

# Lab 3 - Introduction to MOOS

2.680 Unmanned Marine Vehicle Autonomy, Sensing and Communications



**February 15th, 2024**

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# 1 Overview and Objectives

This lab will introduce MOOS to new users. It assumes nothing regarding MOOS background. The goals of this lab are to (a) understand the publish-subscribe architecture, (b) get comfortable launching and interacting with the MOOSDB, (c) understand how to generate scripted interactions with the MOOSDB, (d) understand how the logger operates and basic tools for examining log files.

- MOOS Preliminaries: MOOS vs. MOOS-IvP, the MOOS Architecture
- Launching, Scoping, and Poking the MOOSDB
- Launching a Mission with pAntler
- Scripted Pokes the to the MOOSDB
- A Simple Example with pXRelayTest
- Modify the pXRelayTest Code

## 1.1 Preliminaries

This lab assumes you have a working MOOS-IvP tree checked out and built on your computer. To verify this make sure that the following executables are built and findable in your shell path:

```
$ which MOOSDB
/Users/you/moos-ivp/bin/MOOSDB      (or /home/you/moos-ivp/bin/MOOSDB on Linux)
$ which pHelmIvP
/Users/you/moos-ivp/bin/pHelmIvP
```

If unsuccessful with the above, return to the steps in Lab 1:

[http://oceanai.mit.edu/ivpman/labs/machine\\_setup](http://oceanai.mit.edu/ivpman/labs/machine_setup)

## 1.2 MOOS vs. MOOS-IvP

What is the relationship between MOOS and MOOS-IvP? MOOS-IvP is a superset of MOOS. The additional components include another architecture, the IvP Helm behavior-based architecture, and several additional MOOS applications. This is the nested repository concept depicted in Figure 1.

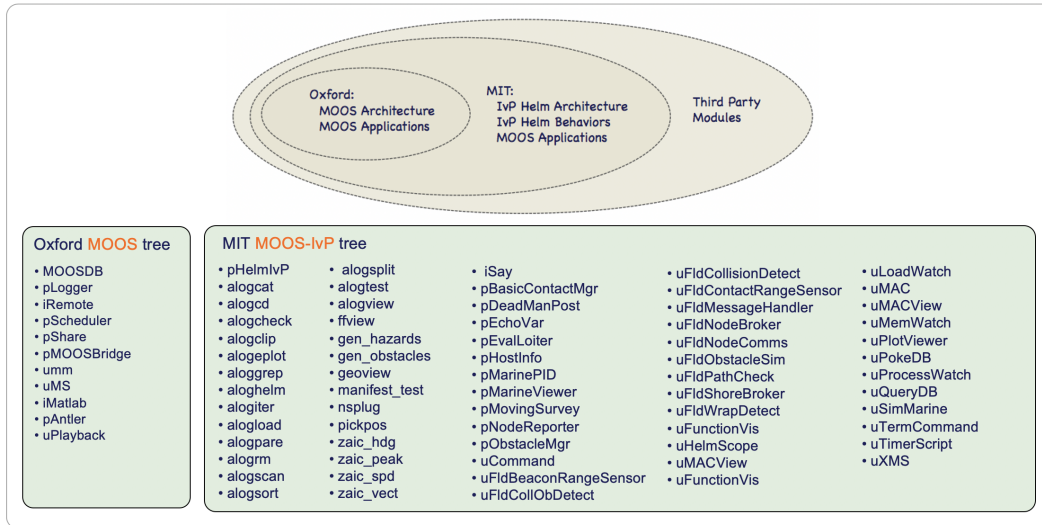


Figure 1: **Nested Repositories:** The MOOS-IvP tree contains the Oxford MOOS tree and additional modules from MIT including the Helm architecture, Helm behaviors and further MOOS applications.

### 1.3 More MOOS / MOOS-IvP Resources

We will only just touch the MOOS basics today. A few further resources are worth mentioning for following up this lab with your own exploration.

- The 2.680 lecture covers much of the material for today’s lab:  
[http://oceanai.mit.edu/2.680/docs/2.680-03-intro\\_to\\_moos\\_2024.pdf](http://oceanai.mit.edu/2.680/docs/2.680-03-intro_to_moos_2024.pdf)
- The "Very Brief Overview of MOOS" page on the course documentation page:  
[http://oceanai.mit.edu/ivpman/chap/moos\\_overview](http://oceanai.mit.edu/ivpman/chap/moos_overview)
- Follow the links to the documentation on the Oxford MOOS github website.  
<https://github.com/themoos>

### 1.4 The MOOS Architecture

The main idea explored today is that MOOS is a publish-subscribe architecture. A single **MOOSDB** serves multiple MOOS applications by essentially handling the mail published and subscribed for by each app. A MOOS *community* is a collection of applications connected to a single **MOOSDB**.

