

# Open MCT Web Tutorials

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## [Introduction](#)

### [Setting Up Open MCT Web](#)

#### [Prerequisites](#)

#### [Check out Open MCT Web Sources](#)

#### [Configuring Persistence](#)

#### [Run a Web Server](#)

#### [Viewing in Browser](#)

## [Tutorials](#)

### [To-do List](#)

#### [Step 1. Create the Plugin](#)

#### [Step 2. Add a Domain Object Type](#)

#### [Step 3. Add a View](#)

#### [Step 4. Add a Controller](#)

#### [Step 5. Support Editing](#)

#### [Step 6. Customizing Look and Feel](#)

### [Bar Graph](#)

#### [Step 1. Define the View](#)

#### [Step 2. Add a Controller](#)

#### [Step 3. Using Telemetry Data](#)

#### [Step 4. View Configuration](#)

### [Telemetry Adapter](#)

#### [Step 0. Expose Your Telemetry](#)

#### [Step 1. Add a Top-level Object](#)

#### [Step 2. Expose the Telemetry Dictionary](#)

#### [Step 3. Historical Telemetry](#)

#### [Step 4. Real-time Telemetry](#)

# Introduction

## Setting Up Open MCT Web

In this section, we will cover the steps necessary to get a minimal Open MCT Web developer environment up and running. Once we have this, we will be able to proceed with writing plugins as described in this tutorial.

### Prerequisites

This tutorial assumes you have the following software installed. Version numbers record what was used in writing this tutorial; the same steps should work with more recent versions, but this cannot be guaranteed.

- Node.js v0.12.2: <https://nodejs.org/>
- git v1.8.3.4: <http://git-scm.com/>
- Google Chrome v42: <https://www.google.com/chrome/>
- A text editor.

Open MCT Web can be run without any of these tools, provided suitable alternatives are taken; see the Open MCT Web Developer Guide for a more general overview of how to run and deploy a Open MCT Web application.

### Check out Open MCT Web Sources

First step is to check out Open MCT Web from the source repository.

```
git clone https://github.com/nasa/openmctweb.git openmctweb
```

This will create a copy of the Open MCT Web source code repository in the folder `openmctweb` (relative to the path from which you ran the command.)

If you have a repository URL, use that as the “path to repo” above. Alternately, if you received Open MCT Web as a git bundle, the path to that bundle on the local filesystem can be used instead.

At this point, it will also be useful to branch off of Open MCT Web v0.6.2 (which was used when writing these tutorials) to begin adding plugins.

```
cd openmctweb  
git branch <my branch name> open-v0.6.2
```

```
git checkout <my branch name>
```

## Configuring Persistence

In its default configuration, Open MCT Web will try to use ElasticSearch (expected to be deployed at `/elastic` on the same HTTP server running Open MCT Web) to persist user-created domain objects. We don't need that for these tutorials, so we will replace the ElasticSearch plugin with the example persistence plugin. This doesn't actually persist, so anything we create within Open MCT Web will be lost on reload, but that's fine for purposes of these tutorials.

To change this configuration, edit `bundles.json` (at the top level of the Open MCT Web repository) and replace `platform/persistence/elastic` with `example/persistence`.

Before	After
<pre>[   "platform/framework",   "platform/core",   "platform/representation",   "platform/commonUI/about",   "platform/commonUI/browse",   "platform/commonUI/edit",   "platform/commonUI/dialog",   "platform/commonUI/general",   "platform/containment",   "platform/telemetry",   "platform/features/layout",   "platform/features/pages",   "platform/features/plot",   "platform/features/scrolling",   "platform/forms",   "platform/persistence/queue",   "platform/persistence/elastic",   "platform/policy",    "example/generator" ]</pre>	<pre>[   "platform/framework",   "platform/core",   "platform/representation",   "platform/commonUI/about",   "platform/commonUI/browse",   "platform/commonUI/edit",   "platform/commonUI/dialog",   "platform/commonUI/general",   "platform/containment",   "platform/telemetry",   "platform/features/layout",   "platform/features/pages",   "platform/features/plot",   "platform/features/scrolling",   "platform/forms",   "platform/persistence/queue",   "platform/policy",    "example/persistence",   "example/generator" ]</pre>
<b>bundles.json</b>	

## Run a Web Server

The next step is to run a web server so that you can view the Open MCT Web client (including the plugins you add to it) in browser. The HTTP server option that is recommended here, for simplicity, is http-server, <https://www.npmjs.com/package/http-server>.

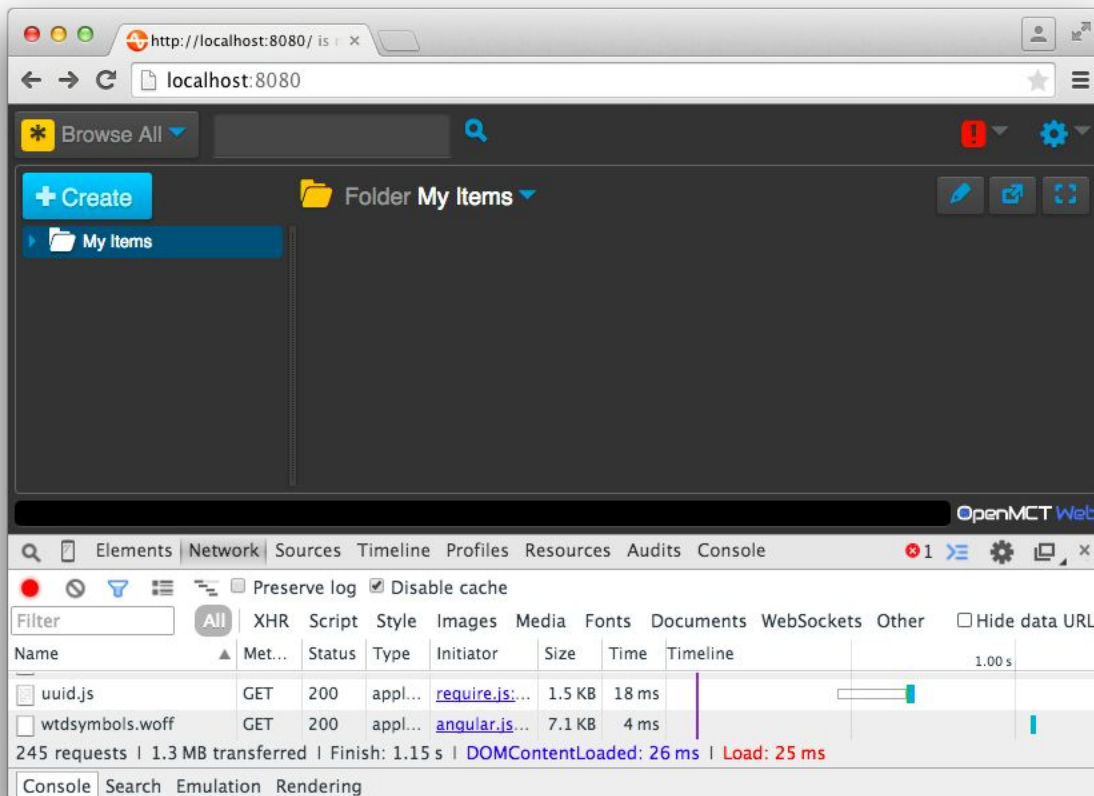
To run:

```
npm install http-server -g
http-server <path to Open MCT Web repository>
```

## Viewing in Browser

Once running, you should be able to view Open MCT Web from your browser at <http://localhost:8080/>. Google Chrome (<https://www.google.com/chrome/>) is recommended for these tutorials, as Chrome is Open MCT Web's "test-to" browser.

The browser cache can sometimes interfere with development (masking changes by using older versions of sources); to avoid this, it is easiest to run Chrome with Developer Tools expanded, and "Disable cache" selected from the Network tab, as shown below.



## Tutorials

These tutorials cover three of the common tasks in Open MCT Web:

- The “to-do list” tutorial illustrates how to add a new application feature.
- The “bar graph” tutorial illustrates how to add a new telemetry visualization.
- The “data set reader” tutorial illustrates how to integrate with a telemetry backend.

### To-do List

The goal of this tutorial is to add a new application feature to Open MCT Web: To-do lists. Users should be able to create and manage these to track items that they need to do. This is modelled after the to-do lists at <http://todomvc.com/>.

## Step 1. Create the Plugin

The first step to adding a new feature to Open MCT Web is to create the plugin which will expose that feature. A plugin in Open MCT Web is represented by what is called a bundle; a bundle, in turn, is a directory which contains a file `bundle.json`, which in turn describes where other relevant sources & resources will be. The syntax of this file is described in more detail in the Open MCT Web Developer Guide.

We will create this file in the directory `tutorials/todo` (we can hereafter refer to this plugin as `tutorials/todo` as well.) We will start with an “empty bundle” - one which exposes no extensions - which looks like:

```
{
  "name": "To-do Plugin",
  "description": "Allows creating and editing to-do lists.",
  "extensions": {
  }
}
```

`tutorials/todo/bundle.json`

We will also include this in our list of active bundles.

Before	After
<pre>[   "platform/framework",   "platform/core",   "platform/representation",   "platform/commonUI/about",   "platform/commonUI/browse",   "platform/commonUI/edit",   "platform/commonUI/dialog",   "platform/commonUI/general",   "platform/containment",   "platform/telemetry",   "platform/features/layout",   "platform/features/pages",   "platform/features/plot",   "platform/features/scrolling",   "platform/forms",   "platform/persistence/queue",   "platform/policy",    "example/persistence",   "example/generator" ]</pre>	<pre>[   "platform/framework",   "platform/core",   "platform/representation",   "platform/commonUI/about",   "platform/commonUI/browse",   "platform/commonUI/edit",   "platform/commonUI/dialog",   "platform/commonUI/general",   "platform/containment",   "platform/telemetry",   "platform/features/layout",   "platform/features/pages",   "platform/features/plot",   "platform/features/scrolling",   "platform/forms",   "platform/persistence/queue",   "platform/policy",    "example/persistence",   "example/generator", ]</pre>

```
    "tutorials/todo"
  ]
}
bundles.json
```

At this point, we can reload Open MCT Web. We haven't introduced any new functionality, so we don't see anything different, but if we run with logging enabled (<http://localhost:8080/?log=info>) and check the browser console, we should see:

```
Resolving extensions for bundle tutorials/todo(To-do Plugin)
```

...which shows that our plugin has loaded.

## Step 2. Add a Domain Object Type

Features in a Open MCT Web application are most commonly expressed as *domain objects* and/or views thereof. A domain object is some thing that is relevant to the work that the Open MCT Web application is meant to support. Domain objects can be created, organized, edited, placed in layouts, and so forth. (For a deeper explanation of domain objects, see the Open MCT Web Developer Guide.)

In the case of our to-do list feature, the to-do list itself is the thing we'll want users to be able to create and edit. So, we will add that as a new type in our bundle definition:

```
{
  "name": "To-do Plugin",
  "description": "Allows creating and editing to-do lists.",
  "extensions": {
    "types": [
      {
        "key": "example.todo",
        "name": "To-Do List",
        "glyph": "j",
        "description": "A list of things that need to be done.",
        "features": ["creation"]
      }
    ]
  }
}
```

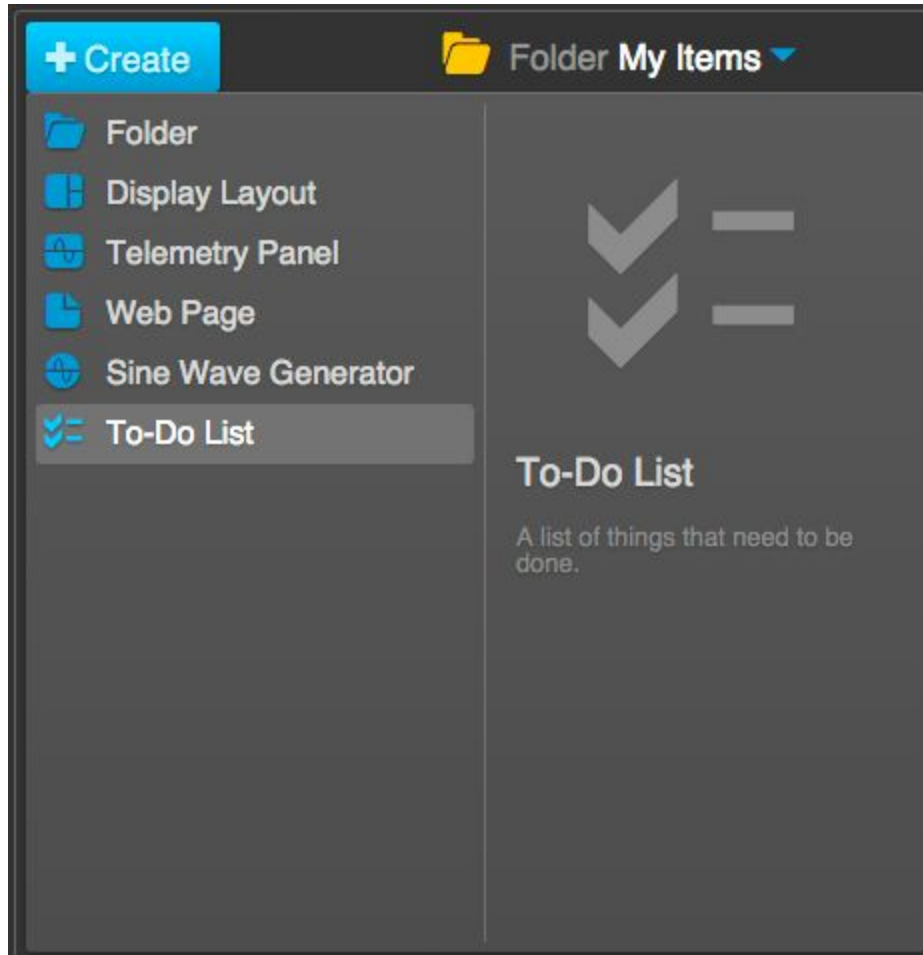


What have we done here? We've stated that this bundle includes extensions of the category `types`, which is used to describe domain object types. Then, we've included a definition for one such extension, which is the to-do list object.

Going through the properties we've defined:

- The key of `example.todo` will be stored as the machine-readable name for domain objects of this type.
- The name of "To-Do List" is the human-readable name for this type, and will be shown to users.
- The `glyph` refers to a special character in Open MCT Web's custom font set; this will be used as an icon.
- The `description` is also human-readable, and will be used whenever a longer explanation of what this type is should be shown.
- Finally, the `features` property describes some special features of objects of this type. Including `creation` here means that we want users to be able to create this (in other cases, we may wish to expose things as domain objects which aren't user-created, in which case we would omit this.)

