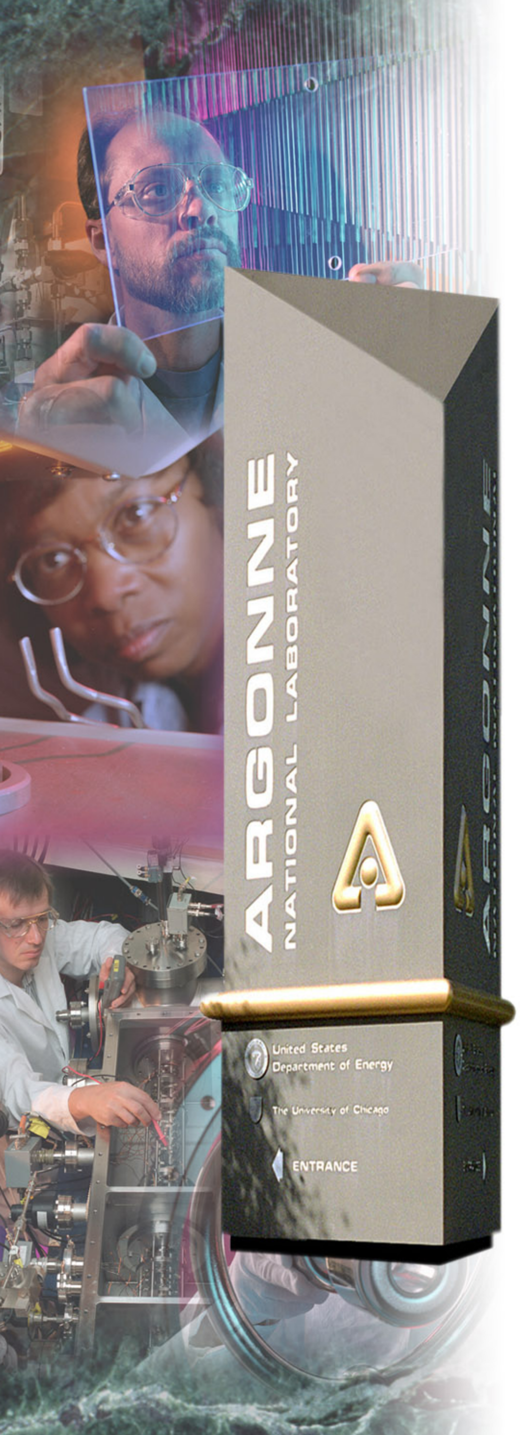

Getting Started with EPICS Lecture Series

State Notation Language and the Sequencer

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Outline

- What is State Notation Language (SNL)
- Where does it fit in the EPICS toolkit
- Components of a state notation program
- Some Notes on the Runtime Sequencer
- Building, running and debugging a state notation program
- Additional Features
- When to use it
- This talk covers Sequencer version 2.0.8
- This talk does not cover all the features of SNL and the sequencer. Consult the manual for more information.

