Surrogate Modeling

User Tutorial for the Dynamics Test Benches (Surrogate Modeling)

May 2, 2014

1.0 Purpose

The purpose of the Dynamics Test Benches is to provide the designer with information about the performance of the FANG vehicle over various terrains.

2.0 Procedures

2.1 Installation

Initial installations will be provided with the installation of the CyPhy tool suite. The test benches will be part of the dynamics test bench suite.

2.2 Tool

The suite of Dynamics Test Benches in GME allows the user to query a surrogate model that represents the performance of the FANG vehicle as a function of several input parameters. The CyPhy Interpreter calls upon a python script that contains the surrogate formulas used to characterize performance.

3.0 Requirements tested

- **Cross Country Land Speed:** The maximum speed a vehicle can reach over cross country terrain
- **Level Road Land Speed:** The maximum speed a vehicle can reach over tarmac
- **Level Road Land Range:** The distance that the vehicle can travel on one tank of fuel (183 gallons) at 25 mph steady state
- **Max Speed on 60 Percent Grade:** The maximum speed a vehicle can achieve on a 60% longitudinal grade
- **Acceleration 0 – 32 kph:** The time it takes the vehicle to accelerate to 32 kph (20 mph) at full throttle

4.0 Required components

4.1 Manually specified information

- Vehicle mass for all test benches
- Fuel tank volume for Level_Road_Land_Range test bench

5.0 Theory of Operation

The overall performance of the FANG vehicle has been abstracted to be a function of the total mass of the design. Since the powertrain system of the vehicle has been pre-determined, the mass of the vehicle becomes the predominant factor. The results of the 5 Dynamics Test Benches mentioned above will be extracted when the user clicks on the Master Interpreter button in GME, and the metrics are provided in the testbench_manifest.json for scoring.

5.1 How to Test Vehicle Performance Using a Dynamics Test Bench

This exercise will introduce you to creating and running test benches in the *dynamics suite*. The dynamics suite is the group of test benches found in the **Dynamics** testing folder in the seed design GME project.
Creating and running a dynamics test bench allows you to grade certain dynamics aspects of your vehicle's performance. In this example, you'll determine a vehicle's max speed on cross country terrain using the **Cross_Country_Land_Speed** test bench.

Step 1 - Create a dynamics test bench in GME

First, you'll create a new test bench. A test bench is an add-on app to GME that rates the performance of a given vehicle characteristic.

1. If you haven't done so already, download the FANG Vehicle Seed Design from the Resources page, and extract (unzip) the folder to a location of your choice.
2. Open the Seed Design. If you downloaded and extracted it following step 1, in the downloaded folder, open the GME **.mga** project file whose name begins with "Official_Seed".
3. Expand **RootFolder**.
4. Right-click the **Test_Benches** folder and, from the **Insert Folder** submenu, click **Testing**.
5. Type **Example_Dynamics_Test_Bench** and press **Enter**.

6. Right-click the folder you just created, and, from the **Insert Model** submenu, click **Test Bench**.
7. Type **Cross_Country_Land_Speed** and press **Enter**.
8. View the **Cross_Country_Land_Speed** test bench in the workspace by double-clicking it.

Step 2 - Choose the vehicle or part whose performance you'll test

1. Expand **Seed_Component_Assemblies**.
2. Choose the FANG Vehicle Seed Design as the vehicle or part to test. To do this, using a right-click, drag **FANG_Design** onto the workspace.
3. Click **Create Reference**.
4. Double-click **TopLevelSystemUnderTest**.

Step 3 - Define the test with a workflow and task

First, you'll create a workflow. A workflow is a set of computer-readable directions that instruct a given test bench. For example, a *CAD workflow* instructs its parent test bench to synthesize a virtual design of the vehicle or part so that it can be tested. To create a workflow:

1. Right-click **Example_Dynamics_Test_Bench**.
2. From the **Insert Folder** submenu, click **Workflow Definitions**.
3. Type **Workflow_Definitions** and press **Enter**.
4. Right-click **Workflow_Definitions**.
5. From the **Insert Model** submenu, click **Workflow**.
6. Type **CyPhyPython_Surrogates** and press **Enter**.