If we reload Open MCT Web, we see that our new domain object type appears in the Create menu:



At this point, our to-do list doesn't do much of anything; we can create them and give them names, but they don't have any specific functionality attached, because we haven't defined any yet.

### Step 3. Add a View

In order to allow a to-do list to be used, we need to define and display its contents. In Open MCT Web, the pattern that the user expects is that they'll click on an object in the left-hand tree, and see a visualization of it to the right; in Open MCT Web, these visualizations are called *views*.

A view in Open MCT Web is defined by an Angular template. We'll add that in the directory `tutorials/todo/res/templates` (`res` is, by default, the directory where bundle-related resources are kept, and `templates` is where HTML templates are stored by convention.)

```

<div>
  <a href="">All</a>
  <a href="">Incomplete</a>
  <a href="">Complete</a>
</div>

<ul>
  <li ng-repeat="task in model.tasks">
    <input type="checkbox" ng-checked="task.completed">
      {{task.description}}
  </li>
</ul>

```

tutorials/todo/res/templates/todo.html

A summary of what's included:

- At the top, we have some buttons that we will later wire in to allow the user to filter down to either complete or incomplete tasks.
- After that, we have a list of tasks. The scope variable `model` is the model of the domain object being viewed; this contains all of the persistent state associated with that object. This model is effectively just a JSON document, so we can choose what goes into it (so long as we take care not to collide with platform-defined properties; see the Open MCT Web Developer Guide.) Here, we assume that all tasks will be stored in a property `tasks`, and that each will be an object containing a `description` (the readable summary of the task) and a boolean `completed` flag.

To expose this view in Open MCT Web, we need to declare it in our bundle definition:

```

{
  "name": "To-do Plugin",
  "description": "Allows creating and editing to-do lists.",
  "extensions": {
    "types": [
      {
        "key": "example.todo",
        "name": "To-Do List",
        "glyph": "j",
        "description": "A list of things that need to be done.",
        "features": ["creation"]
      }
    ],
    "views": [
      {
        "key": "example.todo",
        "type": "example.todo",

```

```

        "glyph": "j",
        "name": "List",
        "templateUrl": "templates/todo.html"
    }
]
}
}

```

tutorials/todo/bundle.json

Here, we've added another extension, this time belonging to category `views`. It contains the following properties:

- Its `key` is its machine-readable name; we've given it the same name here as the domain object type, but could have chosen any unique name.
- The `type` property tells Open MCT Web that this view is only applicable to domain objects of that type. This means that we'll see this view for To-do Lists that we create, but not for other domain objects (such as Folders.)
- The `glyph` and `name` properties describe the icon and human-readable name for this view to display in the UI where needed (if multiple views are available for To-do Lists, the user will be able to choose one.)
- Finally, the `templateUrl` points to the Angular template we wrote; this path is relative to the bundle's `res` folder.

This template looks like it should display tasks, but we don't have any way for the user to create these yet. As a temporary workaround to test the view, we will specify an initial state for To-do List domain object models in the definition of that type.

```

{
  "name": "To-do Plugin",
  "description": "Allows creating and editing to-do lists.",
  "extensions": {
    "types": [
      {
        "key": "example.todo",
        "name": "To-Do List",
        "glyph": "j",
        "description": "A list of things that need to be done.",
        "features": ["creation"],
        "model": {
          "tasks": [
            { "description": "Add a type", "completed": true },
            { "description": "Add a view" }
          ]
        }
      }
    ],
  },
},

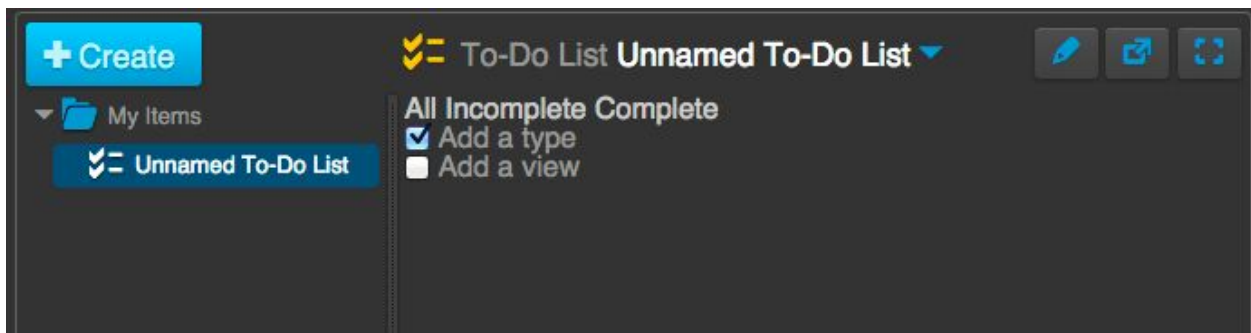
```

```
"views": [
  {
    "key": "example.todo",
    "type": "example.todo",
    "glyph": "j",
    "name": "List",
    "templateUrl": "templates/todo.html"
  }
]
```

tutorials/todo/bundle.json

Now, when To-do List objects are created in Open MCT Web, they will initially have the state described by that `model` property.

If we reload Open MCT Web, create a To-do List, and navigate to it in the tree, we should now see:



This looks roughly like what we want. We'll handle styling later, so let's work on adding functionality. Currently, the filter choices do nothing, and while the checkboxes can be checked/unchecked, we're not actually making the changes in the domain object - if we click over to My Items and come back to our To-Do List, for instance, we'll see that those checkboxes have returned to their initial state.

#### Step 4. Add a Controller

We need to do some scripting to add dynamic behavior to that view. In particular, we want to:

- Filter by complete/incomplete status.
- Change the completion state of tasks in the model.

To do this, we will support this by adding an Angular controller. (See <https://docs.angularjs.org/guide/controller> for an overview of controllers.) We will define that in an AMD module (see <http://requirejs.org/docs/whyamd.html>) in the directory `tutorials/todo/src/controllers` (`src` is, by default, the directory where bundle-related source code is kept, and `controllers` is where Angular controllers are stored by convention.)

```
define(function () {
  function TodoController($scope) {
    var showAll = true,
        showCompleted;

    // Persist changes made to a domain object's model
    function persist() {
      var persistence =
        $scope.domainObject.getCapability('persistence');
      return persistence && persistence.persist();
    }

    // Change which tasks are visible
    $scope.setVisibility = function (all, completed) {
      showAll = all;
      showCompleted = completed;
    };

    // Toggle the completion state of a task
    $scope.toggleCompletion = function (taskIndex) {
      $scope.domainObject.useCapability('mutation', function (model) {
        var task = model.tasks[taskIndex];
        task.completed = !task.completed;
      });
      persist();
    };

    // Check whether a task should be visible
    $scope.showTask = function (task) {
      return showAll || (showCompleted === !(task.completed));
    };
  }

  return TodoController;
});
```

**tutorials/todo/src/controllers/ToDoController.js**

Here, we've defined three new functions and placed them in our `$scope`, which will make them available from the template:

- `setVisibility` changes which tasks are meant to be visible. The first argument is a boolean, which, if true, means we want to show everything; the second argument is the completion state we want to show (which is only relevant if the first argument is falsy.)
- `toggleCompletion` changes whether or not a task is complete. We make the change via the domain object's `mutation` capability, and then persist the change via its `persistence` capability. See the Open MCT Web Developer Guide for more information on these capabilities.
- `showTask` is meant to be used to help decide if a task should be shown, based on the current visibility settings. It is true when we have decided to show everything, or when the completion state matches the state we've chosen. (Note the use of the double-not !! to coerce the completed flag to a boolean, for equality testing.)

Note that these functions make reference to `$scope.domainObject`; this is the domain object being viewed, which is passed into the scope by Open MCT Web prior to our template being utilized.

On its own, this controller merely exposes these functions; the next step is to use them from our template:

```
<div ng-controller="TodoController">
  <div>
    <a ng-click="setVisibility(true)">All</a>
    <a ng-click="setVisibility(false, false)">Incomplete</a>
    <a ng-click="setVisibility(false, true)">Complete</a>
  </div>

  <ul>
    <li ng-repeat="task in model.tasks"
        ng-if="showTask(task)">
      <input type="checkbox"
            ng-checked="task.completed"
            ng-click="toggleCompletion($index)">
      {{task.description}}
    </li>
  </ul>
</div>
```

tutorials/todo/res/templates/todo.html

Summary of changes here:

- First, we surround everything in a `div` which we use to utilize our `TodoController`. This `div` will also come in handy later for styling.
- From our filters at the top, we change the visibility settings when a different option is clicked.

- When showing tasks, we check with `showTask` to see if the task matches current filter settings.
- Finally, when the checkbox for a task is clicked, we make the change in the model via `toggleCompletion`.

If we were to try to run at this point, we'd run into problems because the `TodoController` has not been registered with Angular. We need to first declare it in our bundle definition, as an extension of category controllers:

```
{
  "name": "To-do Plugin",
  "description": "Allows creating and editing to-do lists.",
  "extensions": {
    "types": [
      {
        "key": "example.todo",
        "name": "To-Do List",
        "glyph": "j",
        "description": "A list of things that need to be done.",
        "features": ["creation"],
        "model": {
          "tasks": [
            { "description": "Add a type", "completed": true },
            { "description": "Add a view" }
          ]
        }
      }
    ],
    "views": [
      {
        "key": "example.todo",
        "type": "example.todo",
        "glyph": "j",
        "name": "List",
        "templateUrl": "templates/todo.html"
      }
    ],
    "controllers": [
      {
        "key": "TodoController",
        "implementation": "controllers/TodoController.js",
        "depends": [ "$scope" ]
      }
    ]
  }
}
```

tutorials/todo/bundle.json



In this extension definition we have:

- A `key`, which again is a machine-readable identifier. This is the name that templates will reference.
- An `implementation`, which refers to an AMD module. The path is relative to the `src` directory within the bundle.
- The `depends` property declares the dependencies of this controller. Here, we want Angular to inject `$scope`, the current Angular scope (which, going back to our controller, is expected as our first argument.)

If we reload the browser now, our To-do List looks much the same, but now we are able to filter down the visible list, and the changes we make will stick around if we go to My Items and come back.

## Step 5. Support Editing

We now have a somewhat-functional view of our To-Do List, but we're still missing some important functionality: Adding and removing tasks!

This is a good place to discuss the user interface style of Open MCT Web. Open MCT Web draws a distinction between “using” and “editing” a domain object; in general, you can only make changes to a domain object while in Edit mode, which is reachable from the button with a pencil icon. This distinction helps users keep these tasks separate.

The distinction between “using” and “editing” may vary depending on what domain objects or views are being used. While it may be convenient for a developer to think of “editing” as “any changes made to a domain object,” in practice some of these activities will be thought of as “using.”

For this tutorial we'll consider checking/unchecking tasks as “using” To-Do Lists, and adding/removing tasks as “editing.” We've already implemented the “using” part, in this case, so let's focus on editing.

There are two new pieces of functionality we'll want out of this step:

- The ability to add new tasks.
- The ability to remove existing tasks.

An Editing user interface is typically handled in a tool bar associated with a view. The contents of this tool bar are defined declaratively in a view's extension definition.

```
{  
  "name": "To-do Plugin",
```

```
"description": "Allows creating and editing to-do lists.",
"extensions": {
  "types": [
    {
      "key": "example.todo",
      "name": "To-Do List",
      "glyph": "j",
      "description": "A list of things that need to be done.",
      "features": ["creation"],
      "model": {
        "tasks": [
          { "description": "Add a type", "completed": true },
          { "description": "Add a view" }
        ]
      }
    }
  ],
  "views": [
    {
      "key": "example.todo",
      "type": "example.todo",
      "glyph": "j",
      "name": "List",
      "templateUrl": "templates/todo.html",
      "toolbar": {
        "sections": [
          {
            "items": [
              {
                "text": "Add Task",
                "glyph": "+",
                "method": "addTask",
                "control": "button"
              }
            ]
          },
          {
            "items": [
              {
                "glyph": "Z",
                "method": "removeTask",
                "control": "button"
              }
            ]
          }
        ]
      }
    }
  ],
  "controllers": [
    {
      "key": "TodoController",
      "implementation": "controllers/TodoController.js",
    }
  ]
}
```

```

        "depends": [ "$scope" ]
    }
  ]
}
}

```

tutorials/todo/bundle.json

What we've stated here is that the To-Do List's view will have a toolbar which contains two sections (which will be visually separated by a divider), each of which contains one button. The first is a button labelled "Add Task" that will invoke an `addTask` method; the second is a button with a glyph (which will appear as a trash can in Open MCT Web's custom font set) which will invoke a `removeTask` method. For more information on forms and tool bars in Open MCT Web, see the Open MCT Web Developer Guide.

If we reload and run Open MCT Web, we won't see any tool bar when we switch over to Edit mode. This is because the aforementioned methods are expected to be found on currently-selected elements; we haven't done anything with selections in our view yet, so the Open MCT Web platform will filter this tool bar down to all the applicable controls, which means no controls at all.

To support selection, we will need to make some changes to our controller:

```

define(function () {
  // Form to display when adding new tasks
  var NEW_TASK_FORM = {
    name: "Add a Task",
    sections: [{
      rows: [{
        name: 'Description',
        key: 'description',
        control: 'textfield',
        required: true
      }]
    }]
  };

  function TodoController($scope, dialogService) {
    var showAll = true,
        showCompleted;

    // Persist changes made to a domain object's model
    function persist() {
      var persistence =
        $scope.domainObject.getCapability('persistence');
      return persistence && persistence.persist();
    }

    // Remove a task

```

```

function removeTaskAtIndex(taskIndex) {
    $scope.domainObject.useCapability('mutation', function (model) {
        model.tasks.splice(taskIndex, 1);
    });
    persist();
}

// Add a task
function addNewTask(task) {
    $scope.domainObject.useCapability('mutation', function (model) {
        model.tasks.push(task);
    });
    persist();
}

// Change which tasks are visible
$scope.setVisibility = function (all, completed) {
    showAll = all;
    showCompleted = completed;
};

// Toggle the completion state of a task
$scope.toggleCompletion = function (taskIndex) {
    $scope.domainObject.useCapability('mutation', function (model) {
        var task = model.tasks[taskIndex];
        task.completed = !task.completed;
    });
    persist();
};

// Check whether a task should be visible
$scope.showTask = function (task) {
    return showAll || (showCompleted === !(task.completed));
};

// Handle selection state in edit mode
if ($scope.selection) {
    // Expose the ability to select tasks
    $scope.selectTask = function (taskIndex) {
        $scope.selection.select({
            removeTask: function () {
                removeTaskAtIndex(taskIndex);
            }
        });
    };
}

// Expose a view-level selection proxy
$scope.selection.proxy({
    addTask: function () {
        dialogService.getUserInput(NEW_TASK_FORM, {})
            .then(addNewTask);
    }
});

```

```

        });
    }
}

return TodoController;
});

```

tutorials/todo/src/controllers/ToDoController.js

There are a few changes to pay attention to here. Let's review them:

- At the top, we describe the form that should be shown to the user when they click the Add Task button. This form is described declaratively, and populates an object that has the same format as tasks in the `tasks` array of our To-Do List's model.
- We've added an argument to the `ToDoController`: The `dialogService`, which is exposed by the Open MCT Web platform to handle showing dialogs.
- Some utility functions for handling the actual adding and removing of tasks. These use the `mutation` capability to modify the `tasks` in the To-Do List's model.
- Finally, we check for the presence of a `selection` object in our scope. This object is provided by Edit mode to manage current selections for editing. When it is present, we expose a `selectTask` function to our scope to allow selecting individual tasks; when this occurs, we expose an object to `selection` which has a `removeTask` method, as expected by the tool bar we've defined. We additionally expose a view proxy, to handle view-level changes (e.g. not associated with any specific selected object); this has an `addTask` method, which again is expected by the tool bar we've defined.