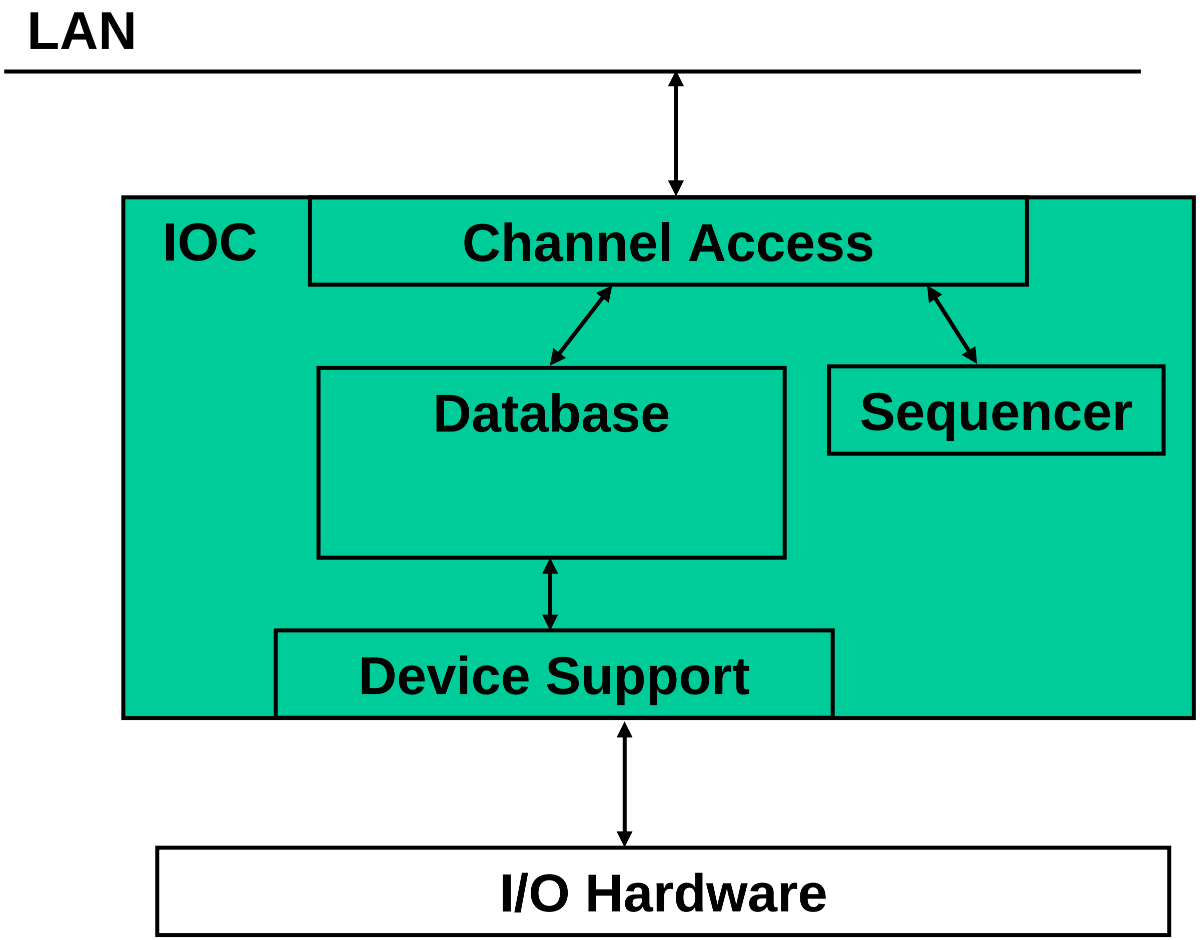
  http://www.slac.stanford.edu/comp/unix/package/epics/sequencer/