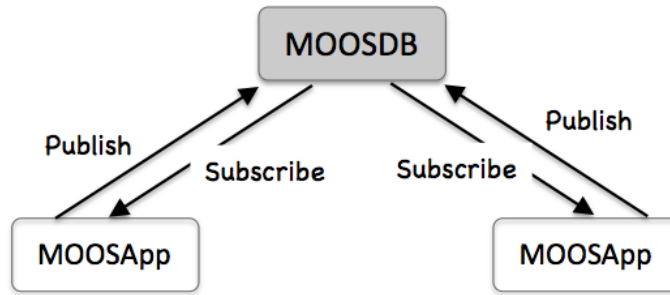


Figure 2: **The MOOS Architecture:** MOOS is a publish-subscribe architecture. The **MOOSDB** serves a number of clients, handling mail for each client as new information is posted. A **MOOSDB** with connected clients constitutes a *MOOS community*. There may be multiple *MOOS communities* on a single machine, and a single *MOOS community* may be distributed over more than one machine.

For typical autonomous vehicle implementations, there is a *MOOS community* on board each vehicle. When simulating multiple vehicles on a single machine, there is also a single community associated with each vehicle. A *MOOS community* consists of a single **MOOSDB** with one or more connected clients (i.e. apps). The communications discussed in today’s lab concern how a single app communicates with another app via the **MOOSDB** in the publish-subscribe architecture. Later labs will address how vehicles communicate with each other, essentially bridging two or more *MOOS communities* with one another.

For today, the focus is on the **MOOSDB** and connected applications. The **MOOSDB**, unlike an actual database, does not contain a full history of information that has passed through it. At most, it stores the latest value for any given *MOOS variable* published to the **MOOSDB**. When a new app connects to the **MOOSDB** it must register for the mail it needs. On startup, an app can expect to get a mail message containing the latest value for any variable it registers for, even if that mail reflects a posting to the **MOOSDB** long ago. Anything happening prior to that will be unknown to the newly connected app.

## 1.5 Launching the MOOSDB

Here we describe how to launch the **MOOSDB** from the perspective of the first-time user. The **MOOSDB** application is a server that runs on the robot or unmanned vehicle computer, or simply on your laptop during simulation. It may be launched from the command line, assuming it is in your path. Two minimalist methods are described here, starting with the most bare-bones.

### 1.5.1 A Bare-Bones Launching of the MOOSDB

In a bare-bones manner, the **MOOSDB** may be launched from the command line without any arguments. Normally the **MOOSDB** needs to know at least two pieces of configuration information, (a) the machine IP address on which to run, and (b) the port number on which to serve clients.

(Recall an IP address is comprised of four numbers in the range of [0,255] separated by a period. IP addresses are used for finding a particular machine on the Internet. For example, the oceanai class server resides at 18.18.38.22. The term "localhost" acts as a stand-in IP address when referring to one's own machine. The port number refers to a channel of sorts on a computer. It's fair to think of the IP address like the street address of an apartment building, and the port number as the unit number within the building where a particular resident resides.)

When launching the **MOOSDB** with no command line arguments, it will default to running on the localhost and port 9000:

```
$ MOOSDB
----- MOOSDB V10 -----
Hosting community      "#1"
Name look up is       off
Asynchronous support is  on
Connect to this server on port  9000
-----
network performance data published on localhost:9020
listen with "nc -u -lk 9020"
```

At this point the **MOOSDB** is running on the local machine, serving clients on port 9000. A few variables are already being published, by the **MOOSDB** itself. You can open a scope with **uXMS** in another terminal window:

```
$ uXMS DB_CLIENTS DB_TIME DB_UPTIME --serverhost=localhost --serverport=9000
=====
uXMS_581                                     0/0(154)
=====
VarName      (S)ource      (T)ime      (C)   VarValue (SCOPING:EVENTS)
-----
DB_CLIENTS   MOOSDB_#1    38.14      "uXMS_581,"
DB_TIME      MOOSDB_#1    38.14      1387380731.414707
DB_UPTIME    MOOSDB_#1    38.14      39.00859
```

The Source and Time columns may be expanded by hitting the "s" and "t" keys respectively after

it launches, or you can add `--show=source,time` as a command line argument to `uXMS`, to launch with these two columns expanded.

Alternatively you can scope with the `umm` tool:

```
$ umm --spy
```

The `umm` tool is part of the MOOS project at Oxford, while `uXMS` tool is part of the MOOS-IvP project at MIT. Overlap between toolset functions can often be found.

### 1.5.2 A More Civilized Launching of the MOOSDB

Virtually all MOOS applications are launched with a "mission configuration" file, a.k.a. a "dot-moos" file. The below mission file, `moosdb_alpha.moos`, provides the minimal configuration parameters the `MOOSDB` likes to see upon starting.

```
// (wget http://oceanai.mit.edu/2.680/examples/moosdb_alpha.moos)
ServerHost = localhost
ServerPort = 9000
Community = alpha
```

Passing the `moosdb_alpha.moos` file as a command line argument produces the below output.

```
$ MOOSDB moosdb_alpha.moos
----- MOOSDB V10 -----
Hosting community      "alpha"
Name look up is       off
Asynchronous support is on
Connect to this server on port 9000
-----
network performance data published on localhost:9020
listen with "nc -u -lk 9020"
```

Try this. Either copy and paste the above `.moos` file, or use `wget` as shown on the first line above in the example file. If you haven't installed `wget` or similar (e.g., `curl`), you should pause here and do that.

```
$ sudo apt install wget          (On Linux)
$ brew install wget             (On MacOS using Homebrew)
$ sudo port install wget        (On MacOS using MacPorts)
```

## 1.6 Scoping the MOOSDB

A MOOS *scope* is a tool for examining the state of the **MOOSDB**. The **MOOSDB** does not keep a history of prior values for a given variable, but rather just the most recent value posted. This means that the *state* of the **MOOSDB** may be regarded as the set of current MOOS variables, their values, and who made the last posting to the variable and when. Scoping allows a view into the current state (or even recent history) of the **MOOSDB**. There are multiple tools for scoping the DB, each providing conveniences of one kind or another. Here we describe the **uXMS**, **uMS**, and **pRealm** tools, the three favorites of our own lab.