Additionally, we need to make changes to our template to select specific tasks in response to some user gesture. Here, we will select tasks when a user clicks the description.

```

<div ng-controller="ToDoController">
  <div>
    <a ng-click="setVisibility(true)">All</a>
    <a ng-click="setVisibility(false, false)">Incomplete</a>
    <a ng-click="setVisibility(false, true)">Complete</a>
  </div>

  <ul>
    <li ng-repeat="task in model.tasks"
        ng-if="showTask(task)">
      <input type="checkbox"
            ng-checked="task.completed"
            ng-click="toggleCompletion($index)">
      <span ng-click="selectTask($index)">
        {{task.description}}
      </span>
    </li>
  </ul>

```

```
</ul>
</div>
```

```
tutorials/todo/res/templates/todo.html
```

Finally, the `TodoController` uses the `dialogService` now, so we need to declare that dependency in its extension definition:

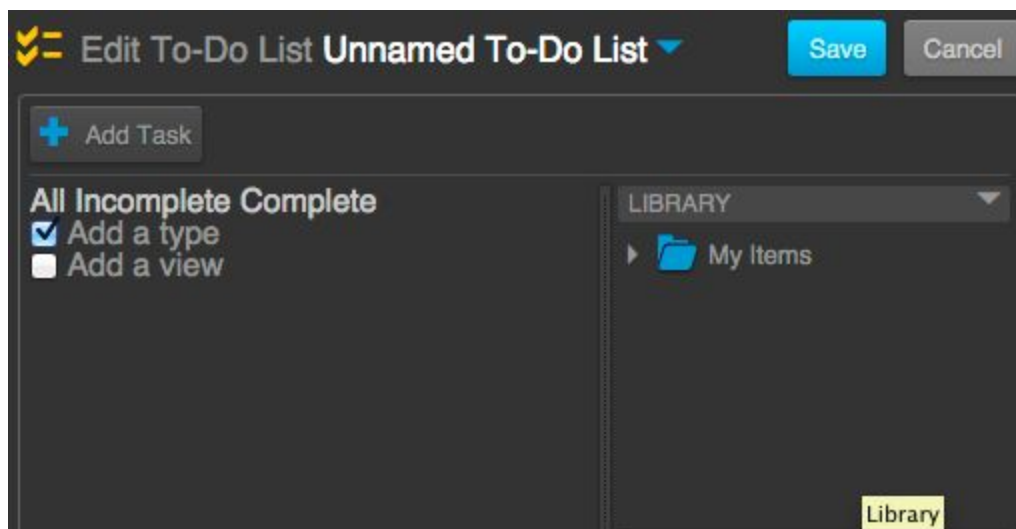
```
{
  "name": "To-do Plugin",
  "description": "Allows creating and editing to-do lists.",
  "extensions": {
    "types": [
      {
        "key": "example.todo",
        "name": "To-Do List",
        "glyph": "j",
        "description": "A list of things that need to be done.",
        "features": ["creation"],
        "model": {
          "tasks": [
            { "description": "Add a type", "completed": true },
            { "description": "Add a view" }
          ]
        }
      }
    ],
    "views": [
      {
        "key": "example.todo",
        "type": "example.todo",
        "glyph": "j",
        "name": "List",
        "templateUrl": "templates/todo.html",
        "toolbar": {
          "sections": [
            {
              "items": [
                {
                  "text": "Add Task",
                  "glyph": "+",
                  "method": "addTask",
                  "control": "button"
                }
              ]
            }
          ],
          {
            "items": [
              {
                "glyph": "Z",

```

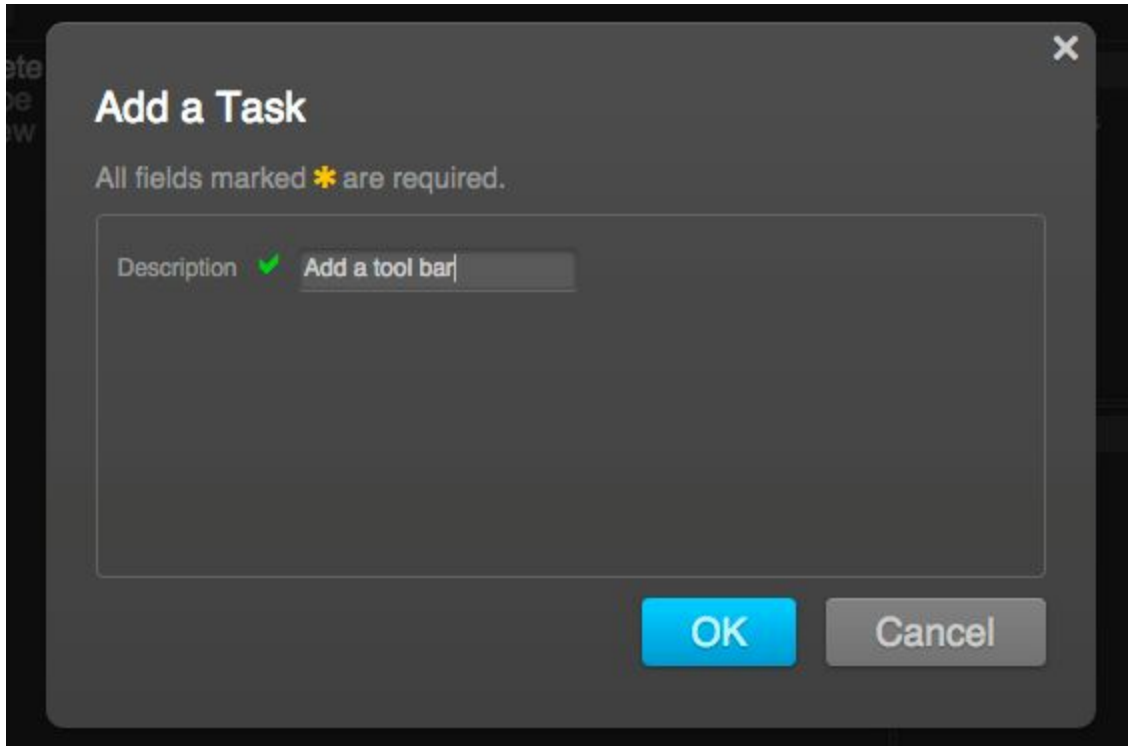
```
        "method": "removeTask",
        "control": "button"
      }
    ]
  },
  ],
  "controllers": [
    {
      "key": "TodoController",
      "implementation": "controllers/TodoController.js",
      "depends": [ "$scope", "dialogService" ]
    }
  ]
}
}
```

tutorials/todo/bundle.json

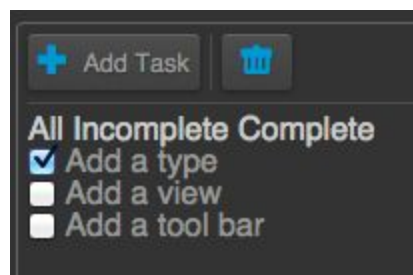
If we now reload Open MCT Web, we'll be able to see the new functionality we've added. If we Create a new To-Do List, navigate to it, and click the button with the Pencil icon in the top-right, we'll be in edit mode. We see, first, that our "Add Task" button appears in the tool bar:



If we click on this, we'll get a dialog allowing us to add a new task:



Finally, if we click on the description of a specific task, we'll see a new button appear, which we can then click on to remove that task:



As always in Edit mode, the user will be able to Save or Cancel any changes they have made.

In terms of functionality, our To-Do List can do all the things we want, but the appearance is still lacking. In particular, we can't distinguish our current filter choice or our current selection state.

## Step 6. Customizing Look and Feel

In this section, our goal is to:

- Display the current filter choice.



- Display the current task selection (when in Edit mode.)
- Tweak the general aesthetics to our liking.
- Get rid of those default tasks (we can create our own now.)

To support the first two, we'll need to expose some methods for checking these states in the controller:

```
define(function () {
  // Form to display when adding new tasks
  var NEW_TASK_FORM = {
    name: "Add a Task",
    sections: [{
      rows: [{
        name: 'Description',
        key: 'description',
        control: 'textfield',
        required: true
      }]
    }]
  };

  function TodoController($scope, dialogService) {
    var showAll = true,
        showCompleted;

    // Persist changes made to a domain object's model
    function persist() {
      var persistence =
        $scope.domainObject.getCapability('persistence');
      return persistence && persistence.persist();
    }

    // Remove a task
    function removeTaskAtIndex(taskIndex) {
      $scope.domainObject.useCapability('mutation', function (model) {
        model.tasks.splice(taskIndex, 1);
      });
      persist();
    }

    // Add a task
    function addNewTask(task) {
      $scope.domainObject.useCapability('mutation', function (model) {
        model.tasks.push(task);
      });
      persist();
    }

    // Change which tasks are visible
    $scope.setVisibility = function (all, completed) {
```

```

        showAll = all;
        showCompleted = completed;
    };

    // Check if current visibility settings match
    $scope.checkVisibility = function (all, completed) {
        return showAll ? all : (completed === showCompleted);
    };

    // Toggle the completion state of a task
    $scope.toggleCompletion = function (taskIndex) {
        $scope.domainObject.useCapability('mutation', function (model) {
            var task = model.tasks[taskIndex];
            task.completed = !task.completed;
        });
        persist();
    };

    // Check whether a task should be visible
    $scope.showTask = function (task) {
        return showAll || (showCompleted === !(task.completed));
    };

    // Handle selection state in edit mode
    if ($scope.selection) {
        // Expose the ability to select tasks
        $scope.selectTask = function (taskIndex) {
            $scope.selection.select({
                removeTask: function () {
                    removeTaskAtIndex(taskIndex);
                    $scope.selection.deselect();
                },
                taskIndex: taskIndex
            });
        };

        // Expose a check for current selection state
        $scope.isSelected = function (taskIndex) {
            return ($scope.selection.get() || {}).taskIndex ===
taskIndex;
        };

        // Expose a view-level selection proxy
        $scope.selection.proxy({
            addTask: function () {
                dialogService.getUserInput(NEW_TASK_FORM, {})
                    .then(addNewTask);
            }
        });
    }
}

return TodoController;

```

```
});
```

```
tutorials/todo/src/controllers/ToDoController.js
```

A summary of these changes:

- `checkVisibility` has the same arguments as `setVisibility`, but instead of making a change, it simply returns a boolean true/false indicating whether those settings are in effect. The logic reflects the fact that the second parameter is ignored when showing all.
- To support checking for selection, the index of the currently-selected task is tracked as part of the selection object.
- Finally, an `isSelected` function is exposed which checks if the indicated task is currently selected, using the index from above.

Additionally, we will want to define some CSS rules in order to reflect these states visually, and to generally improve the appearance of our view. We add another file to the `res` directory of our bundle; this time, it is `css/todo.css` (with the `css` directory again being a convention.)

```
.example-todo div.example-button-group {
  margin-top: 12px;
  margin-bottom: 12px;
}

.example-todo .example-button-group a {
  padding: 3px;
  margin: 3px;
}

.example-todo .example-button-group a.selected {
  border: 1px gray solid;
  border-radius: 3px;
  background: #444;
}

.example-todo .example-task-completed .example-task-description {
  text-decoration: line-through;
  opacity: 0.75;
}

.example-todo .example-task-description.selected {
  background: #46A;
  border-radius: 3px;
}

.example-todo .example-message {
```

```
font-style: italic;
}
```

tutorials/todo/res/css/todo.css

Here, we have defined classes and appearances for:

- Our filter choosers (`example-button-group`).
- Our selected and/or completed tasks (`example-task-description`).
- A message, which we will add next, to display when there are no tasks (`example-message`).

To include this CSS file in our running instance of Open MCT Web, we need to declare it in our bundle definition, this time as an extension of category `stylesheets`:

```
{
  "name": "To-do Plugin",
  "description": "Allows creating and editing to-do lists.",
  "extensions": {
    "types": [
      {
        "key": "example.todo",
        "name": "To-Do List",
        "glyph": "j",
        "description": "A list of things that need to be done.",
        "features": ["creation"],
        "model": {
          "tasks": []
        }
      }
    ],
    "views": [
      {
        "key": "example.todo",
        "type": "example.todo",
        "glyph": "j",
        "name": "List",
        "templateUrl": "templates/todo.html",
        "toolbar": {
          "sections": [
            {
              "items": [
                {
                  "text": "Add Task",
                  "glyph": "+",
                  "method": "addTask",
                  "control": "button"
                }
              ]
            }
          ]
        }
      }
    ]
  }
}
```

```

        }
      ],
    },
    {
      "items": [
        {
          "glyph": "Z",
          "method": "removeTask",
          "control": "button"
        }
      ]
    }
  ]
},
"controllers": [
  {
    "key": "TodoController",
    "implementation": "controllers/TodoController.js",
    "depends": [ "$scope", "dialogService" ]
  }
],
"stylesheets": [
  {
    "stylesheetUrl": "css/todo.css"
  }
]
}
}

```

tutorials/todo/bundle.json

Note that we've also removed our placeholder tasks from the `model` of the To-Do List's type above; now To-Do Lists will start off empty.