SNL and the Sequencer

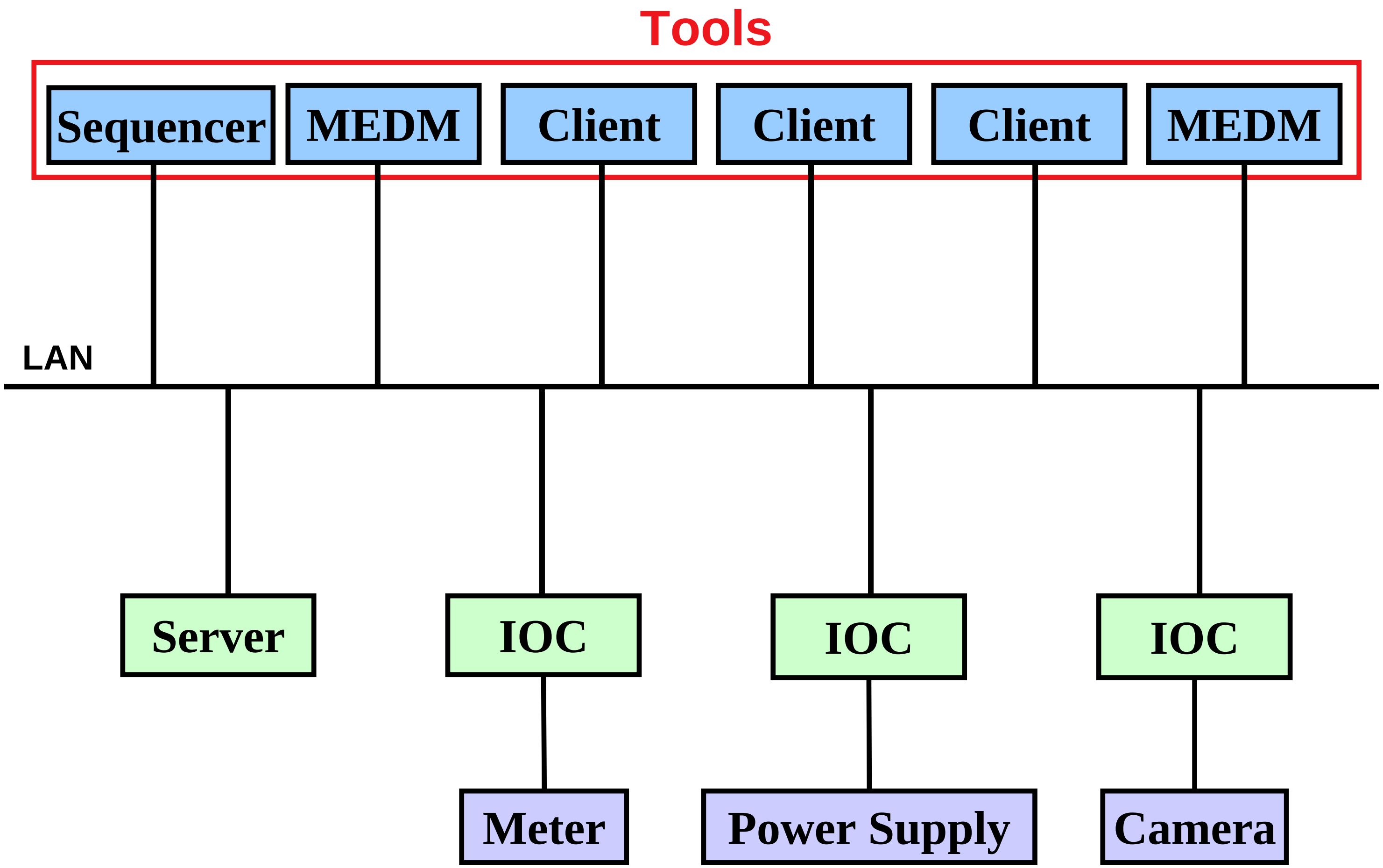
- **The sequencer runs programs written in State Notation Language (SNL)**
- **SNL is a ‘C’ like language to facilitate programming of sequential operations**
- **Fast execution - compiled code**
- **Programming interface to extend EPICS in the real-time environment**
- **Common uses**
  - Provide automated start-up sequences like vacuum or RF where subsystems need coordination
  - Provide fault recovery or transition to a safe state
  - Provide automatic calibration of equipment

Where's the Sequencer?

The major software components of an IOC (IOC Core)



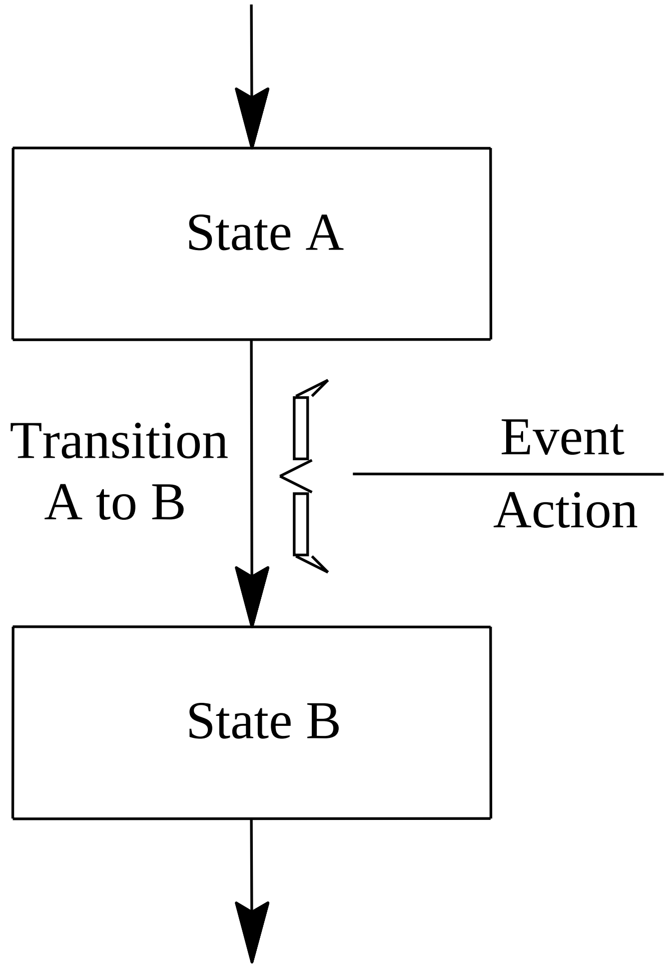
Where's the Sequencer Now?