More info on these two tools can be found at:

- uXMS: <http://oceanai.mit.edu/ivpman/apps/uXMS>
- pRealm: <http://oceanai.mit.edu/ivpman/apps/pRealm>

You can also navigate to the above two web pages by launching the app with the `--web` or `-w` option.

```
$ uXMS --web
$ pRealm -w
```

Most MOOS-IvP distributed apps support this command-line option.

### 1.6.1 Scoping the MOOSDB with uXMS

Your goals in this part are:

1. Open a terminal window and launch the **MOOSDB** as done at the end of the previous exercise:

```
$ MOOSDB
----- MOOSDB V10 -----
Hosting community          "#1"
Name look up is           off
Asynchronous support is   on
Connect to this server on port 9000
-----
network performance data published on localhost:9020
listen with "nc -u -lk 9020"
```

The **MOOSDB** is normally launched with a mission file specifying the **ServerHost** and **ServerPort** parameters. When launched from the command line as above with no command line arguments, these two parameters default to `localhost` and `9000`.

2. Open a second terminal window and launch **uXMS**, passing it the `--all` command line switch. Just hit `ENTER` when prompted for the IP address and Port number, accepting the defaults of `localhost` and `9000`. It should look something like:



```

$ uXMS --all
Enter IP address: [localhost]
Enter Port number: [9000]
*****
* uXMS_632 starting ...
*****
uXMS_632 is Running:
|-Baseline AppTick @ 5.0 Hz
|--Comms is Full Duplex and Asynchronous
-Iterate Mode 0 :
|-Regular iterate and message delivery at 5 Hz

```

After the above initial standard MOOSApp output, you should see a sequence of **uXMS** reports similar to:

```

=====
uXMS_443                                     0/0(31)
=====
VarName          (S) (T) (C)  VarValue (SCOPING:EVENTS)
-----
DB_CLIENTS              "uXMS_443,"
DB_EVENT                "connected=uXMS_443"
DB_QOS                  "uXMS_443=0.448942:0.573874:0.364065:0.490189,"
DB_TIME                 1424028179.877422
DB_UPTIME               16.741557
UXMS_443_ITER_GAP      1.019045
UXMS_443_ITER_LEN      0.00024
-- displaying all variables --

```

Notice the number in parentheses on the second line is incrementing. This indicates that the report has been refreshed to your terminal. If you launched as above, the scope should come up in a mode that refreshes the report any time a scoped variable changes values. In this case, the **MOOSDB** is updating **DB\_TIME** and **DB\_UPTIME** about once per second. By default, **uXMS** only scopes on the variables named on the command line. In the above case, the **--all** option was used to tell **uXMS** to scope on all variables known to the **MOOSDB**.

The five variables shown beginning with **DB\_** are all published by the **MOOSDB**. The user may choose whether or not to show the variable (S)ource, (T)ime of post, or (C)ommunity from where the post was made. A key feature of **uXMS** vs. **uMS** is the ability to specify on the command-line exactly which subset of variables to scope, possibly with color-coding. This is helpful when there are hundreds of variables in the DB.

**1.6.2 More Suggested Tinkering with uXMS**

Try a few other things:

1. Hit the 'h' key to see some keyboard interaction options that are available anytime the scope is running. Hit 'h' again any time to return to the previous mode.
2. Hit the space-bar to pause the stream of reports. This is useful if numbers are changing rapidly and you just need to take a close look at something. Return to the previous mode by hitting 'e'.

3. Hit the 's' key to expand the (S)ource column. This column tells you which app made the last posting. Try the same for the (T)ime and (C)ommunity columns.
4. The whole purpose of a scope is to give you the key information you're looking for, without needing to sift through a lot of unwanted information, with as little effort as possible. In this step we'll pretend to be interested in focusing our attention on the `DB_UPTIME` variable. Try launching `uXMS` with an additional command line argument:

```
$ uXMS --all --colormap=DB_UPTIME,blue
```

This may seem unnecessary when there are only three variables, but in real applications there may be hundreds of variables. In fact, the variable you're looking for may have scrolled off the window!

5. A similar way to focus on a single variable is to only scope on the one variable we're looking for:

```
$ uXMS DB_UPTIME
```

6. `uXMS` only shows you the current snapshot of the variables in the `MOOSDB`. What if you would like to see how a variable is changing? In our case, we know how the `DB_UPTIME` variable is changing, but for the sake of showing this feature, try:

```
$ uXMS --history=DB_UPTIME
```

### 1.6.3 Scoping with `uMS`

The `uMS` scope is a graphical MOOS scope, often preferred by those inclined to like GUIs vs. command line tools. It has some other advantages over `uXMS` as well.