Next, you'll create a task. A task is simply an item used to pick its parent workflow's type, such as the "CyPhy2CAD_CSharp" type, that ultimately synthesizes a virtual design of the vehicle or part so that it can be tested. To create a task:

1. In the **GME Browser**, right-click the **CyPhyPython_Surrogates** workflow.
2. From the **Insert Atom** submenu, click **Task**.
3. Pick **CyPhyPython Interpreter** and click **OK**.
4. Press **Enter** to use the assigned name "Task".
5. Double-click the **Task** task to view it in the workspace.
6. Double-click the only item in the workspace, called **Task CyPhyPython**.
7. Click twice in the **name** field, and type **CyPhyPython_Surrogates**.
8. Click twice in the **script_file** field, and type "New_PP\PostProc_SurrogateDynamics.py".
9. Close the **Workflow Parameters** window.
10. Close the active workspace tab.

11. Using a right-click, drag **CyPhyPython_Surrogates** onto the **Cross_Country_Land_Speed** workspace.
12. Click **Create Reference**.

Step 4 - Define input parameters

1. In the **GME Browser**, expand **UnitLibrary QUDT**, then **TypeSpecifications**, then **Units**.
2. Using a right-click, drag **Kilogram** onto the workspace.
3. Click **Create Reference**.
4. Double-click **Parameter**.
5. In the **Object Inspector**, in the **field at the top**, type **Mass**.
6. On the **Attributes** tab, at **Data Type**, pick **Integer**.
7. Also on the Attributes tab, at **Value**, type **27000**.

Step 5 - Pick output metrics

1. From the **Part Browser**, drag the below pictured **Metric** onto the workspace.

2. In the **Object Inspector**, in the **field at the top**, type **Cross_Country_Land_Speed**. When adding this metric to the test bench, it isn't necessary to specify units since the output performance metric you'll later view in the **testbench_manifest.json** file assigns km/hr as the units.

Step 6 - Run the test bench

1. Begin the test bench by, in the toolbar, clicking the **CyPhy Master Interpreter** button .
2. Allow the master interpreter to start up.
3. To the top-left in the **CyPhy Master Interpreter** window, check **Post to META Job Manager** if it isn't.
4. Click **OK**.
5. When the **CAD Options** window appears, check **Use Project Manifest** if it isn't.
6. Click **OK**.
7. Allow a few moments for the test bench to get started.
8. When the **JobManager Configuration** window appears, uncheck **Remote Execution** if it's checked.
9. Click **Save**.

10. In the **Job Manager**, wait until the top row turns green and **Succeeded** appears in the Status column.
11. Right-click the **green row** and click **Show in explorer**.
12. Open **testbench_manifest.json**.
13. Find and view the resulting performance metrics, listed below in the **Metrics** section.

6.0 Metrics

Test Bench #	Metric	Description
1.1	Cross_Country_Land_Speed	Maximum speed (in kph) that the vehicle can achieve over cross country terrain.
1.2	Level_Road_Land_Speed	Maximum speed (in kph) that the vehicle can achieve over tarmac.
3.1	Acc32kph	Time (in seconds) that it takes the vehicle to reach 20 mph from rest.
3.2	Land_Range_on_Level_Ground	Range (in km) that a vehicle can travel at 25mph steady state over tarmac.
17.1	Speed_on_60_Percent_Grade	Speed (in kph) that the vehicle achieved during a wide open throttle maneuver up a 60% grade.

Table 1: Dynamics Test Bench Metrics

7.0 Required Connection to System Under Test

- Vehicle Mass (All dynamics)
- Fuel Tank Volume (Level Road Land Range Only)

8.0 Outputs

8.1 Text

The output of the test bench is in the file: “testbench_manifest.json.”

testbench_manifest.json


```
{
  "Status": "UNEXECUTED",
  "Artifacts": [],
  "VisualizationArtifacts": [],
  "Created": "2014-01-24T21:51:46.3172445Z",
  "DesignID": "{90b2b46c-0183-431a-b239-7c67ee39a281}",
  "DesignName": "FANG_Design",
  "Metrics": [
    {
      "VisualizationArtifacts": [],
      "Description": "",
      "Name": "Cross_Country_Land_Speed",
      "Unit": "km/hr",
      "Value": "65.4752618058136",
      "ID": "996c284c-58d8-4129-9e20-4a1aa6a38f2c",
      "DisplayedName": null,
      "GMEID": "id-0067-00001c49"
    }
  ],
  "Parameters": [
    {
      "Range": "-inf..inf",
      "Description": "",
      "Name": "Mass",
      "Unit": "Kilogram",
      "Value": "27000",
      "ID": "4829d437-9bd9-4c80-b8f5-f16b6d55fd10",
      "DisplayedName": null,
      "GMEID": "id-0067-000022ad"
    }
  ],
  "Steps": [
```


Figure 1: Summary Results sample