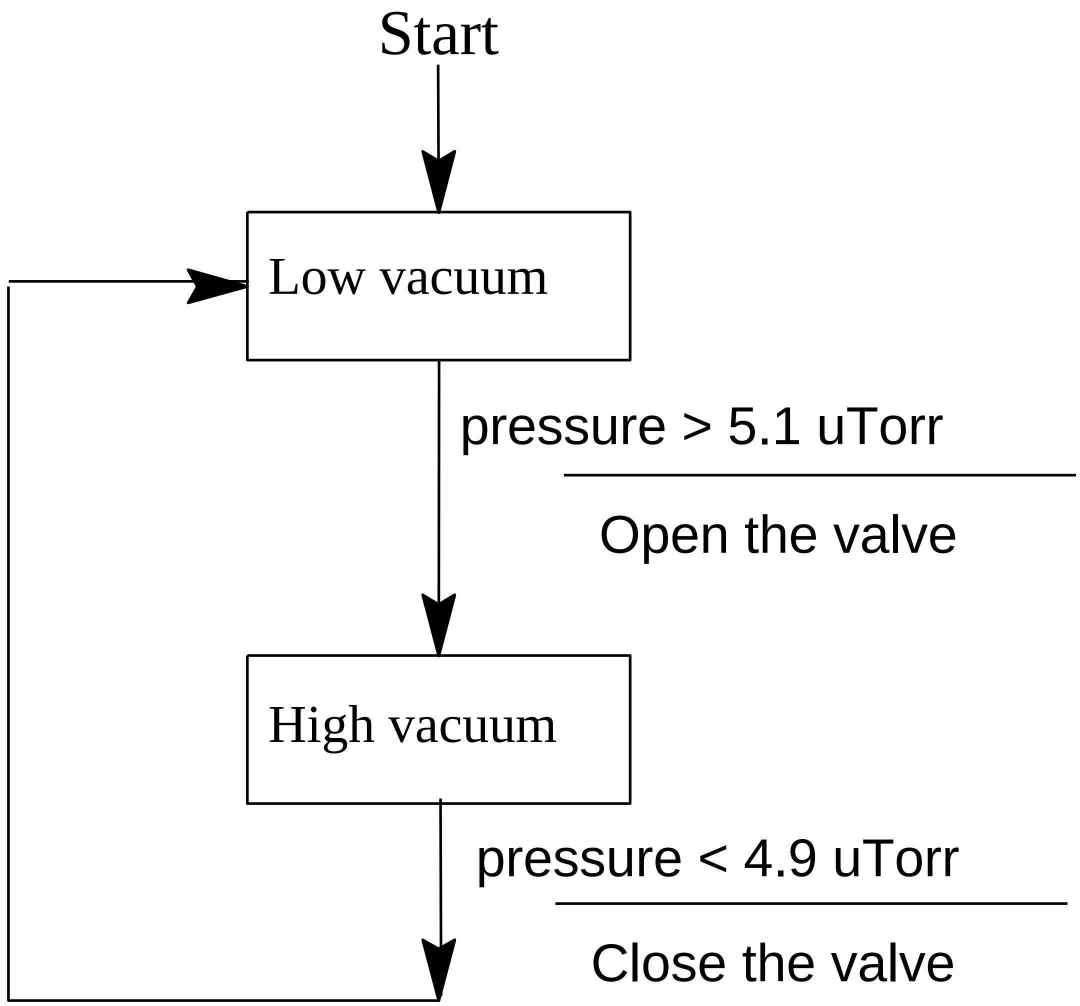
The Best Place for the Sequencer

- **From Sequencer Version 2.0.0 can be either in the IOC or on a workstation**
- **Traditionally in the IOC**
- **Locating it in the IOC probably makes it easier to manage**
- **Running on workstation could make testing easier**
- **Workstation gives an easy way to write the CA parts of CA clients**