Your goals in this part are:

1. If you don't still have a `MOOSDB` running, open a terminal window and launch the `MOOSDB` as done previously:

```
$ MOOSDB
```

2. Open a second terminal window and launch `uMS`, passing it the same mission file as an argument:

```
$ uMS
```

You should see a window open and, after clicking on the `Connect` button, you should see something similar to:

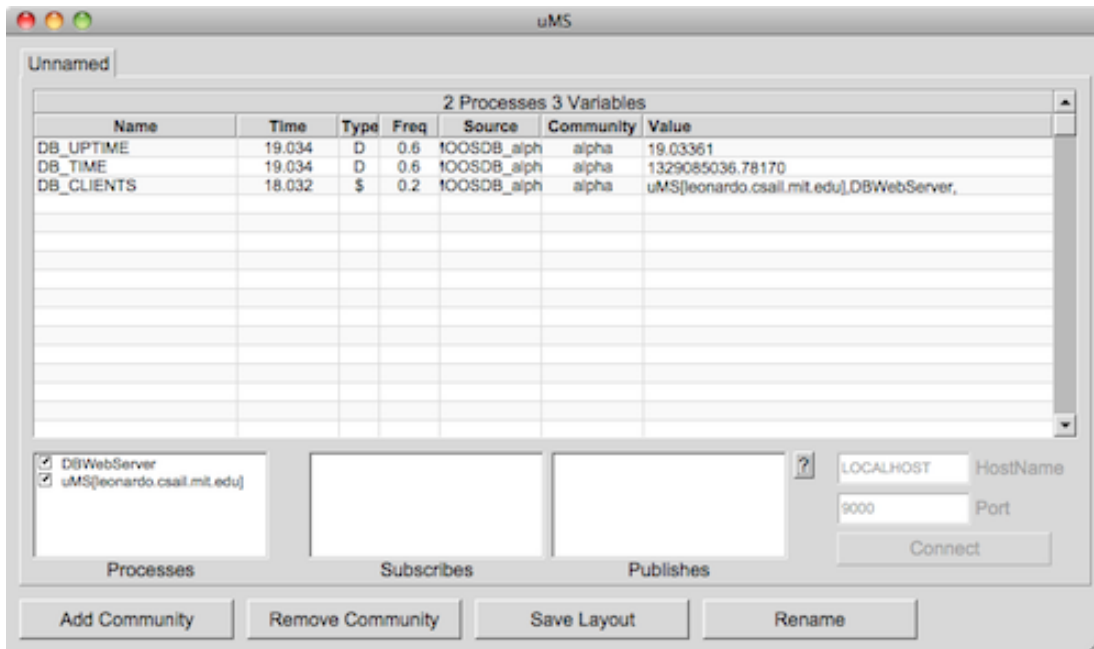


Figure 3: The uMS MOOS Scope

#### 1.6.4 Pros/Cons of uXMS vs uMS

The choice of **uXMS** vs **uMS** is often just a matter of taste. A couple of differences are noteworthy however.

- **uMS** allows for connections to multiple MOOSDBs, on perhaps multiple vehicles, simultaneously. The user may select the vehicle with the tab at the top of the screen.
- **uXMS** allows the user to scope on as few as one single variable, or to name the variable scope list explicitly. **uMS** scopes on all variables all the time, with a few mechanisms for reducing the scope list based on process name.
- **uXMS** may be a better choice if one is scoping on a remote **MOOSDB**, perhaps on a robot with a poor connection. It is a low-bandwidth client compared to **uMS**. If running on a remote terminal, its bandwidth back to the user is zero in the paused mode.
- **uXMS** has provisions for at least limited scoping on a variable history.
- **uXMS** will display a variable's "auxiliary source" information. This is a secondary field associated with each posting describing the source of the posting. This is key when using the IvPHelm. Variables posted by helm behaviors will have a source of **pHelmIvP** and an auxiliary source showing the behavior responsible for the posting.

#### 1.6.5 Scoping with pRealm

Realmcasting is a feature first introduced in 2021. It complements Appcasting, which is the default set of windows open to the left of the GUI when running **pMarineViewer** in say the Alpha mission. If you are running a mission with **pMarineViewer**, it may be the only scoping tool you need. You can scope on selected vehicle (MOOS community), and selected app, as shown in Figure 4.