Finally, let's utilize these changes from our view's template:

```

<div ng-controller="TodoController" class="example-todo">
  <div class="example-button-group">
    <a ng-class="{ selected: checkVisibility(true) }"
      ng-click="setVisibility(true)">All</a>
    <a ng-class="{ selected: checkVisibility(false, false) }"
      ng-click="setVisibility(false, false)">Incomplete</a>
    <a ng-class="{ selected: checkVisibility(false, true) }"
      ng-click="setVisibility(false, true)">Complete</a>
  </div>

  <ul>

```

```

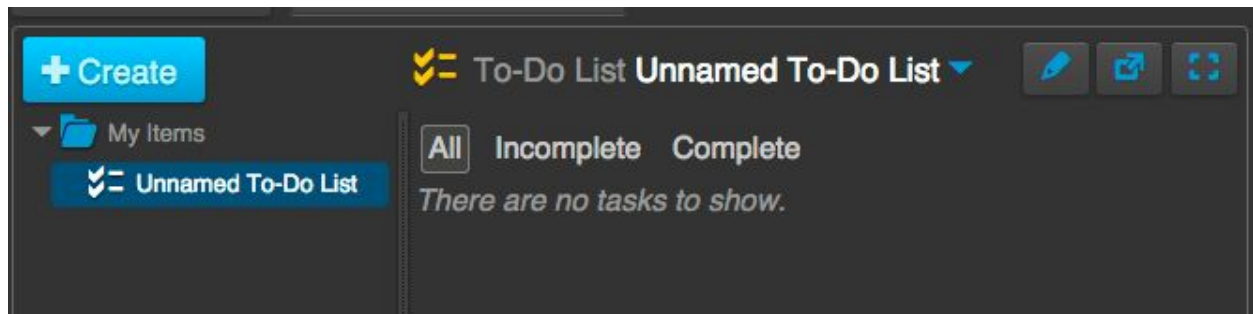
<li ng-repeat="task in model.tasks"
  ng-class="{ 'example-task-completed': task.completed }"
  ng-if="showTask(task)">
  <input type="checkbox"
    ng-checked="task.completed"
    ng-click="toggleCompletion($index)">
  <span ng-click="selectTask($index)"
    ng-class="{ selected: isSelected($index) }"
    class="example-task-description">
    {{task.description}}
  </span>
</li>
</ul>

<div ng-if="model.tasks.length < 1" class="example-message">
  There are no tasks to show.
</div>
</div>

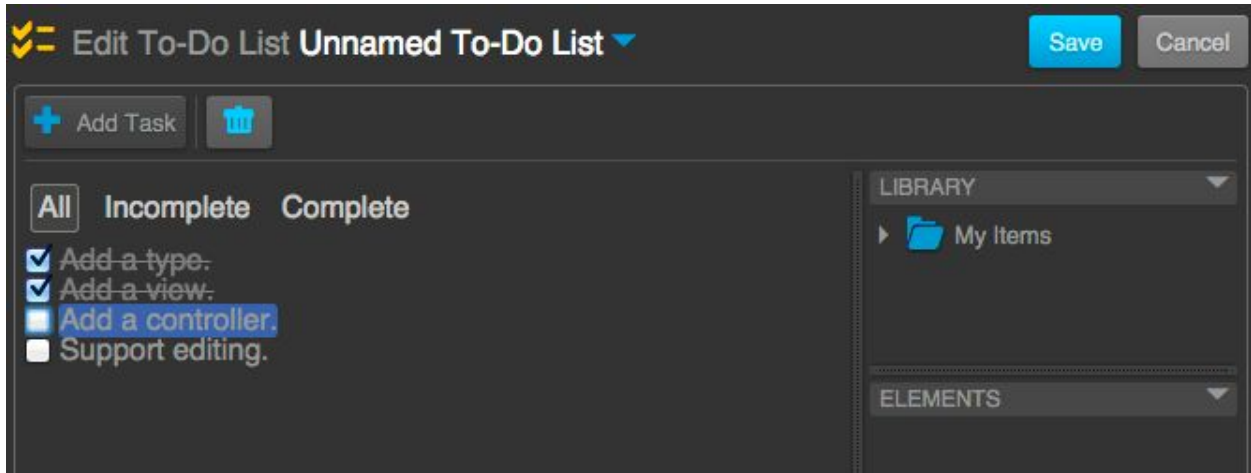
```

tutorials/todo/res/templates/todo.html

Now, if we reload our page and create a new To-Do List, we will initially see:



If we then go into Edit mode, add some tasks, and select one, it will now be much clearer what the current selection is (e.g. before we hit the remove button in the toolbar):



## Bar Graph

In this tutorial, we will look at creating a bar graph plugin for visualizing telemetry data. Specifically, we want some bars that raise and lower to match the observed state of real-time telemetry; this is particularly useful for monitoring things like battery charge levels.

It is recommended that the reader completes (or is familiar with) the To-Do List tutorial before completing this tutorial, as certain concepts discussed there will be addressed in more brevity here.

### Step 1. Define the View

Since the goal is to introduce a new view and expose it from a plugin, we will want to create a new bundle which declares an extension of `category views`. We'll also be defining some custom styles, so we'll include that extension as well. We'll be creating this plugin in `tutorials/bargraph`, so our initial bundle definition looks like:

```
{
  "name": "Bar Graph",
  "description": "Provides the Bar Graph view of telemetry elements.",
  "extensions": {
    "views": [
      {
        "name": "Bar Graph",
        "key": "example.bargraph",
        "glyph": "H",
        "templateUrl": "templates/bargraph.html",
        "needs": [ "telemetry" ],
        "delegation": true
      }
    ]
  },
}
```

```

    "stylesheets": [
      {
        "stylesheetUrl": "css/bargraph.css"
      }
    ]
  }
}

```

tutorials/bargraph/bundle.json

The view definition should look familiar after the To-Do List tutorial, with some additions:

- The `needs` property indicates that this view is only applicable to domain objects with a `telemetry` capability. This ensures that this view is available for telemetry points, but not for other objects (like folders.)
- The `delegation` property indicates that the above constraint can be satisfied via capability delegation; that is, by domain objects which delegate the `telemetry` capability to their contained objects. This allows this view to be used for Telemetry Panel objects as well as for individual telemetry-providing domain objects.

For this tutorial, we'll assume that we've sketched out our template and CSS file ahead of time to describe the general look we want for the view. These look like:

```

<div class="example-bargraph">
  <div class="example-tick-labels">
    <div class="example-tick-label" style="bottom: 0%">High</div>
    <div class="example-tick-label" style="bottom: 50%">Middle</div>
    <div class="example-tick-label" style="bottom: 100%">Low</div>
  </div>

  <div class="example-graph-area">
    <div style="left: 0; width: 33.3%;" class="example-bar-holder">
      <div class="example-bar" style="top: 25%; bottom: 50%;">
      </div>
    </div>
    <div style="left: 33.3%; width: 33.3%;" class="example-bar-holder">
      <div class="example-bar" style="top: 40%; bottom: 10%;">
      </div>
    </div>
    <div style="left: 66.6%; width: 33.3%;" class="example-bar-holder">
      <div class="example-bar" style="top: 30%; bottom: 40%;">
      </div>
    </div>
    <div style="bottom: 50%" class="example-graph-tick">
    </div>
  </div>

```



```

<div class="example-bar-labels">
  <div style="left: 0; width: 33.3%;"
    class="example-bar-holder example-label">
    Label A
  </div>
  <div style="left: 33.3%; width: 33.3%;"
    class="example-bar-holder example-label">
    Label B
  </div>
  <div style="left: 66.6%; width: 33.3%;"
    class="example-bar-holder example-label">
    Label C
  </div>
</div>
</div>

```

<tutorials/bargraph/res/templates/bargraph.html>

Here, three regions are defined. The first will be for tick labels along the vertical axis, showing the numeric value that certain heights correspond to. The second will be for the actual bar graphs themselves; three are included here. The third is for labels along the horizontal axis, which will indicate which bar corresponds to which telemetry point. Inline `style` attributes are used wherever dynamic positioning (handled by a script) is anticipated.

The corresponding CSS file which styles and positions these elements:

```

.example-bargraph {
  position: absolute;
  top: 0;
  bottom: 0;
  right: 0;
  left: 0;
  mid-width: 160px;
  min-height: 160px;
}

.example-bargraph .example-tick-labels {
  position: absolute;
  left: 0;
  top: 24px;
  bottom: 32px;
  width: 72px;
  font-size: 75%;
}

.example-bargraph .example-tick-label {
  position: absolute;
  right: 0;
  height: 1em;
  margin-bottom: -0.5em;
}

```

```
padding-right: 6px;
text-align: right;
}

.example-bargraph .example-graph-area {
  position: absolute;
  border: 1px gray solid;
  left: 72px;
  top: 24px;
  bottom: 32px;
  right: 0;
}

.example-bargraph .example-bar-labels {
  position: absolute;
  left: 72px;
  bottom: 0;
  right: 0;
  height: 32px;
}

.example-bargraph .example-bar-holder {
  position: absolute;
  top: 0;
  bottom: 0;
}

.example-bargraph .example-graph-tick {
  position: absolute;
  width: 100%;
  height: 1px;
  border-bottom: 1px gray dashed;
}

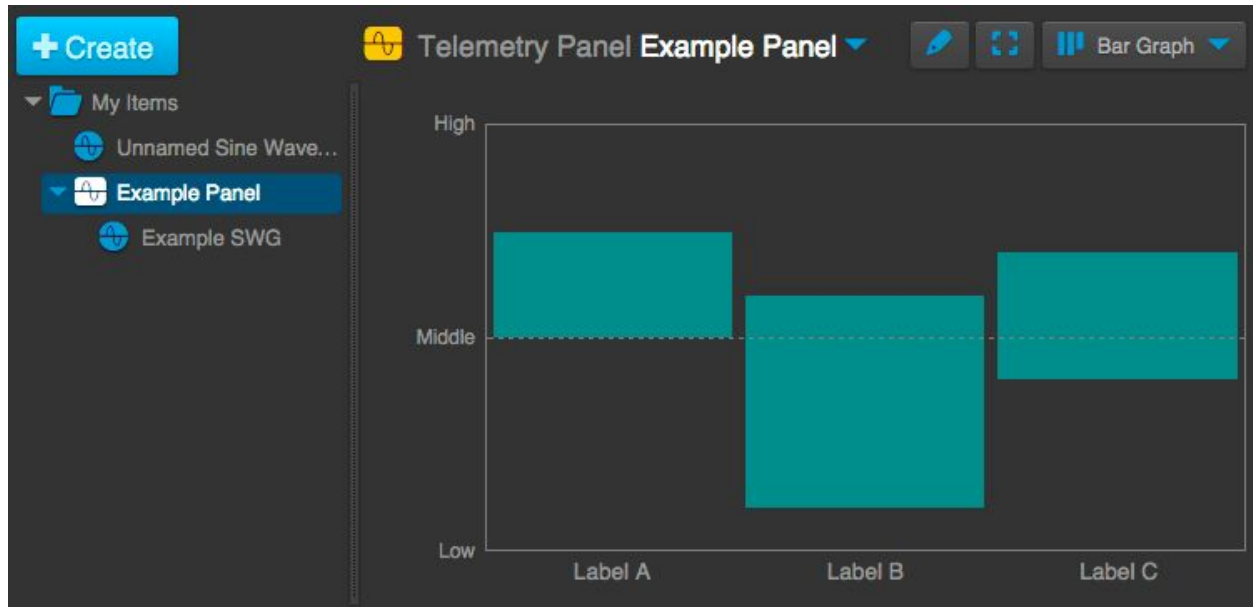
.example-bargraph .example-bar {
  position: absolute;
  background: darkcyan;
  right: 4px;
  left: 4px;
}

.example-bargraph .example-label {
  text-align: center;
  font-size: 85%;
  padding-top: 6px;
}
```

**tutorials/bargraph/res/css/bargraph.css**

This is already enough that, if we add “tutorials/bargraph” to bundles.json, we should be able to run Open MCT Web and see our Bar Graph as an available view for domain objects

which provide telemetry (such as the example Sine Wave Generator) as well as for Telemetry Panel objects:



This means that our remaining work will be to populate and position these elements based on the actual contents of the domain object.

## Step 2. Add a Controller

Our next step will be to begin dynamically populating this template's contents. Specifically, our goals for this step will be to:

- Show one bar per telemetry-providing domain object (for which we'll be getting actual telemetry data in subsequent steps.)
- Show correct labels for these objects at the bottom.
- Show numeric labels on the left-hand side.

Notably, we will not try to show telemetry data after this step.

To support this, we will add a new controller which supports our Bar Graph view:

```
define(function () {
  function BarGraphController($scope, telemetryHandler) {
    var handle;

    // Add min/max defaults
    $scope.low = -1;
```

```

$scope.middle = 0;
$scope.high = 1;

// Convert value to a percent between 0-100, keeping values in points
$scope.toPercent = function (value) {
    var pct = 100 * (value - $scope.low) / ($scope.high - $scope.low);
    return Math.min(100, Math.max(0, pct));
};

// Use the telemetryHandler to get telemetry objects here
handle = telemetryHandler.handle($scope.domainObject, function () {
    $scope.telemetryObjects = handle.getTelemetryObjects();
    $scope.barWidth =
        100 / Math.max(($scope.telemetryObjects).length, 1);
});

// Release subscriptions when scope is destroyed
$scope.$on('$destroy', handle.unsubscribe);
}

return BarGraphController;
});

```

**tutorials/bargraph/src/controllers/BarGraphController.js**

A summary of what we've done here:

- We're exposing some numeric values that will correspond to the `low`, `middle`, and `high` end of the graph. (The `medium` attribute will be useful for positioning the middle line, which are graphs will ultimately descend down or push up from.)
- Add a utility function which converts from numeric values to percentages. This will help support some positioning in the template.
- Utilize the `telemetryHandler`, provided by the platform, to start listening to real-time telemetry updates. This will deal with most of the complexity of dealing with telemetry (e.g. differentiating between individual telemetry points and telemetry panels, monitoring latest values) and provide us with a useful interface for populating our view. The the Open MCT Web Developer Guide for more information on dealing with telemetry.

Whenever the telemetry handler invokes its callbacks, we update the set of telemetry objects in view, as well as the width for each bar.

We will also utilize this from our template:

```

<div class="example-bargraph">
  <div class="example-tick-labels">
    <div ng-repeat="value in [low, middle, high] track by $index"
      class="example-tick-label"

```

```

        style="bottom: {{ toPercent(value) }}%">
        {{value}}
    </div>
</div>

<div class="example-graph-area">
    <div ng-repeat="telemetryObject in telemetryObjects"
        style="left: {{barWidth * $index}}%; width: {{barWidth}}%"
        class="example-bar-holder">
        <div class="example-bar"
            style="top: 25%; bottom: 50%;">
        </div>
    </div>
    <div style="bottom: {{ toPercent(middle) }}%"
        class="example-graph-tick">
    </div>
</div>

<div class="example-bar-labels">
    <div ng-repeat="telemetryObject in telemetryObjects"
        style="left: {{barWidth * $index}}%; width: {{barWidth}}%"
        class="example-bar-holder example-label">
        <mct-representation key="'label'"
            mct-object="telemetryObject">
        </mct-representation>
    </div>
</div>
</div>
</div>

```

tutorials/bargraph/res/templates/bargraph.html

Summarizing these changes:

- Utilize the exposed `low`, `middle`, and `high` values to populate our labels along the vertical axis. Additionally, use the `toPercent` function to position these from the bottom.
- Replace our three hard-coded bars with a repeater that looks at the `telemetryObjects` exposed by the controller and adds one bar each.
- Position the dashed tick-line using the `middle` value and the `toPercent` function, lining it up with its label to the left.
- At the bottom, repeat a set of labels for the telemetry-providing domain objects, with matching alignment to the bars above. We use an existing representation, `label`, to make this easier.