SNL implements State Transition Diagrams



STD Example


Start
Low vacuum
pressure > 5.1 uTorr
Open the valve
High vacuum
pressure < 4.9 uTorr
Close the valve

Some Definitions

- ***SNL*** **: State Notation Language**
- ***SNC*** **: State Notation Compiler**
- ***sequencer*** **: The tool that executes the compiled SNL code**
- ***Program*** **: A complete SNL application consisting of declarations and one or more state sets**
- ***State Set*** **: A set of states that make a complete finite state machine**
- ***State*** **: A particular mode of the state set in which it remains until one of its transition conditions is evaluated to be TRUE**

SNL: General Structure and Syntax

```
program program_name
declarations

ss state_set_name {

    state state_name{
        entry{
            action statements
        }
        when (event){
            action_statements
        } state new_state_name

        when(event)
            ...
        exit{
            action statements
        }
    }
    state state_name{
        ...
    }
}
```

SNL: General Structure and Syntax

Program name	A Program contains many state sets. The program name is used as the handle to the sequencer manager for state programs.
ss name **{**	A state set becomes a task in the vxWorks environment.
state name**{**	A state is an area where the task waits for events. The related task waits until one of the events occurs and then checks to see which it should execute. The first state defined in a state set is the initial state.
option flag;	A state specific option
when(*event*) **{**	Is used to define the events for which this state waits.
}state statename	Is used to define the new state after the actions are taken.
entry{	Do these actions on entry to this state from another state (using **option -e;** will do these actions even if it enters from the same state)
}	
exit{	Do these actions before exiting this state to another state. (using **option -x**; will do these actions even if it exits to the same state.)
}	

Declarations

- **Occur before a state set and have a scope of the entire program.**

- **Scalar types**

```
int       variableIname;
short     variableSname;
long      variableLname;
char      variableCname;
float     variableFname;
double    variableDname;
string    variableStrname;   /* currently limited to 40 characters*/
```

- **Vector types**

```
int       arrayIname[array_length];
short     arraySname[array_length];
long      arrayLname[array_length];
char      arrayCname[array_length];
float     arrayFname[array_length];
double    arrayDname[array_length];
```

Declarations - Assignments

- **Assignment to channel access server channels**

```
float  pressure;
assign pressure to “CouplerPressureRB1”;

double pressures[2];
assign pressures to {“CouplerPressureRB1”,
”CouplerPressureRB2”, ” CouplerPressureRB3”};
```

- **To use these channel in *when* clauses, they must be monitored**

```
monitor pressure;
monitor pressures;
```

- **Can be written like this to aid readability**

```
float pressure; assign pressure to “PressureRB1”; monitor pressure;
```

Declarations – Event Flags

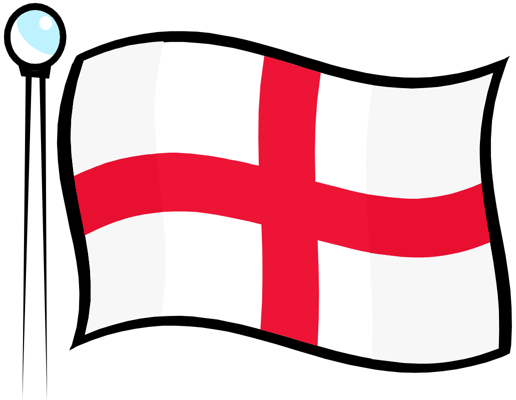
Declaring Event Flags

Event for state sets to set, clear and test

```
evflag    event_flag_name;
```

Flag monitor is set when PV changes (posts a monitor)

```
evflag    flag_monitor;
sync      pressure   flag_monitor;
```



Events

An event is the condition on which statements following a when **are executed and a state transition is made**

Possible events:

- Change in value of a variable that is being monitored

  example: **`when(achan < 10.0)`**

- A timed event (not a task delay!)

  example: **`when(delay(`*`1.5`*`))`**

  The delay value is in seconds. It is delclared internally as a double and constant arguments to the delay function **must** contain a decimal point.