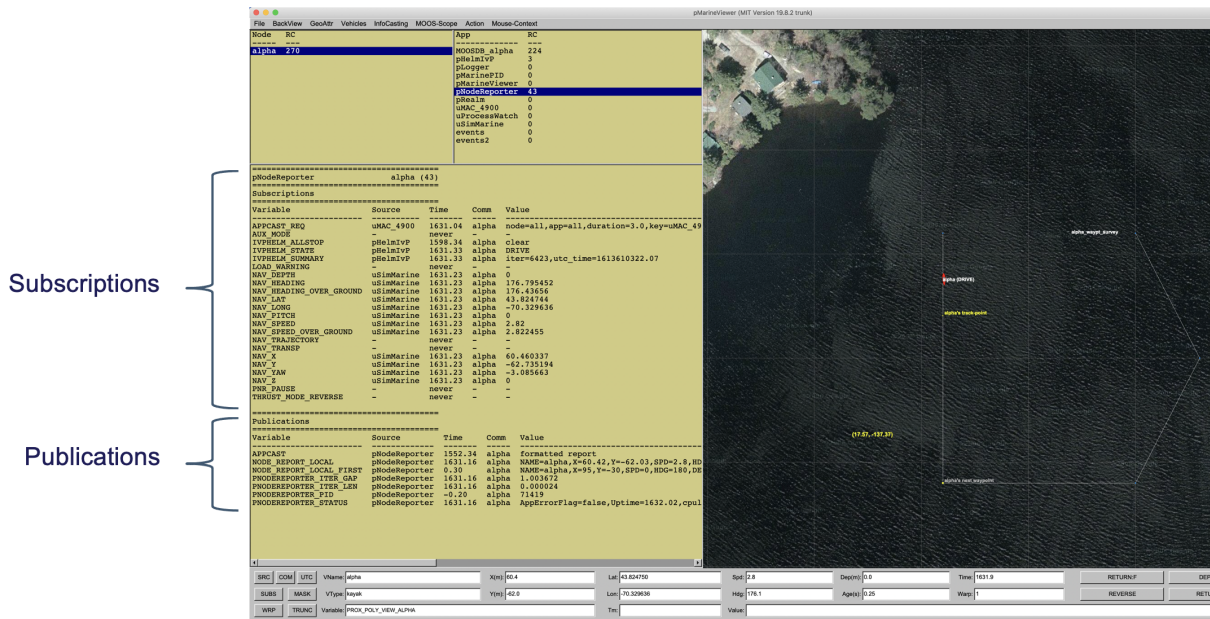


Figure 4: The RealmCasting interface in pMarineViewer is the lefthand side of the GUI comprising the three panels shown. Toggling between AppCasting and RealmCasting is done with the 'a' key.

The realmcasting pane on the lower-left is the primary output. It is split into two parts. On the top is a scope on all variables subscribed to by the selected application. The bottom half is a scope on all variables published by the application.

If you are running pMarineViewer and do not see any content in this window, it is most likely due to the omission of running pRealm in both the shoreside and vehicle communities. It is enabled by default in the Alpha mission. Most other example missions also have realmcasting enabled.

## 1.7 Poking the MOOSDB

Poking refers to the idea of publishing a variable-value pair to the **MOOSDB**. Many apps publish to the **MOOSDB** during the course of normal operation. Poking implies a publication that perhaps was not planned, or outside the normal mode of business. It is often very useful for debugging. Here we describe the **uPokeDB** tool.

Where to get more information:

- **uPokeDB**: <http://oceanai.mit.edu/ivpman/apps/uPokeDB>

Or simply:

```
$ uPokeDB --web
```

### 1.7.1 Poking the MOOSDB with uPokeDB

**uPokeDB** is a command-line tool for poking the **MOOSDB** with one or more variable-value pairs. Poking the **MOOSDB** requires knowing where the **MOOSDB** is running in terms of its IP address, (**ServerHost** parameter), and port number, (**ServerPort** parameter). These may be specified on the command line to **uPokeDB**, but for our purposes here we assume the existence of a mission file, **alpha.moos** with this information:

```
// (wget http://oceanai.mit.edu/2.680/examples/alpha.moos)
ServerHost = localhost
ServerPort = 9000
Community  = alpha
```

Your goals in this part are:

1. Open two terminal windows and launch the **MOOSDB** and **uXMS** as done previously:

```
$ MOOSDB alpha.moos
$ uXMS alpha.moos --all
```

Now open a third terminal window for poking the **MOOSDB** as follows:

```
$ uPokeDB DEPLOY=true SPEED=2 alpha.moos
```

Note the two new variables, **DEPLOY** and **SPEED**, appearing in the **uXMS** window. It should look something like:

```
=====
uXMS_655                                0/0(204)
=====
VarName      (S) (T) (C)  VarValue (SCOPING:EVENTS)
-----
DB_CLIENTS           "uXMS_655,"
DB_TIME              1386249435.276804
DB_UPTIME            46.213629
DEPLOY              "true"
SPEED                2
```

- Note the variable values in `uXMS`. `DEPLOY` has the value `"true"` with double quotes, indicating that it is a string. The variable `SPEED` is of type double, indicated by the lack of quotes. The types were inferred by `uPokeDB` by heuristically checking whether the arguments are numerical or not. But sometimes you *do* want to publish a string with a numerical value. Try posting the variable `HEIGHT` with the string value of `"192"`, noting the colon-equals instead of equals:

```
$ uPokeDB HEIGHT:=192 alpha.moos
```

Note the new variable, `HEIGHT`, appearing in the `uXMS` window. It should look something like the below output, where in this case, the (S)ource column is expanded to show the source of the postings.

```
=====
uXMS_655                                0/0(347)
=====
VarName      (S)ource      (T) (C)  VarValue (SCOPING:EVENTS)
-----
DB_CLIENTS   MOOSDB_alpha    "uXMS_655,"
DB_TIME      MOOSDB_alpha    1386250092.847527
DB_UPTIME    MOOSDB_alpha    703.784353
DEPLOY       uPokeDB         "true"
HEIGHT       uPokeDB         "192"
SPEED        uPokeDB         2
```

### 1.7.2 Further things to try Using uPokeDB

Here's some other things to consider and try:

- Trying poking the `DEPLOY` variable to the `MOOSDB` a second time, this time with:

```
$ uPokeDB DEPLOY=100 alpha.moos
```

Does the value of `DEPLOY` change? If not, why not?