Finally, we expose our controller from our bundle definition. Note that the `depends` declaration includes both `$scope` as well as the `telemetryHandler` service we made use of.

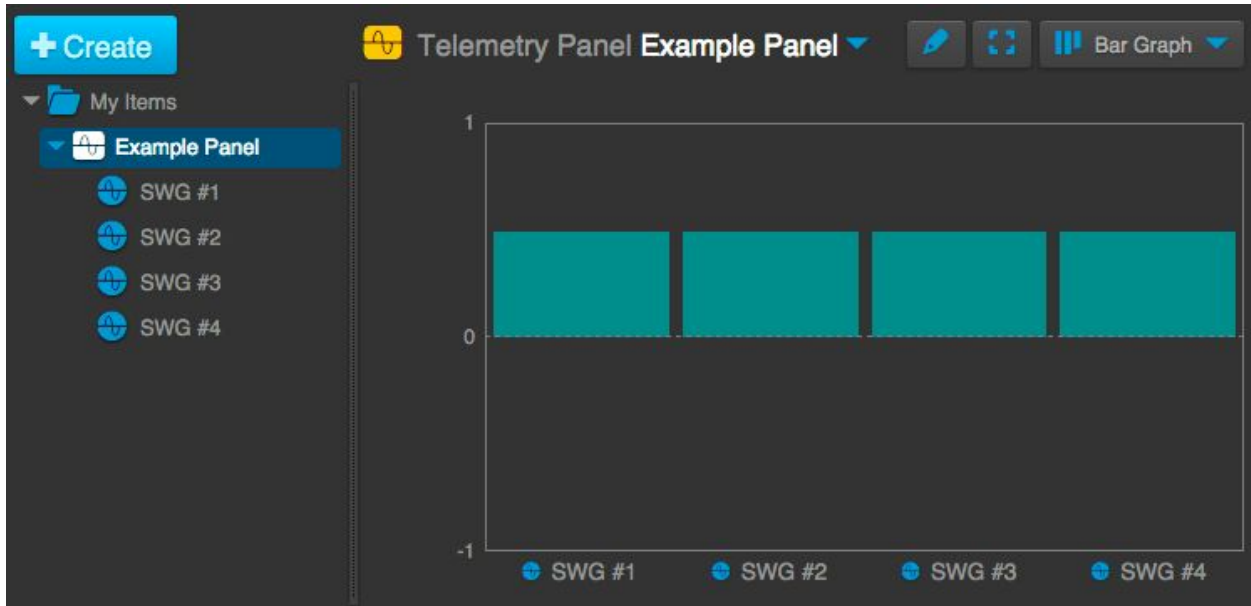
```

{
  "name": "Bar Graph",
  "description": "Provides the Bar Graph view of telemetry elements.",
  "extensions": {
    "views": [
      {
        "name": "Bar Graph",
        "key": "example.bargraph",
        "glyph": "H",
        "templateUrl": "templates/bargraph.html",
        "needs": [ "telemetry" ],
        "delegation": true
      }
    ],
    "stylesheets": [
      {
        "stylesheetUrl": "css/bargraph.css"
      }
    ],
    "controllers": [
      {
        "key": "BarGraphController",
        "implementation": "controllers/BarGraphController.js",
        "depends": [ "$scope", "telemetryHandler" ]
      }
    ]
  }
}

```

tutorials/bargraph/bundle.json

When we reload Open MCT Web, we are now able to see that our bar graph view correctly labels one bar per telemetry-providing domain object, as shown for this Telemetry Panel containing four Sine Wave Generators.



### Step 3. Using Telemetry Data

Now that our bar graph is labeled correctly, it's time to start putting data into the view.

First, let's add expose some more functionality from our controller. To make it simple, we'll expose the top and bottom for a bar graph for a given telemetry-providing domain object, as percentages.

```
define(function () {
  function BarGraphController($scope, telemetryHandler) {
    var handle;

    // Add min/max defaults
    $scope.low = -1;
    $scope.middle = 0;
    $scope.high = 1;

    // Convert value to a percent between 0-100, keeping values in points
    $scope.toPercent = function (value) {
      var pct = 100 * (value - $scope.low) / ($scope.high - $scope.low);
      return Math.min(100, Math.max(0, pct));
    };

    // Get bottom and top (as percentages) for current value
    $scope.getBottom = function (telemetryObject) {
      var value = handle.getRangeValue(telemetryObject);
      return $scope.toPercent(Math.min($scope.middle, value));
    }
  }
});
```

```

$scope.getTop = function (telemetryObject) {
    var value = handle.getRangeValue(telemetryObject);
    return 100 - $scope.toPercent(Math.max($scope.middle, value));
}

// Use the telemetryHandler to get telemetry objects here
handle = telemetryHandler.handle($scope.domainObject, function () {
    $scope.telemetryObjects = handle.getTelemetryObjects();
    $scope.barWidth =
        100 / Math.max(($scope.telemetryObjects).length, 1);
});

// Release subscriptions when scope is destroyed
$scope.$on('$destroy', handle.unsubscribe);
}

return BarGraphController;
});

```

**tutorials/bargraph/src/controllers/BarGraphController.js**

The `telemetryHandler` exposes a method to provide us with our latest data value (the `getRangeValue` method), and we already have a function to convert from a numeric value to a percentage within the view, so we just use those. The only slight complication is that we want our bar to move up or down from the middle value, so either of our top or bottom position for the bar itself could be either the middle line, or the data value. We let `Math.min` and `Math.max` decide this.

Next, we utilize this functionality from the template:

```

<div class="example-bargraph">
  <div class="example-tick-labels">
    <div ng-repeat="value in [low, middle, high] track by $index"
      class="example-tick-label"
      style="bottom: {{ toPercent(value) }}%">
      {{value}}
    </div>
  </div>

  <div class="example-graph-area">
    <div ng-repeat="telemetryObject in telemetryObjects"
      style="left: {{barWidth * $index}}%; width: {{barWidth}}%"
      class="example-bar-holder">
      <div class="example-bar"
        ng-style="{
          bottom: getBottom(telemetryObject) + '%',
          top: getTop(telemetryObject) + '%',
        }">
      </div>
    </div>
  </div>

```



```

</div>
<div style="bottom: {{ toPercent(middle) }}%"
      class="example-graph-tick">
</div>
</div>

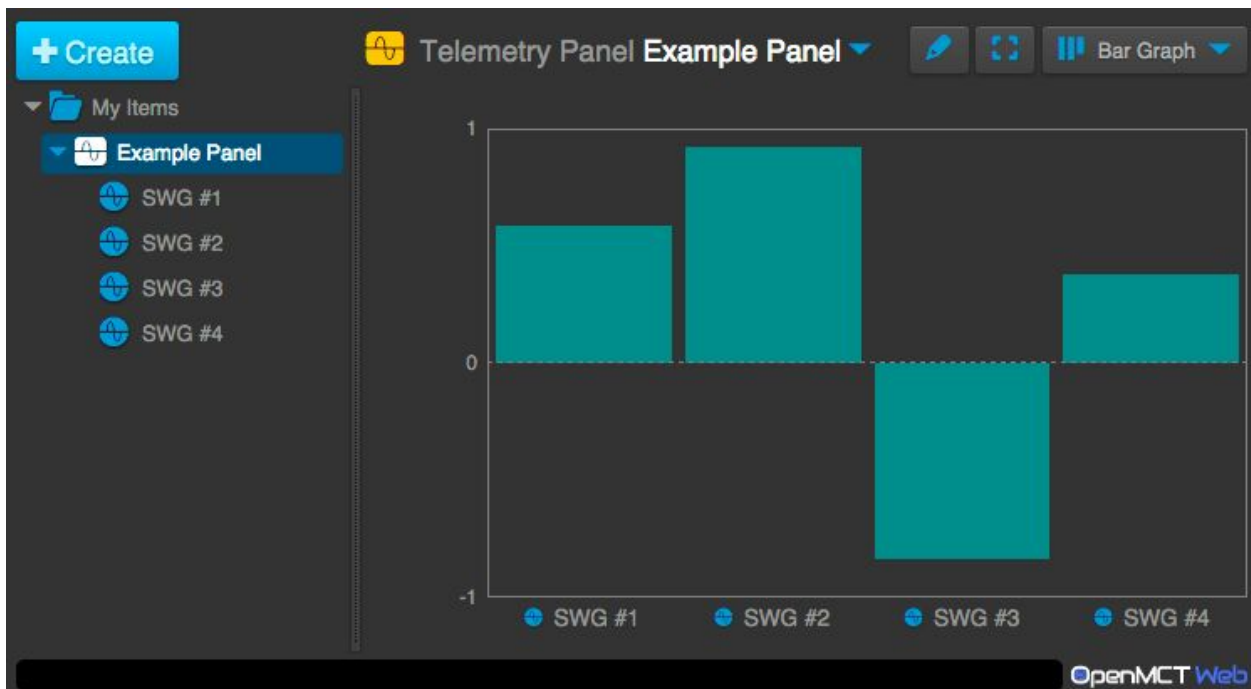
<div class="example-bar-labels">
  <div ng-repeat="telemetryObject in telemetryObjects"
        style="left: {{ barWidth * $index }}%; width: {{ barWidth }}%"
        class="example-bar-holder example-label">
    <mct-representation key="'label'"
                      mct-object="telemetryObject">
      </mct-representation>
    </div>
  </div>
</div>

```

tutorials/bargraph/res/templates/bargraph.html

Here, we utilize the functions we just provided from the controller to position the bar, using an `ng-style` attribute.

When we reload Open MCT Web, our bar graph view now looks like:



#### Step 4. View Configuration

The default minimum and maximum values we've provided happen to make sense for sine waves, but what about other values? We want to provide the user with a means of configuring these boundaries.

This is normally done via Edit mode. Since view configuration is a common problem, the Open MCT Web platform exposes a configuration object - called `configuration` - into our view's scope. We can populate it as we please, and when we return to our view later, those changes will be persisted.

First, let's add a tool bar for changing these three values in Edit mode:

```
{
  "name": "Bar Graph",
  "description": "Provides the Bar Graph view of telemetry elements.",
  "extensions": {
    "views": [
      {
        "name": "Bar Graph",
        "key": "example.bargraph",
        "glyph": "H",
        "templateUrl": "templates/bargraph.html",
        "needs": [ "telemetry" ],
        "delegation": true,
        "toolbar": {
          "sections": [
            {
              "items": [
                {
                  "name": "Low",
                  "property": "low",
                  "required": true,
                  "control": "textfield",
                  "size": 4
                },
                {
                  "name": "Middle",
                  "property": "middle",
                  "required": true,
                  "control": "textfield",
                  "size": 4
                },
                {
                  "name": "High",
                  "property": "high",
                  "required": true,
                  "control": "textfield",
                  "size": 4
                }
              ]
            }
          ]
        }
      }
    ]
  }
}
```

```

    ]
  },
  "stylesheets": [
    {
      "stylesheetUrl": "css/bargraph.css"
    }
  ],
  "controllers": [
    {
      "key": "BarGraphController",
      "implementation": "controllers/BarGraphController.js",
      "depends": [ "$scope", "telemetryHandler" ]
    }
  ]
}

```

tutorials/bargraph/bundle.json

As we saw in the To-Do List plugin, a tool bar needs either a selected object or a view proxy to work from. We will add this to our controller, and additionally will start reading/writing those properties to the view's configuration object.

```

define(function () {
  function BarGraphController($scope, telemetryHandler) {
    var handle;

    // Expose configuration constants directly in scope
    function exposeConfiguration() {
      $scope.low = $scope.configuration.low;
      $scope.middle = $scope.configuration.middle;
      $scope.high = $scope.configuration.high;
    }

    // Populate a default value in the configuration
    function setDefault(key, value) {
      if ($scope.configuration[key] === undefined) {
        $scope.configuration[key] = value;
      }
    }

    // Getter-setter for configuration properties (for view proxy)
    function getterSetter(property) {
      return function (value) {
        value = parseFloat(value);
        if (!isNaN(value)) {
          $scope.configuration[property] = value;
          exposeConfiguration();
        }
      };
    }
  }
}