  A delay is normally reset whenever the state containing it is exited. Use the state specific **option -t** to keep it from being reset when exiting to the same state..

Events (continued)

- **An internally generated event (event flag)**

  examples: **when(efTestAndClear(myflag))**

  when(efTest(myflag))

  efTest does not clear the flag. **efClear** must be called sometime later to avoid an infinite loop.

  The event flag can be set internally by **efSet**(event_flag_name)

  or if the flag is synced to a monitored channel it will be set when

  the channel changes.

- **Change in the channel access connection status.**

  examples: **when(pvConnectCount() < pvChannelCount())**

  when(pvConnected(mychan))

Actions

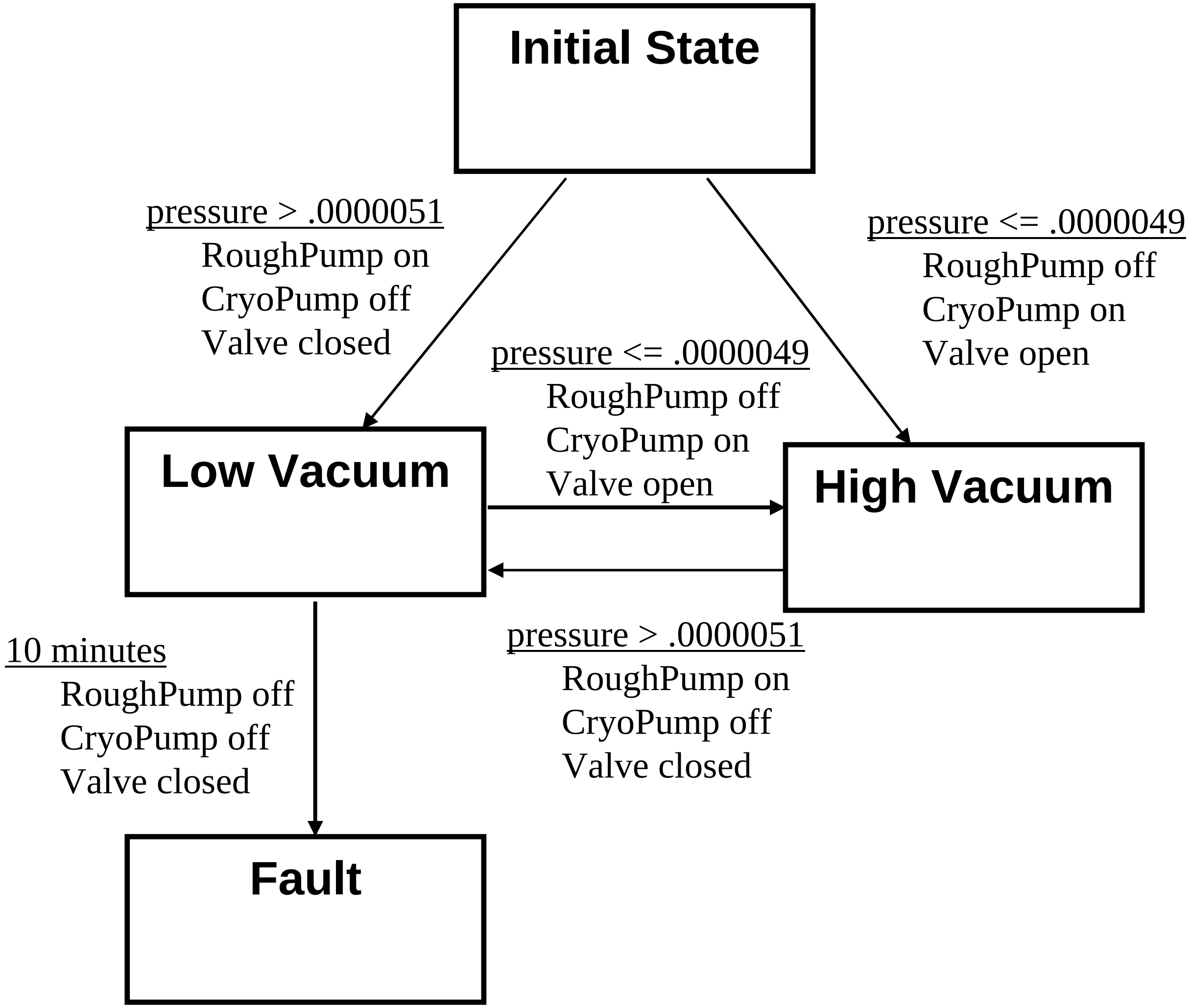
- **Built-in action function, e.g. :**
  - **pvPut** (variable_name);
  - **pvGet** (variable_name);
  - **efSet** (event_flag_name);
  - **efClear** (event_flag_name);
- **Almost any C expression**