- Create a simple script of pokes on the command line as follows:

```
$ uPokeDB APPLES=1 alpha.moos; sleep 5; uPokeDB APPLES=2 alpha.moos;
```

If you're new to the command line environment, the semicolon above separates successful command line invocations. The `sleep` command is a common shell utility that will simply pause a given number of seconds before completing.

3. Another way to execute the same simple script as above is to store the above three commands in a file named, for example, `myscript`:

```
uPokeDB APPLES=1 alpha.moos
sleep 5
uPokeDB APPLES=2 alpha.moos
```

With the above file you can make the two successive pokes to the `MOOSDB`, with five seconds in between, with:

```
$ source myscript
```

There are many other ways of poking the `MOOSDB`. All MOOS apps that publish anything are examples. Of course many MOOS applications publish a fixed set of variables that are not easily changeable without re-coding. But certain apps like `uTimerScript` and `pMarineViewer` have built-in configuration file parameters for poking the `MOOSDB` in user configurable ways.

## 1.8 Launching a Mission with pAntler

In theory a set of N MOOS applications may be launched from N terminal windows, but this is cumbersome in practice. The `pAntler` tool allows this to be done from a single mission file. In this file, a block of lines declares all the apps to be launched with one invocation of `pAntler`.

Where to get more information:

- `pAntler`: <http://oceanai.mit.edu/ivpman/apps/pAntler>

### 1.8.1 Basic pAntler Usage

The Antler block is typically the first configuration block in a `.moos` file, declared with `ProcessConfig = ANTLER` as below. The `MSBetweenLaunches` parameter specifies the number of milliseconds between launching processes. Each line thereafter specifies an app to be launched and whether a dedicated console window should be opened for the application.

```
ProcessConfig = ANTLER
{
  MSBetweenLaunches = 200

  Run = MOOSDB      @ NewConsole = true/false
  Run = AnotherApp @ NewConsole = true/false
  ...
  Run = AnotherApp @ NewConsole = true/false
}
```

Further options exist beyond the vanilla launch configuration described above, including (a) the ability to launch a given app under an aliased name, (b) specifying command-line arguments to an app at launch time and more. See the documentation.

### 1.8.2 An Example: Launching the MOOSDB along with uXMS

In the example below we use `pAntler` to launch the `MOOSDB` and the `uXMS` scope from a single mission file. The user preferences for `uXMS` are provided in its configuration block. Type `uXMS --example` on the command line for further options if you're curious.

Note: in this example, the launch process should result in a new `xterm` window opening. If you are running on GNU/Linux, the `xterm` should be available by default. If you are running MacOS, you may need to install `xterm`. If you type `xterm` on the MacOS Terminal command line and you receive a "command not found" error, then you may need to install `xterm`.

<https://www.xquartz.org>

You may need to log out and log back in for this to take effect.

Your goals in this part are:

1. Create a copy of the example mission file shown in Listing 1 below and save it locally as `db_and_uxms.moos`. (hint: the easiest way to do this is to just invoke the `wget` expression on the top line of this file. This will pull the file down from the server into your current directory.)



The mission may be launched from the command-line with:

```
$ pAntler db_and_uXMS.moos
```

This should open a new console window for **uXMS** displaying the variables posted by the DB, with the (S)ource and (T)ime columns expanded, but not the (C)ommunity column.

2. Modify the **uXMS** configuration block in the `.moos` file to configure **uXMS** to keep a history of the **DB.UPTIME** variable. To see configuration options for **uXMS**, type:

```
$ uXMS --example
```

Once you have launched **uXMS** with the new configuration, type 'z' to toggle in and out of history mode.

3. Modify the `db_and_uXMS.moos` file to launch a new terminal window for the **MOOSDB** in addition to the **uXMS** application.

*Listing 1.1: A simple mission file.*

```
// (wget http://oceanai.mit.edu/2.680/examples/db_and_uXMS.moos)
ServerHost = localhost
ServerPort = 9000
Community = alpha

ProcessConfig = ANTLER
{
  MSBetweenLaunches = 200

  Run = MOOSDB      @ NewConsole = false
  Run = uXMS        @ NewConsole = true
}

ProcessConfig = uXMS
{
  AppTick = 4
  CommsTick = 4

  VAR          = DB_CLIENTS, DB_UPTIME, DB_TIME
  DISPLAY_SOURCE = true
  DISPLAY_TIME  = true
  COLOR_MAP     = DB_CLIENTS, red
}
```

## 1.9 Scripted Pokes to the MOOSDB

Here we cover how to have a script of pre-arranged pokes to the `MOOSDB`. This may be useful for a number of reasons besides debugging. The primary tool described here is the `uTimerScript` MOOS application. It is capable of (a) scripted pokes at a pre-defined times after launch, (b) pokes having a poke-time specified to fall randomly within a specified interval, (c) pokes having numerical values falling with a uniformly random interval, and several other features including conditioning the running of the script based on other MOOS variables.