```

```

        }
        return $scope.configuration[property];
    };
}

// Add min/max defaults
setDefault('low', -1);
setDefault('middle', 0);
setDefault('high', 1);
exposeConfiguration($scope.configuration);

// Expose view configuration options
if ($scope.selection) {
    $scope.selection.proxy({
        low: getterSetter('low'),
        middle: getterSetter('middle'),
        high: getterSetter('high')
    });
}

// Convert value to a percent between 0-100
$scope.toPercent = function (value) {
    var pct = 100 * (value - $scope.low) /
        ($scope.high - $scope.low);
    return Math.min(100, Math.max(0, pct));
};

// Get bottom and top (as percentages) for current value
$scope.getBottom = function (telemetryObject) {
    var value = handle.getRangeValue(telemetryObject);
    return $scope.toPercent(Math.min($scope.middle, value));
}
$scope.getTop = function (telemetryObject) {
    var value = handle.getRangeValue(telemetryObject);
    return 100 - $scope.toPercent(Math.max($scope.middle, value));
}

// Use the telemetryHandler to get telemetry objects here
handle = telemetryHandler.handle($scope.domainObject, function () {
    $scope.telemetryObjects = handle.getTelemetryObjects();
    $scope.barWidth =
        100 / Math.max(($scope.telemetryObjects).length, 1);
});

// Release subscriptions when scope is destroyed
$scope.$on('$destroy', handle.unsubscribe);
}

return BarGraphController;
});

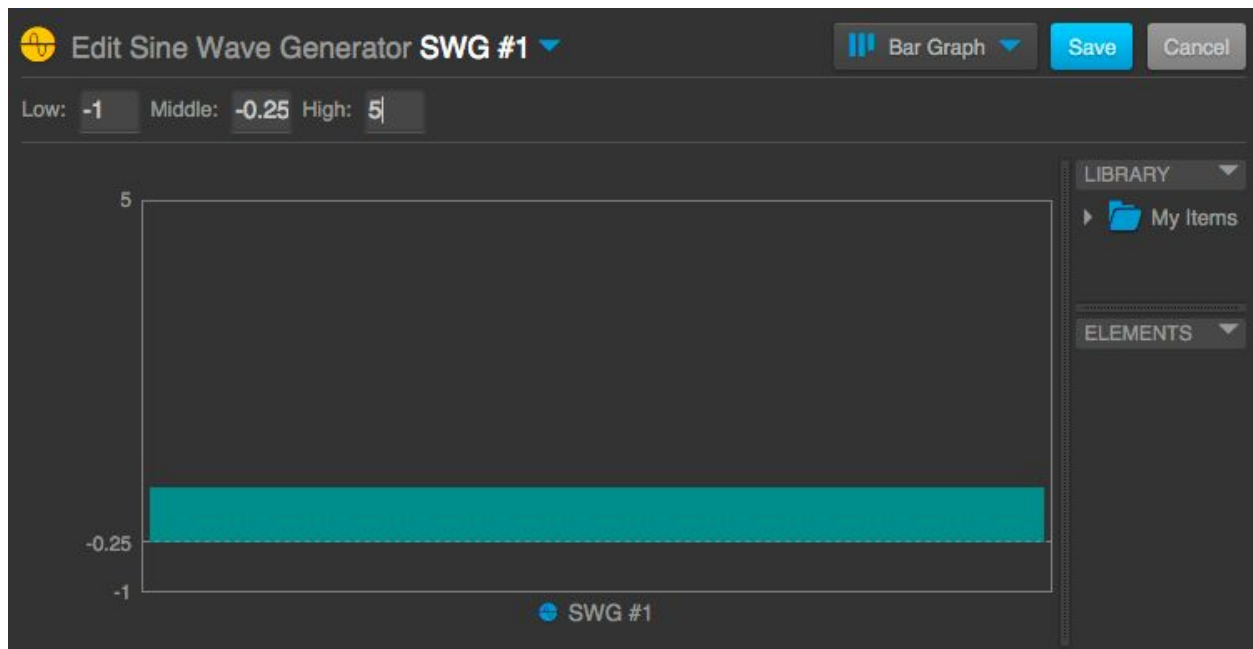
```

tutorials/bargraph/src/controllers/BarGraphController.js

A summary of these changes:

- First, read `low`, `middle`, and `high` from the view configuration instead of initializing them to explicit values. This is placed into its own function, since it will be called a lot.
- The function `setDefault` is included; it will be used to set the default values for `low`, `middle`, and `high` in the view configuration, but only if they aren't present.
- The tool bar will treat properties in a view proxy as getter-setters if they are functions; that is, they will be called with an argument to be used as a setter, and with no argument to use as a getter. We provide ourselves a function for making these getter-setters (since we'll need three) that additionally handles some checking to ensure that these are actually numbers.
- After that, we actually initialize both the view configuration object with defaults (if needed), and expose its state into the scope.
- Finally, we expose a view proxy which will handle changes to `low`, `middle`, and `high` as entered by the user from the tool bar. This uses the getter-setters we defined previously.

If we reload Open MCT Web and go to a Bar Graph view in Edit mode, we now see that we can change these bounds from the tool bar.



## Telemetry Adapter

The goal of this tutorial is to demonstrate how to integrate Open MCT Web with an existing telemetry system.

A summary of the steps we will take:

- Expose the telemetry dictionary within the user interface.
- Support subscription/unsubscription to real-time streaming data.
- Support historical retrieval of telemetry data.

## Step 0. Expose Your Telemetry

As a precondition to integrating telemetry data into Open MCT Web, this information needs to be available over web-based interfaces. In practice, this will most likely mean exposing data over HTTP, or over WebSockets.

For purposes of this tutorial, a simple node server is provided to stand in place of this existing telemetry system. It generates real-time data and exposes it over a WebSocket connection.

```
/*global require,process,console*/

var CONFIG = {
  port: 8081,
  dictionary: "dictionary.json",
  interval: 1000
};

(function () {
  "use strict";

  var WebSocketServer = require('ws').Server,
      fs = require('fs'),
      wss = new WebSocketServer({ port: CONFIG.port }),
      dictionary = JSON.parse(fs.readFileSync(CONFIG.dictionary, "utf8")),
      spacecraft = {
        "prop.fuel": 77,
        "prop.thrusters": "OFF",
        "comms.recd": 0,
        "comms.sent": 0,
        "pwr.temp": 245,
        "pwr.c": 8.15,
        "pwr.v": 30
      },
      histories = {},
      listeners = [];

  function updateSpacecraft() {
    spacecraft["prop.fuel"] = Math.max(
```

```

    0,
    spacecraft["prop.fuel"] -
      (spacecraft["prop.thrusters"] === "ON" ? 0.5 : 0)
  );
  spacecraft["pwr.temp"] = spacecraft["pwr.temp"] * 0.985
    + Math.random() * 0.25 + Math.sin(Date.now());
  spacecraft["pwr.c"] = spacecraft["pwr.c"] * 0.985;
  spacecraft["pwr.v"] = 30 + Math.pow(Math.random(), 3);
}

function generateTelemetry() {
  var timestamp = Date.now(), sent = 0;
  Object.keys(spacecraft).forEach(function (id) {
    var state = { timestamp: timestamp, value: spacecraft[id] };
    histories[id] = histories[id] || []; // Initialize
    histories[id].push(state);
    spacecraft["comms.sent"] += JSON.stringify(state).length;
  });
  listeners.forEach(function (listener) {
    listener();
  });
}

function update() {
  updateSpacecraft();
  generateTelemetry();
}

function handleConnection(ws) {
  var subscriptions = {}, // Active subscriptions for this connection
      handlers = { // Handlers for specific requests
        dictionary: function () {
          ws.send(JSON.stringify({
            type: "dictionary",
            value: dictionary
          }));
        },
        subscribe: function (id) {
          subscriptions[id] = true;
        },
        unsubscribe: function (id) {
          delete subscriptions[id];
        },
        history: function (id) {
          ws.send(JSON.stringify({
            type: "history",
            id: id,
            value: histories[id]
          }));
        }
      }
  };
}

function notifySubscribers() {

```

```

        Object.keys(subscriptions).forEach(function (id) {
            var history = histories[id];
            if (history) {
                ws.send(JSON.stringify({
                    type: "data",
                    id: id,
                    value: history[history.length - 1]
                }));
            }
        });
    }

    // Listen for requests
    ws.on('message', function (message) {
        var parts = message.split(' ');
        handler = handlers[parts[0]];
        if (handler) {
            handler.apply(handlers, parts.slice(1));
        }
    });

    // Stop sending telemetry updates for this connection when closed
    ws.on('close', function () {
        listeners = listeners.filter(function (listener) {
            return listener !== notifySubscribers;
        });
    });

    // Notify subscribers when telemetry is updated
    listeners.push(notifySubscribers);
}

update();
setInterval(update, CONFIG.interval);

wss.on('connection', handleConnection);

console.log("Example spacecraft running on port ");
console.log("Press Enter to toggle thruster state.");
process.stdin.on('data', function (data) {
    spacecraft['prop.thrusters'] =
        (spacecraft['prop.thrusters'] === "OFF") ? "ON" : "OFF";
    console.log("Thrusters " + spacecraft["prop.thrusters"]);
});
}());

```

**tutorial-server/app.js**

For purposes of this tutorial, how this server has been implemented is not important; it has just enough functionality to resemble a WebSocket interface to a real telemetry system, and



niceties such as error-handling have been omitted. (For more information on using WebSockets, both in the client and on the server, [https://developer.mozilla.org/en-US/docs/Web/API/WebSockets\\_API](https://developer.mozilla.org/en-US/docs/Web/API/WebSockets_API) is an excellent starting point.)

What does matter for this tutorial is the interfaces that are exposed. Once a WebSocket connection has been established to this server, it accepts plain text messages in the following formats, and issues JSON-formatted responses.

The requests it handles are:

- `dictionary`: Responds with a JSON response with the following fields:
  - `type`: "dictionary"
  - `value`: ... the telemetry dictionary (see below) ...
- `subscribe <id>`: Subscribe to new telemetry data for the measurement with the provided identifier. The server will begin sending messages of the following form:
  - `type`: "data"
  - `id`: The identifier for the measurement.
  - `value`: An object containing the actual measurement, in two fields:
    - `timestamp`: A UNIX timestamp (in milliseconds) for the "measurement"
    - `value`: The data value for the measurement (either a number, or a string)
- `unsubscribe <id>`: Stop receiving new data for the identified measurement.
- `history <id>`: Request a history of all telemetry data for the identified measurement.
  - `type`: "history"
  - `id`: The identifier for the measurement.
  - `value`: An array of objects containing the actual measurement, each of which having two fields:
    - `timestamp`: A UNIX timestamp (in milliseconds) for the "measurement"
    - `value`: The data value for the measurement (either a number, or a string)

(Note that the term "measurement" is used to describe a distinct data series within this system; in other systems, these have been called channels, mnemonics, telemetry points, or other names. No preference is made here; Open MCT Web is easily adapted to use the terminology appropriate to your system.)

Additionally, while running the server from the terminal we can toggle the state of the "spacecraft" by hitting enter; this will turn the "thrusters" on and off, having observable changes in telemetry.

The telemetry dictionary referenced previously is contained in a separate file, used by the server. It uses a custom format and, for purposes of example, contains three "subsystems" containing a mix of numeric and string-based telemetry.

```
{
  "name": "Example Spacecraft",
  "identifier": "sc",
  "subsystems": [
    {
      "name": "Propulsion",
      "identifier": "prop",
      "measurements": [
        {
          "name": "Fuel",
          "identifier": "prop.fuel",
          "units": "kilograms",
          "type": "float"
        },
        {
          "name": "Thrusters",
          "identifier": "prop.thrusters",
          "units": "None",
          "type": "string"
        }
      ]
    },
    {
      "name": "Communications",
      "identifier": "comms",
      "measurements": [
        {
          "name": "Received",
          "identifier": "comms.recd",
          "units": "bytes",
          "type": "integer"
        },
        {
          "name": "Sent",
          "identifier": "comms.sent",
          "units": "bytes",
          "type": "integer"
        }
      ]
    },
    {
      "name": "Power",
      "identifier": "pwr",
      "measurements": [
        {
          "name": "Generator Temperature",
          "identifier": "pwr.temp",
          "units": "\u0080C",
          "type": "float"
        },
        {
          "name": "Generator Current",
          "identifier": "pwr.c",

```

```

        "units": "A",
        "type": "float"
      },
      {
        "name": "Generator Voltage",
        "identifier": "pwr.v",
        "units": "V",
        "type": "float"
      }
    ]
  }
]
}

```

tutorial-server/dictionary.json

It should be noted that neither the interface for the example server nor the dictionary format are expected by Open MCT Web; rather, these are intended to stand in for some existing source of telemetry data to which we wish to *adapt* Open MCT Web.

We can run this example server by:

```

cd tutorial-server
npm install ws
node app.js

```

To verify that this is running and try out its interface, we can use a tool like <https://www.npmjs.com/package/wscat>:

```

wscat -c ws://localhost:8081
connected (press CTRL+C to quit)
> dictionary
< {"type":"dictionary","value":{"name":"Example
Spacecraft","identifier":"sc","subsystems":[{"name":"Propulsion","ide
ntifier":"prop","measurements":[{"name":"Fuel","identifier":"prop.fue
l","units":"kilograms","type":"float"}, {"name":"Thrusters","identifie
r":"prop.thrusters","units":"None","type":"string"}]}, {"name":"Commun
ications","identifier":"comms","measurements":[{"name":"Received","id
entifier":"comms.recd","units":"bytes","type":"integer"}, {"name":"Sen
t","identifier":"comms.sent","units":"bytes","type":"integer"}]}, {"na
me":"Power","identifier":"pwr","measurements":[{"name":"Generator
Temperature","identifier":"pwr.temp","units":"C","type":"float"}, {"na
me":"Generator
Current","identifier":"pwr.c","units":"A","type":"float"}, {"name":"Ge

```

```
nerator
Voltage", "identifier": "pwr.v", "units": "V", "type": "float"}]]]]}
```

Now that the example server's interface is reasonably well-understood, a plugin can be written to adapt Open MCT Web to utilize it.

## Step 1. Add a Top-level Object

Since Open MCT Web uses an “object-first” approach to accessing data, before we'll be able to do anything with this new data source, we'll need to have a way to explore the available measurements in the tree. In this step, we will add a top-level object which will serve as a container; in the next step, we will populate this with the contents of the telemetry dictionary (which we will retrieve from the server.)

```
{
  "name": "Example Telemetry Adapter",
  "extensions": {
    "types": [
      {
        "name": "Spacecraft",
        "key": "example.spacecraft",
        "glyph": "o"
      }
    ],
    "roots": [
      {
        "id": "example:sc",
        "priority": "preferred",
        "model": {
          "type": "example.spacecraft",
          "name": "My Spacecraft",
          "composition": []
        }
      }
    ]
  }
}
```

tutorials/telemetry/bundle.json

Here, we've created our initial telemetry plugin. This exposes a new domain object type (the “Spacecraft”, which will be represented by the contents of the telemetry dictionary) and also adds one instance of it as a root-level object (by declaring an extension of category `roots`.) We have also set `priority` to `preferred` so that this shows up near the top, instead of below My Items.