  switch *is not implemented and code using it must be escaped.*


```
%% escape one line of C code

%{
escape any number of lines of C code
}%
```

Example - State Definitions and Transitions



Example - Declarations

```
double  pressure;
assign  pressure to “Tank1Coupler1PressureRB”;
monitor pressure;

short   RoughPump;
assign  RoughPump to “Tank1Coupler1RoughPump”;
short   CryoPump;
assign  CryoPump to “Tank1Coupler1CryoPump”;
short   Valve;
assign  Valve to “Tank1Coupler1IsolationValve”;
String  CurrentState;
assign  CurrentState to “Tank1Coupler1VacuumState”;
```

Example – State Transitions

```
program vacuum_control

ss coupler_control
{
   state init{
        when(pressure > .0000051){
        } state low_vacuum
        when(pressure <= .0000049){
        } state high_vacuum
   }
   state high_vacuum{
        when(pressure > .0000051){
        } state low_vacuum
   }
   state low_vacuum{
        when(pressure <= .0000049){
        }state high_vacuum
        when(delay(600.0)){
        }state fault
   }
   state fault{
   }
}
```

Example – Init State

```
    state init {
            entry {
                    strcpy(CurrentState,"Init");
                    pvPut(CurrentState);
            }
            when(pressure > .0000051){
                    RoughPump = 1;
                    pvPut(RoughPump);
                    CryoPump = 0;
                    pvPut(CryoPump);
                    Valve = 0;
                    pvPut(Valve);
            } state low_vacuum
            when(pressure <= .0000049){
                    RoughPump = 0;
                    pvPut(RoughPump);
                    CryoPump = 1;
                    pvPut(CryoPump);
                    Valve = 1;
                    pvPut(Valve);
            } state high_vacuum
        }
```

Example – State low_vacuum

```
state low_vacuum{
   entry{
       strcpy(CurrentState,"Low Vacuum");
       pvPut(CurrentState);
   }
   when(pressure <= .0000049){
       RoughPump = 0;
       pvPut(RoughPump);
       CryoPump = 1;
       pvPut(CryoPump);
       Valve = 1;
       pvPut(Valve);
   }state high_vacuum
   when(delay(600.0)){
   }state fault
}
```

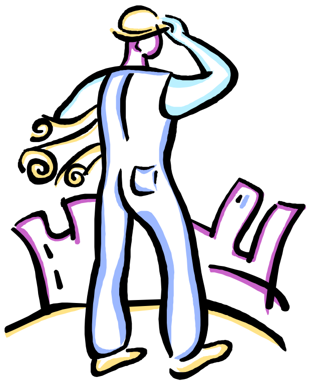
Example – State high_vacuum

```
state high_vacuum{
      entry{
            strcpy(CurrentState,"High Vacuum");
            pvPut(CurrentState);
      }
      when(pressure > .0000051){
            RoughPump = 1;
            pvPut(RoughPump);
            CryoPump = 0;
            pvPut(CryoPump);
            Valve = 0;
            pvPut(Valve);
      } state low_vacuum
   }
```

Example – State fault

```
state fault{
      entry{
            strcpy(CurrentState,”Vacuum Fault”);
            pvPut(CurrentState);
      }
  }
```