Where to get more information:

- `uTimerScript`: <http://oceanai.mit.edu/ivpman/apps/uTimerScript>

Or simply:

```
$ uTimerscript --web
```

### 1.9.1 Basic `uTimerScript` Usage

`uTimerScript` is configured with its own block in the MOOS configuration file. The general format is below. The primary entries are the events themselves, defined by a MOOS variable, value, and time or time-range when the event is to occur. There are many options for configuring the script. These options are described in the documentation, but a quick look at the options can be seen by typing `uTimerScript --example` on the command line.

```
ProcessConfig = uTimerScript
{
  event = var=<MOOSVar>, val=<value>, time=<value>
  event = var=<MOOSVar>, val=<value>, time=<value>
  ...
  event = var=<MOOSVar>, val=<value>, time=<value>

  [OPTIONS]
}
```

## 1.9.2 A Simple Example with uTimerScript

The below mission file contains a `uTimerScript` script for repeatedly posting the variable `COUNTER_A` with values 1-10 in ascending order roughly once every half second. The last event in the script is posted at time chosen from a random five second interval.

*Listing 1.2: A simple counter example with uTimerScript.*

```
// (wget http://oceanai.mit.edu/2.680/examples/utscript.moos)
ServerHost = localhost
ServerPort = 9000
Community = alpha

ProcessConfig = ANTLER
{
  MSBetweenLaunches = 200

  Run = MOOSDB @ NewConsole = false
  Run = uXMS @ NewConsole = true
  Run = uTimerScript @ NewConsole = false
}

ProcessConfig = uXMS
{
  VAR = COUNTER_A, DB_CLIENTS, DB_UPTIME
  COLOR_MAP = COUNTER_A, red
  HISTORY_VAR = COUNTER_A
}

ProcessConfig = uTimerScript
{
  paused = false

  event = var=COUNTER_A, val=1, time=0.5
  event = var=COUNTER_A, val=2, time=1.0
  event = var=COUNTER_A, val=3, time=1.5
  event = var=COUNTER_A, val=4, time=2.0
  event = var=COUNTER_A, val=5, time=2.5
  event = var=COUNTER_A, val=6, time=3.0
  event = var=COUNTER_A, val=7, time=3.5
  event = var=COUNTER_A, val=8, time=4.0
  event = var=COUNTER_A, val=9, time=4.5
  event = var=COUNTER_A, val=10, time=5:10

  reset_max = nolimit
  reset_time = all-posted
}
```

The mission may be launched from the command-line with:

```
$ pAntler utscript.moos
```

This should open a new console window for `uXMS` displaying the variables `COUNTER_A` variable repeatedly

incrementing from 1 to 10. Note that reaching 10 happens somewhere between 0.5 and 5.5 seconds after reaching 9.

### 1.9.3 Exercises

Your goals in this part are:

1. Create a copy of the example mission file in Listing 2 above and save it locally.
2. Launch the mission. It should open a `uXMS` window. Follow the progress of the counter script.

```
$ pAntler utscript.moos
```

3. Take a look at the `uTimerScript` documentation linked from the web page. In particular, Section 3 Script Flow Control. Configure the script such that it is paused when `uTimerScript` is launched. Launch the same mission and confirm that the script is initially not running. Then use `uPokeDB` to un-pause the script, and confirm it is running. Hint: to un-pause the script with `uPokeDB`, you'll need to know which variable to poke, and this also can be found in the `uTimerScript` documentation or by typing `uTimerScript -i` on the command line.
4. This is a bit of a `pAntler` exercise. Configure your mission to launch two versions of the script, the second version publishing to `COUNTER.B`. Note you will need two configuration blocks, each with a unique name. And you will need to launch `uTimerScript` twice within the Antler block, each with an alias. Hint: see the `pXRelay` example at the end of Lab 3.
5. Confirm your new mission launches and executes the two separate scripts and both counters are incrementing.
6. Configure the second script with a `condition` parameter. See Section 3.2 of the `uTimerScript` documentation. Use a condition such as "`condition = COUNTER_A > 5`". Re-launch your mission. Confirm that the second script is paused periodically based on the state of the first script.
7. Add the `pLogger` application to your mission. You will need to add a `pLogger` entry to your ANTLER configuration block, and add the following `pLogger` configuration block at the end of your file.

```
ProcessConfig = pLogger
{
  AsyncLog = true
  WildCardLogging = true
  WildCardOmitPattern = *_STATUS
}
```

Re-run the mission. Confirm that you see the `pLogger` application listed in the `DB_CLIENTS` variable in the `uXMS` scope.

8. Verify that a log file has been created. Since we didn't specify a name for the log file, by default it should be in a subdirectory of where you launched the mission, looking something like `MOOSLog_11.23.2016_11.31.13/`. Enter the directory and confirm that you see an `.alog` file.
9. Take a look at the file by typing `more filename.alog`. Then take a look at the `COUNTER` variables using `allogrep` (substituting of course the name of your `.alog` file:

```
$ aloggrep COUNTER_A COUNTER_B MOOSLog_11_23_2016____11_31_13.aalog
```

## 2 A Simple Example with pXRelay

`pXRelay` is a simple MOOS app designed solely to illustrate basic functions of a MOOS app. It registers for a single variable, and upon receiving mail for that variable, it publishes another variable incremented by 1. It provides a framework for illustrating a few other introductory topics.