If we include this in our set of active bundles:

```
[
  "platform/framework",
  "platform/core",
  "platform/representation",
  "platform/commonUI/about",
  "platform/commonUI/browse",
  "platform/commonUI/edit",
  "platform/commonUI/dialog",
  "platform/commonUI/general",
  "platform/containment",
  "platform/telemetry",
  "platform/features/layout",
  "platform/features/pages",
  "platform/features/plot",
  "platform/features/scrolling",
  "platform/forms",
  "platform/persistence/queue",
  "platform/policy",

  "example/persistence",
  "example/generator"
]

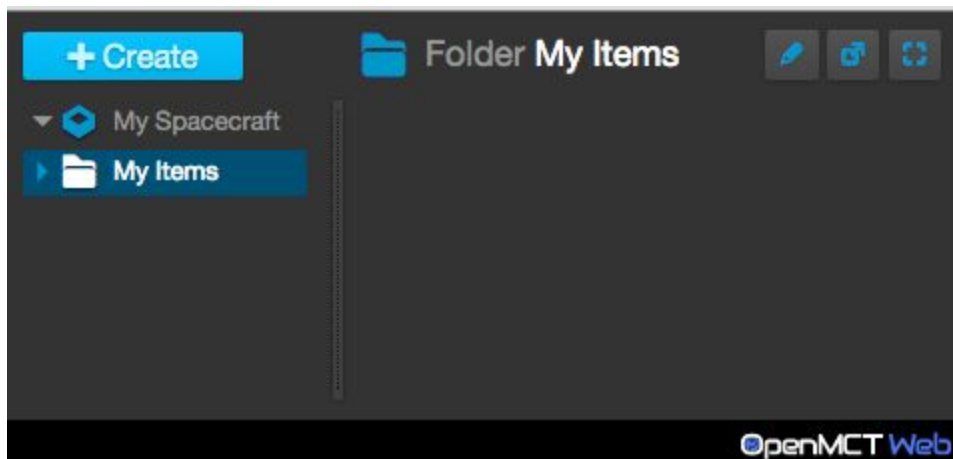
[
  "platform/framework",
  "platform/core",
  "platform/representation",
  "platform/commonUI/about",
  "platform/commonUI/browse",
  "platform/commonUI/edit",
  "platform/commonUI/dialog",
  "platform/commonUI/general",
  "platform/containment",
  "platform/telemetry",
  "platform/features/layout",
  "platform/features/pages",
  "platform/features/plot",
  "platform/features/scrolling",
  "platform/forms",
  "platform/persistence/queue",
  "platform/policy",

  "example/persistence",
  "example/generator",

  "tutorials/telemetry"
]
```

bundles.json

...we will be able to reload Open MCT Web and see that it is present:



Now, we have somewhere in the UI to put the contents of our telemetry dictionary.

## Step 2. Expose the Telemetry Dictionary

In order to expose the telemetry dictionary, we first need to read it from the server. Our first step will be to add a service that will handle interactions with the server; this will not be used by Open MCT Web directly, but will be used by subsequent components we add.

```
/*global define,WebSocket*/

define(
  [],
  function () {
    "use strict";

    function ExampleTelemetryServerAdapter($q, wsUrl) {
      var ws = new WebSocket(wsUrl),
          dictionary = $q.defer();

      // Handle an incoming message from the server
      ws.onmessage = function (event) {
        var message = JSON.parse(event.data);

        switch (message.type) {
          case "dictionary":
            dictionary.resolve(message.value);
            break;
        }
      };

      // Request dictionary once connection is established
      ws.onopen = function () {
        ws.send("dictionary");
      };

      return {
        dictionary: function () {
          return dictionary.promise;
        }
      };
    }

    return ExampleTelemetryServerAdapter;
  }
);
```

**tutorials/telemetry/src/ExampleTelemetryServerAdapter.js**

When created, this service initiates a connection to the server, and begins loading the dictionary. This will occur asynchronously, so the `dictionary()` method it exposes returns a Promise for the loaded dictionary (`dictionary.json` from above), using Angular's `$q` (see

[https://docs.angularjs.org/api/ng/service/\\$q](https://docs.angularjs.org/api/ng/service/$q).) Note that error- and close-handling for this WebSocket connection have been omitted for brevity.

Once the dictionary has been loaded, we will want to represent its contents as domain objects. Specifically, we want subsystems to appear as objects under My Spacecraft, and measurements to appear as objects within those subsystems. This means that we need to convert the data from the dictionary into *domain object models*, and expose these to Open MCT Web via a `modelService`.

```
/*global define*/

define(
  function () {
    "use strict";

    var PREFIX = "example_tlm:",
        FORMAT_MAPPINGS = {
          float: "number",
          integer: "number",
          string: "string"
        };

    function ExampleTelemetryModelProvider(adapter, $q) {
      var modelPromise, empty = $q.when({});

      // Check if this model is in our dictionary (by prefix)
      function isRelevant(id) {
        return id.indexOf(PREFIX) === 0;
      }

      // Build a domain object identifier by adding a prefix
      function makeId(element) {
        return PREFIX + element.identifier;
      }

      // Create domain object models from this dictionary
      function buildTaxonomy(dictionary) {
        var models = {};

        // Create & store a domain object model for a measurement
        function addMeasurement(measurement) {
          var format = FORMAT_MAPPINGS[measurement.type];
          models[makeId(measurement)] = {
            type: "example.measurement",
            name: measurement.name,
            telemetry: {
              key: measurement.identifier,
              ranges: [{
                key: "value",

```

```

        name: "Value",
        units: measurement.units,
        format: format
    }
}

// Create & store a domain object model for a subsystem
function addSubsystem(subsystem) {
    var measurements =
        (subsystem.measurements || []);
    models[makeId(subsystem)] = {
        type: "example.subsystem",
        name: subsystem.name,
        composition: measurements.map(makeId)
    };
    measurements.forEach(addMeasurement);
}

(dictionary.subsystems || []).forEach(addSubsystem);

return models;
}

// Begin generating models once the dictionary is available
modelPromise = adapter.dictionary().then(buildTaxonomy);

return {
    getModels: function (ids) {
        // Return models for the dictionary only when they
        // are relevant to the request.
        return ids.some(isRelevant) ? modelPromise : empty;
    }
};
}

return ExampleTelemetryModelProvider;
}
);

```

**tutorials/telemetry/src/ExampleTelemetryModelProvider.js**

This script implements a provider for `modelService`; the `modelService` is a composite service, meaning that multiple such services can exist side by side. (For example, there is another provider for `modelService` that reads domain object models from the persistence store.)

Here, we read the dictionary using the server adapter from above; since this will be loaded asynchronously, we use promise-chaining (see [https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Global\\_Objects/Promise/th](https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Global_Objects/Promise/th)



[en#Chaining](#)) to take that result and build up an object mapping identifiers to new domain object models. This is returned from our `modelService`, but only when the request actually calls for identifiers that look like they're from the dictionary. This means that loading other models is not blocked by loading the dictionary. (Note that the `modelService` contract allows us to return either a sub- or superset of the requested models, so it is fine to always return the whole dictionary.)

Some notable points to call out here:

- Every subsystem and every measurement from the dictionary has an `identifier` field declared. We use this as part of the domain object identifier, but we also prefix it with `example_tlm:`. This accomplishes a few things:
  - We can easily tell whether an identifier is expected to be in the dictionary or not.
  - We avoid naming collisions with other model providers.
  - Finally, Open MCT Web uses the colon prefix as a hint that this domain object will *not* be in the persistence store.
- A couple of new types are introduced here (in the `type` field of the domain object models we create); we will need to define these as extensions as well in order for them to display correctly.
- The `composition` field of each subsystem contained the Open MCT Web identifiers of all the measurements in that subsystem. This `composition` field will be used by Open MCT Web to determine what domain objects contain other domain objects (e.g. to populate the tree.)
- The `telemetry` field of each measurement will be used by Open MCT Web to understand how to request and interpret telemetry data for this object. The `key` is the machine-readable identifier for this measurement within the telemetry system; the `ranges` provide metadata about the values for this data. (A separate field, `domains`, provides metadata about timestamps or other ordering properties of the data, but this will be the same for all measurements, so we will define that later at the type level.)
  - This field (whose contents will be merged atop the `telemetry` property we define at the type-level) will serve as a template for later telemetry requests to the `telemetryService`, so we'll see the properties we define here again later in Steps 3 and 4.

This allows our telemetry dictionary to be expressed as domain object models (and, in turn, as domain objects), but these objects still aren't reachable. To fix this, we will need another script which will add these subsystems to the root-level object we added in Step 1.

```
/*global define*/  
  
define(  
  function () {
```

```

"use strict";

var TAXONOMY_ID = "example:sc",
    PREFIX = "example_tlm:";

function ExampleTelemetryInitializer(adapter, objectService) {
    // Generate a domain object identifier for a dictionary element
    function makeId(element) {
        return PREFIX + element.identifier;
    }

    // When the dictionary is available, add all subsystems
    // to the composition of My Spacecraft
    function initializeTaxonomy(dictionary) {
        // Get the top-level container for dictionary objects
        // from a group of domain objects.
        function getTaxonomyObject(domainObjects) {
            return domainObjects[TAXONOMY_ID];
        }

        // Populate
        function populateModel(taxonomyObject) {
            return taxonomyObject.useCapability(
                "mutation",
                function (model) {
                    model.name =
                        dictionary.name;
                    model.composition =
                        dictionary.subsystems.map(makeId);
                }
            );
        }

        // Look up My Spacecraft, and populate it accordingly.
        objectService.getObjects([TAXONOMY_ID])
            .then(getTaxonomyObject)
            .then(populateModel);
    }

    adapter.dictionary().then(initializeTaxonomy);
}

return ExampleTelemetryInitializer;
};

```

**tutorials/telemetry/src/ExampleTelemetryInitializer.js**

At the conclusion of Step 1, the top-level My Spacecraft object was empty. This script will wait for the dictionary to be loaded, then load My Spacecraft (by its identifier), and “mutate” it. The `mutation` capability allows changes to be made to a domain object’s model. Here, we

take this top-level object, update its name to match what was in the dictionary, and set its `composition` to an array of domain object identifiers for all subsystems contained in the dictionary (using the same identifier prefix as before.)

Finally, we wire in these changes by modifying our plugin's `bundle.json` to provide metadata about how these pieces interact (both with each other, and with the platform):

```
{
  "name": "Example Telemetry Adapter",
  "extensions": {
    "types": [
      {
        "name": "Spacecraft",
        "key": "example.spacecraft",
        "glyph": "o"
      },
      {
        "name": "Subsystem",
        "key": "example.subsystem",
        "glyph": "o",
        "model": { "composition": [] }
      },
      {
        "name": "Measurement",
        "key": "example.measurement",
        "glyph": "T",
        "model": { "telemetry": {} },
        "telemetry": {
          "source": "example.source",
          "domains": [
            {
              "name": "Time",
              "key": "timestamp"
            }
          ]
        }
      }
    ]
  },
  "roots": [
    {
      "id": "example:sc",
      "priority": "preferred",
      "model": {
        "type": "example.spacecraft",
        "name": "My Spacecraft",
        "composition": []
      }
    }
  ],
  "services": [
```

```

    {
      "key": "example.adapter",
      "implementation": "ExampleTelemetryServerAdapter.js",
      "depends": [ "$q", "EXAMPLE_WS_URL" ]
    }
  ],
  "constants": [
    {
      "key": "EXAMPLE_WS_URL",
      "priority": "fallback",
      "value": "ws://localhost:8081"
    }
  ],
  "runs": [
    {
      "implementation": "ExampleTelemetryInitializer.js",
      "depends": [ "example.adapter", "objectService" ]
    }
  ],
  "components": [
    {
      "provides": "modelService",
      "type": "provider",
      "implementation": "ExampleTelemetryModelProvider.js",
      "depends": [ "example.adapter", "$q" ]
    }
  ]
}

```

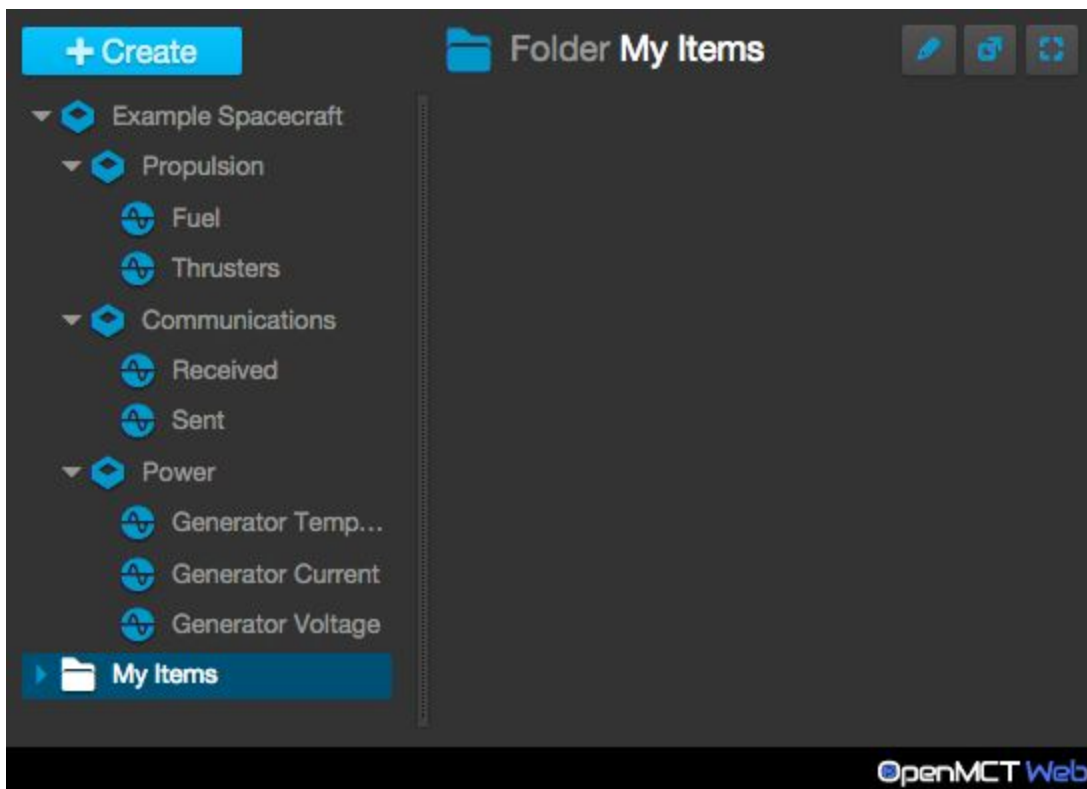
tutorials/telemetry/bundle.json

A summary of what we've added here:

- New type definitions have been added to represent Subsystems and Measurements, respectively.
  - Measurements have a `telemetry` field; this is similar to the `telemetry` field added in the model, but contains properties that will be common among all Measurements. In particular, the `source` field will be used later as a symbolic identifier for the telemetry data source.
  - We have also added some “initial models” for these two types using the `model` field. While domain objects of these types cannot be created via the Create menu, some policies will look at initial models to predict what capabilities domain objects of certain types would have, so we want to ensure that Subsystems and Measurements will be recognized as having `composition` and `telemetry` capabilities, respectively.
- The adapter to the WebSocket server has been added as a service with the symbolic name `example.adapter`; it is depended-upon elsewhere within this plugin.

- A constant, `EXAMPLE_WS_URL`, is defined, and depended-upon by `example.server`. Setting `priority` to `fallback` means this constant will be overridden if defined anywhere else, allowing configuration bundles to specify different URLs for the WebSocket connection.
- The initializer script is registered using the `runs` category of extension, to ensure that this executes (and populates the contents of the top-level My Spacecraft object) once Open MCT Web is started.
  - This depends upon the `example.adapter` service we exposed above, as well as Angular's `$q`; these services will be made available in the constructor call.
- Finally, the `modelService` provider which presents dictionary elements as domain object models is exposed. Since `modelService` is a composite service, this is registered under the extension category `components`.
  - As with the initializer, this depends upon the `example.adapter` service we exposed above, as well as Angular's `$q`; these services will be made available in the constructor call.

