performance_SSS_tt.m. This function will be called within your algorithm to generate analysis results. You will also run this program as part of your algorithm in M4, using the experimental data. The results of your analysis will be part of your justification to the client in your final deliverable.

*Note: the experimental and benchmark data come from experiments with varying acceleration start times. CruiseAuto expects an acceleration start time of 5.0 seconds for the performance boundaries. When creating your images, adjust your data or models to have a start time of 5.0 seconds without changing the shape or pattern of the data.*

Provide all figures and solutions in Part 5 of the M3 Answer Sheet. Use professional written language. Be sure to fill out Part 8 on the M3 Answer Sheet if you used any MATLAB built-in functions not explicitly taught in class (see Milestone 3 Context for more information). Document any external references in Part 7 of the M3 Answer Sheet.

## Part 6. Observations and Improvements

Based on the work your team has completed for M3, you will suggest at least two ways to improve your algorithm based on your plots and SSE results. Describe the improvements with evidence-based justifications. If you feel that you do not need to make changes to your algorithm, based on your benchmark analysis, explain why with evidence-based justifications. **You do not need to code these changes**; at this point, simply describe changes you think might be useful in professional written language in Part 6 of the M3 Answer Sheet.

In your description,

- → explain which parameter(s) your improvement will target,
- → explain the improvement with a level of detail that can be understood by others (provide sketches or flowcharts as necessary to clarify your improvement),
- → describe the performance metrics you will use to determine whether your proposed improvement really does improve your solution, and

→ provide evidence-based rationales for each proposed improvement and the metrics selected. Your rationales should answer the questions:
  - *What is your evidence that this improvement is necessary?*
  - *Why is this method for making the improvement a good idea? Justify it.*
  - *Why is this metric a good idea? Justify it.*

Be sure to fill out Part 8 on the M3 Answer Sheet if you used any MATLAB built-in functions not explicitly taught in class (see Milestone 3 Context for more information). Document any external references in Part 7 of the M3 Answer Sheet.

## Submitting your Deliverables to Gradescope

Once you have completed each of the parts above, you will submit all of your deliverables to the associated Gradescope assignment as a team.

### Submitting to the Team Assignment

1. Save the answer sheet as a PDF named M3_AnswerSheet_SSS_TT.pdf where SSS is your section number (e.g., 001 for section 001) and TT is your team number (e.g., 07 for team 7).
2. Select one person to submit all files for the team. They should log into Gradescope and submit all these files together to the M3 assignment:
   a. M3_AnswerSheet_SSS_TT.pdf
   b. M3_main_SSS_TT_login.m
   c. M3_sub2_SSS_TT_login.m
   d. M3_sub3_SSS_TT_login.m
   e. M3_sub4_SSS_TT_login.m
   f. M3_benchmark_SSS_TT.m
   g. M3_performance_SSS_TT.m
3. Select all team members for the group assignment. [Help Link].
   a. Each team member should confirm that they are part of the submission. Everyone received an email when they were added. You will lose points if you do not include all teammates in the submission.
4. You will see "Autograder" information when you view your submission. Select "Code" in the upper right. That will show all your submission files. The autograder feature is not enabled for this project.
5. After submission, distribute the submitted files to all team members. Ensure all members of the team have copies of the submitted files.

**It is important to note that if you need to resubmit anything for any reason, you must resubmit ALL files for the assignment.** Gradescope will allow for multiple submissions up until the due date. The person who originally submitted should be the one to resubmit. If someone else resubmits, it can create issues where not everyone is tagged in the assignment and you will lose points.