### 2.1 Basic pXRelay Usage

`pXRelay` is configured with its own block in the MOOS configuration file. It is configured with (a) an incoming variable, the variable it will register for incoming mail, and (b) an outgoing variable, a variable it will post an incremented integer each time it receives mail on the incoming variable. The basic form is:

```
ProcessConfig = pXRelay
{
  outgoing_var = <MOOSVar>
  incoming_var = <MOOSVar>
}
```

### 2.2 A Simple Example with pXRelay

The below mission file contains a configuration for two instances of the `pXRelay` application. All MOOS apps must have a unique name to connect to the MOOSDB, so we launch them with an alias with `pAntler` using the `pXRelay_PEARs` alias for example. The two apps each register for what the other produces, and each produces what the other registers for.

*Listing 2.3: Example Code.*

```
0 // (wget http://oceanai.mit.edu/2.680/examples/xrelay.moos)
1 ServerHost = localhost
2 ServerPort = 9000
3 Community = alpha
4
5 ProcessConfig = ANTLER
6 {
7   MSBetweenLaunches = 200
8
9   Run = MOOSDB @ NewConsole = false
10  Run = pXRelay @ NewConsole = false ~pXRelay_PEARs
11  Run = pXRelay @ NewConsole = false ~pXRelay_APPLES
12 }
13
14 ProcessConfig = pXRelay_APPLES
15 {
16  AppTick = 10
17  CommsTick = 10
18  incoming_var = APPLES
19  outgoing_var = PEARs
20 }
21
22 ProcessConfig = pXRelay_PEARs
```

```
23 {
24   AppTick      = 10
25   CommsTick    = 10
26   incoming_var = PEARS
27   outgoing_var = APPLES
28 }
```

Upon launch, the two pXRelay apps are in a stalemate, each waiting for the other to make the first posting. We can break this stalemate with `uPokeDB`:

```
$ uPokeDB xrelay.moos PEARS=1
```

This should get things going. Now it would be good to see it all running by launching a scope:

```
$ uXMS xrelay.moos --all --show=time
```

Your goals in this part are:

1. Create a copy of the example mission file shown in Listing 3 above and save it locally as `pxrelay.moos`. (hint: use `wget!`)
2. Launch the mission. Open up `uXMS` in another Terminal window with the parameters of your choosing. I recommend

```
$ uXMS pxrelay.moos --colorany=APPLES,PEARS --all
```

3. Kick off the activity by poking one of the `APPLES` or `PEARS` variables with an initial value. Confirm that things are working as they should.
4. Add `uTimerScript` to your mission file, with a simple script to kick off the `pXRelay` handshaking at some point after launch (say 10 secs), as an alternative way to kicking off the activity instead of `uPokeDB`. You'll need to add `uTimerScript` to your ANTLER configuration block, and add a simple script (a `uTimerScript` configuration block) to your `.moos` file.
5. Change your `uTimerScript` script to be the ascending counter script from Section 1.9, incrementing `COUNTER.A` 1 to 10. Configure it with `paused=false`, but add a condition to your script (`condition = APPLES == $(PEARS)`). Re-launch the revised mission. Since `APPLES` is equal to `PEARS` periodically, the condition will periodically be met. (You will still need to kick things off with either an initial poke from the command line, or re-use the script from the previous item as a second script to kick things off.)
6. Try changing the `AppTick` in one of the `pXRelay` configurations to 0.1. You should note that the script is now mostly in the state where its conditions are not met. Can you explain why?

## 3 First Experiments in Modifying MOOS App Code

Next we will take the first steps toward extending the MOOS-IvP code. This is done by creating your own "third-party" tree, with your own MOOS apps.

### 3.1 Download a Template Tree for Extending MOOS

In writing MOOS apps and later helm behaviors in this class, you'll need your own software folder. This folder will need a bit of structure and CMake files for compiling the source code. To make this a bit easier, a template for this is available. Follow the instructions in the separate [Version Control with Git](#) document alongside the other lab documents, linked from the Labs section on the course website. Follow these instructions before proceeding to Section 3.2.

This folder has an example MOOS app and example helm behavior and the CMake files for building the code. We will use this as starting point for writing code in the class. And our first exercise below, involves trying to make some simple modifications of the example app.

The name of your tree should be `moos-ivp-janedoe`, where `janedoe` is your MIT Athena name. Hereafter we will simply refer to this tree generically as the `moos-ivp-extend` tree.

### 3.2 Building Your Tree

Verify that you can build your `moos-ivp-extend` tree by:

```
$ cd moos-ivp-extend
$ ./build.sh
```

It should add the executable, `pXRelayTest`, in `moos-ivp-extend/bin/`.

Add the above directory to your shell path. Replacing `extend` with your username in all of the above.

### 3.3 Exercises in Modifying the `pXRelayTest` Code

The `moos-ivp-extend` tree contains an app very similar to `pXRelay` from the `moos-ivp` tree. This app is call `pXRelayTest`. We will attempt to modify some of the behavior of the `pXRelay` application while putting our modifications in the new `moos-ivp-extend` tree, in `pXRelayTest`.

1. Take a look at the `pXRelayTest` source code. It is inside `moos-ivp-extend/src/pXRelayTest`. Look inside `Relayer.cpp`. Check out the `OnNewMail()` and `Iterate()` loops.
2. Can you modify this code to make it increment by ten instead of one?
3. Can you modify this code such that it takes *two* incoming variables, and does its thing if *either* of the two variables is written to?