Now if we run Open MCT Web (assuming our example telemetry server is also running) and expand our top-level node completely, we see the contents of our dictionary:



Note that “My Spacecraft” has changed its name to “Example Spacecraft”, which is the name it had in the dictionary.

### Step 3. Historical Telemetry

After Step 2, we are able to see our dictionary in the user interface and click around our different measurements, but we don't see any data. We need to give ourselves the ability to retrieve this data from the server. In this step, we will do so for the server's historical telemetry.

Our first step will be to add a method to our server adapter which allows us to send history requests to the server:

```
/*global define,WebSocket*/

define(
    [],
    function () {
        "use strict";

        function ExampleTelemetryServerAdapter($q, wsUrl) {
            var ws = new WebSocket(wsUrl),
                histories = {},
                dictionary = $q.defer();

            // Handle an incoming message from the server
            ws.onmessage = function (event) {
                var message = JSON.parse(event.data);

                switch (message.type) {
                    case "dictionary":
                        dictionary.resolve(message.value);
                        break;
                    case "history":
                        histories[message.id].resolve(message);
                        delete histories[message.id];
                        break;
                }
            };

            // Request dictionary once connection is established
            ws.onopen = function () {
                ws.send("dictionary");
            };

            return {
                dictionary: function () {
                    return dictionary.promise;
                },
                history: function (id) {
                    histories[id] = histories[id] || $q.defer();
                    ws.send("history " + id);
                    return histories[id].promise;
                }
            };
        }
    }
);
```

```

    }

    return ExampleTelemetryServerAdapter;
  }
};

```

**tutorials/telemetry/src/ExampleTelemetryServerAdapter.js**

When the `history` method is called, a new request is issued to the server for historical telemetry, *unless* a request for the same historical telemetry is still pending. Similarly, when historical telemetry arrives for a given identifier, the pending promise is resolved.

This `history` method will be used by a `telemetryService` provider which we will implement:

```

/*global define*/

define(
  ['./ExampleTelemetrySeries'],
  function (ExampleTelemetrySeries) {
    "use strict";

    var SOURCE = "example.source";

    function ExampleTelemetryProvider(adapter, $q) {
      // Used to filter out requests for telemetry
      // from some other source
      function matchesSource(request) {
        return (request.source === SOURCE);
      }

      return {
        requestTelemetry: function (requests) {
          var packaged = {},
              relevantReqs = requests.filter(matchesSource);

          // Package historical telemetry that has been received
          function addToPackage(history) {
            packaged[SOURCE][history.id] =
              new ExampleTelemetrySeries(history.value);
          }

          // Retrieve telemetry for a specific measurement
          function handleRequest(request) {
            var key = request.key;
            return adapter.history(key).then(addToPackage);
          }
        }
      };
    }
  }
);

```

```

        packaged[SOURCE] = {};
        return $q.all(relevantReqs.map(handleRequest))
            .then(function () { return packaged; });
    },
    subscribe: function (callback, requests) {
        return function () {};
    }
};
}

return ExampleTelemetryProvider;
}
);

```

`tutorials/telemetry/src/ExampleTelemetryProvider.js`

The `requestTelemetry` method of a `telemetryService` is expected to take an array of requests (each with `source` and `key` parameters, identifying the general source of data and the specific element within that source, respectively) and return a Promise for any telemetry data it knows of which satisfies those requests, packaged in a specific way. This packaging is as an object containing key-value pairs, where keys correspond to `source` properties of requests and values are key-value pairs, where keys correspond to `key` properties of requests and values are `TelemetrySeries` objects. (We will see our implementation below.)

To do this, we create a container for our telemetry source, and consult the adapter to get telemetry histories for any relevant requests, then package them as they come in. The `$q.all` method is used to return a single Promise that will resolve only when all histories have been packaged. Promise-chaining is used to ensure that the resolved value will be the fully-packaged data.

It is worth mentioning here that the `requests` we receive should look a little familiar. When Open MCT Web generates a `request` object associated with a domain object, it does so by merging together three JavaScript objects:

- First, the `telemetry` property from that domain object's type definition.
- Second, the `telemetry` property from that domain object's model.
- Finally, the `request` object that was passed in via that domain object's `telemetry` capability.

As such, the `source` and `key` properties we observe here will come from the type definition and domain object model, respectively, as we specified them during Step 2. (Or, they



might come from somewhere else entirely, if we have other telemetry-providing domain objects in our system; that is something we check for using the `source` property.)

Finally, note that we also have a `subscribe` method, to satisfy the interface of `telemetryService`, but this `subscribe` method currently does nothing.

This script uses an `ExampleTelemetrySeries` class, which looks like:

```
/*global define*/

define(
  function () {
    "use strict";

    function ExampleTelemetrySeries(data) {
      return {
        getPointCount: function () {
          return data.length;
        },
        getDomainValue: function (index) {
          return (data[index] || {}).timestamp;
        },
        getRangeValue: function (index) {
          return (data[index] || {}).value;
        }
      };
    }

    return ExampleTelemetrySeries;
  }
);
```

`tutorials/telemetry/src/ExampleTelemetrySeries.js`

This takes the array of telemetry values (as returned by the server) and wraps it with the interface expected by the platform (the methods shown.)

Finally, we expose this `telemetryService` provider declaratively:

```
{
  "name": "Example Telemetry Adapter",
  "extensions": {
    "types": [
      {
        "name": "Spacecraft",
        "key": "example.spacecraft",
        "glyph": "o"
      }
    ]
  }
}
```

```

    },
    {
      "name": "Subsystem",
      "key": "example.subsystem",
      "glyph": "o",
      "model": { "composition": [] }
    },
    {
      "name": "Measurement",
      "key": "example.measurement",
      "glyph": "T",
      "model": { "telemetry": {} },
      "telemetry": {
        "source": "example.source",
        "domains": [
          {
            "name": "Time",
            "key": "timestamp"
          }
        ]
      }
    }
  ],
  "roots": [
    {
      "id": "example:sc",
      "priority": "preferred",
      "model": {
        "type": "example.spacecraft",
        "name": "My Spacecraft",
        "composition": []
      }
    }
  ],
  "services": [
    {
      "key": "example.adapter",
      "implementation": "ExampleTelemetryServerAdapter.js",
      "depends": [ "$q", "EXAMPLE_WS_URL" ]
    }
  ],
  "constants": [
    {
      "key": "EXAMPLE_WS_URL",
      "priority": "fallback",
      "value": "ws://localhost:8081"
    }
  ],
  "runs": [
    {
      "implementation": "ExampleTelemetryInitializer.js",
      "depends": [ "example.adapter", "objectService" ]
    }
  ]
}

```

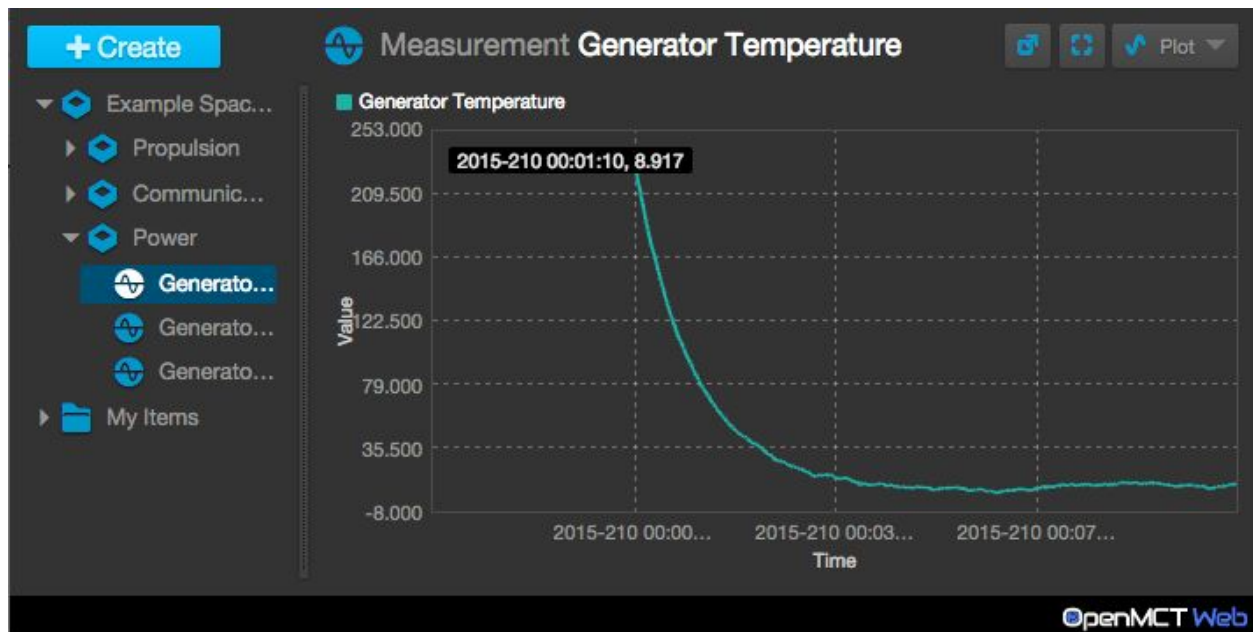
```

    ],
    "components": [
      {
        "provides": "modelService",
        "type": "provider",
        "implementation": "ExampleTelemetryModelProvider.js",
        "depends": [ "example.adapter", "$q" ]
      },
      {
        "provides": "telemetryService",
        "type": "provider",
        "implementation": "ExampleTelemetryProvider.js",
        "depends": [ "example.adapter", "$q" ]
      }
    ]
  }
}

```

tutorials/telemetry/bundle.json

Now, if we navigate to one of our numeric measurements, we should see a plot of its historical telemetry:



We can now visualize our data, but it doesn't update over time - we know the server is continually producing new data, but we have to click away and come back to see it. We can fix this by adding support for telemetry subscriptions.

## Step 4. Real-time Telemetry

Finally, we want to utilize the server's ability to subscribe to telemetry from Open MCT Web. To do this, first we want to expose some new methods for this from our server adapter:

```
/*global define,WebSocket*/

define(
  [],
  function () {
    "use strict";

    function ExampleTelemetryServerAdapter($q, wsUrl) {
      var ws = new WebSocket(wsUrl),
          histories = {},
          listeners = [],
          dictionary = $q.defer();

      // Handle an incoming message from the server
      ws.onmessage = function (event) {
        var message = JSON.parse(event.data);

        switch (message.type) {
          case "dictionary":
            dictionary.resolve(message.value);
            break;
          case "history":
            histories[message.id].resolve(message);
            delete histories[message.id];
            break;
          case "data":
            listeners.forEach(function (listener) {
              listener(message);
            });
            break;
        }
      };

      // Request dictionary once connection is established
      ws.onopen = function () {
        ws.send("dictionary");
      };

      return {
        dictionary: function () {
          return dictionary.promise;
        },
        history: function (id) {
          histories[id] = histories[id] || $q.defer();
        }
      };
    }
  }
);
```

```

        ws.send("history " + id);
        return histories[id].promise;
    },
    subscribe: function (id) {
        ws.send("subscribe " + id);
    },
    unsubscribe: function (id) {
        ws.send("unsubscribe " + id);
    },
    listen: function (callback) {
        listeners.push(callback);
    }
    };
}

return ExampleTelemetryServerAdapter;
}
);

```

`tutorials/telemetry/src/ExampleTelemetryServerAdapter.js`

Here, we have added `subscribe` and `unsubscribe` methods which issue the corresponding requests to the server. Separately, we introduce the ability to listen for data messages as they come in: These will contain the data associated with these subscriptions.

We then need only to utilize these methods from our `telemetryService`:

```

/*global define*/

define(
    ['./ExampleTelemetrySeries'],
    function (ExampleTelemetrySeries) {
        "use strict";

        var SOURCE = "example.source";

        function ExampleTelemetryProvider(adapter, $q) {
            var subscribers = {};

            // Used to filter out requests for telemetry
            // from some other source
            function matchesSource(request) {
                return (request.source === SOURCE);
            }

            // Listen for data, notify subscribers
            adapter.listen(function (message) {
                var packaged = {};
                packaged[SOURCE] = {};
                packaged[SOURCE][message.id] =

```

```

        new ExampleTelemetrySeries([message.value]);
        (subscribers[message.id] || []).forEach(function (cb) {
            cb(packaged);
        });
    });
});

return {
    requestTelemetry: function (requests) {
        var packaged = {},
            relevantReqs = requests.filter(matchesSource);

        // Package historical telemetry that has been received
        function addToPackage(history) {
            packaged[SOURCE][history.id] =
                new ExampleTelemetrySeries(history.value);
        }

        // Retrieve telemetry for a specific measurement
        function handleRequest(request) {
            var key = request.key;
            return adapter.history(key).then(addToPackage);
        }

        packaged[SOURCE] = {};
        return $q.all(relevantReqs.map(handleRequest))
            .then(function () { return packaged; });
    },
    subscribe: function (callback, requests) {
        var keys = requests.filter(matchesSource)
            .map(function (req) { return req.key; });

        function notCallback(cb) {
            return cb !== callback;
        }

        function unsubscribe(key) {
            subscribers[key] =
                (subscribers[key] || []).filter(notCallback);
            if (subscribers[key].length < 1) {
                adapter.unsubscribe(key);
            }
        }

        keys.forEach(function (key) {
            subscribers[key] = subscribers[key] || [];
            adapter.subscribe(key);
            subscribers[key].push(callback);
        });

        return function () {
            keys.forEach(unsubscribe);
        };
    }
}

```

```
        };  
    }  
  
    return ExampleTelemetryProvider;  
}  
);
```

tutorials/telemetry/src/ExampleTelemetryProvider.js

A quick summary of these changes:

- First, we maintain current subscribers (callbacks) in an object containing key-value pairs, where keys are request `key` properties, and values are callback arrays.
- We listen to new data coming in from the server adapter, and invoke any relevant callbacks when this happens. We package the data in the same manner that historical telemetry is packaged (even though in this case we are providing single-element series objects.)
- Finally, in our `subscribe` method we add callbacks to the lists of active subscribers. This method is expected to return a function which terminates the subscription when called, so we do some work to remove subscribers in this situations. When our subscriber count for a given measurement drops to zero, we issue an unsubscribe request. (We don't take any care to avoid issuing multiple subscribe requests to the server, because we happen to know that the server can handle this.)

Running Open MCT Web again, we can still plot our historical telemetry - but now we also see that it updates in real-time as more data comes in from the server.