Building an SNL program



- **Use editor to build the source file: file name must end with ".st", e.g. "example.st".**
- **“make” automates these steps:**
  - Optionally runs the C preprocessor
  - Compiles the state program with SNC to produce C code:

    snc example.st -> example.c

  - Compiles the resultant C code with the C compiler:

    cc example.c -> example.o

  - The file "example.o” becomes part of the application library, which is ready to be loaded by VxWorks**.**
  - For Unix systems an executable file “example” is created

Run Time Sequencer

- **The sequencer executes the state program.**
- **The sequencer supports the event-driven execution; no polling needed.**
- **Each state set becomes a VxWorks task or UNIX thread.**
- **The sequencer manages connections to database channels through "channel access".**
- **The sequencer provides support for channel access (put, get, and monitor).**
- **The sequencer supports asynchronous execution of delay, event flag, pv put and pv get functions.**
- **Only one copy (object module) of the sequencer is required on an IOC.**
- **Query commands display information about executing state programs.**

Executing a State Program – IOC

Assumes you are at an IOC console and database is loaded

1. **Load the sequencer**

   ```
   ld < pvLibrary
   ld < sequencer
   ```

2. **Load a state program**

   ```
   ld < example.o
   ```

3. **Execute program**

   ```
   seq &vacuum_control
   ```

4. **Er… That's it! Exercise program**
5. **To stop program**

   ```
   seqStop vacuum_control
   ```

Debugging

- **Use special state program query commands:**

  `seqShow`

  displays information on all running state programs

  `seqShow vacuum_control`

  displays detailed information on program

  `seqChanShow vacuum_control`

  displays information on all channels

  `seqChanShow vacuum_control,-`

  displays information on all disconnected channels

Debugging (continued)

- **Use printf functions to print to the console**

```
printf("Here I am in state xyz \n");
```

- **Put strings to pvs**

```
sprintf(seqMsg1, "Here I am in state xyz");
pvPut(seqMsg1);
```

- **Reload and restart**

```
seqStop vacuum_control
```

Edit

```
ld < example.o
seqStart &vacuum_control
```

Debugging - seqShow

- seqShow

```
epics> seqShow
Program Name      Thread ID  Thread Name      SS Name

stabilizer        ede78      stabilizer       stabilizerSS1

beamTrajectory    db360      beamTrajectory   bpmTrajectorySS

autoControl       ed620      autoControl      autoCtlSS
```

Debugging - seqShow

- **seqShow stabilizer**

```
epics> seqShow stabilizer
State Program: "stabilizer"
  initial thread id = ede78
  thread priority = 50
  number of state sets = 1
  number of syncQ queues = 0
  number of channels = 3
  number of channels assigned = 3
  number of channels connected = 3
  options: async=0, debug=0, newef=1, reent=0, conn=1, main=0

  State Set: "stabilizerSS1"
  thread name = stabilizer;  thread id = 974456 = 0xede78
  First state = "init"
  Current state = "waitForEnable"
  Previous state = "init"
  Elapsed time since state was entered = 88.8 seconds
```

Debugging - seqChanShow

- **seqChanShow stabilizer**

```
epics> seqChanShow stabilizer
State Program: "stabilizer"
Number of channels=3

#1 of 3:
Channel name: "jfm:OP:stabilizerC"
  Unexpanded (assigned) name: "{user}:OP:stabilizerC"
  Variable name: "enableButton"
    address = 154120 = 0x25a08
    type = short
    count = 1
  Value = 0
  Monitor flag = 1
    Monitored
  Assigned
  Connected
  Get not completed or no get issued
  Put not completed or no put issued
  Status = 17
  Severity = 3
  Message =
  Time stamp = <undefined>
Next? ( skip count)
```

Additional Features

- **Connection management:**
  - `when ( pvConnectCount() != pvChannelCount() )`
  - `when ( pvConnected(Vin) )`

- **Macros:**
  - `assign Vout to "{unit}:OutputV";`
  - (must use the +r compiler options for this if more than one copy of the sequence is running on the same ioc)
  - `seq &example, "unit=HV01"`

- **Compiler options:**
  - +r make program reentrant (default is -r)
  - -c don't wait for all channel connections (default is +c)
  - +a asynchronous pvGet() (default is -a)
  - -w don't print compiler warnings (default is +w)
  - +e eftest automatically clears flag (default is -e)

Additional Features (continued)

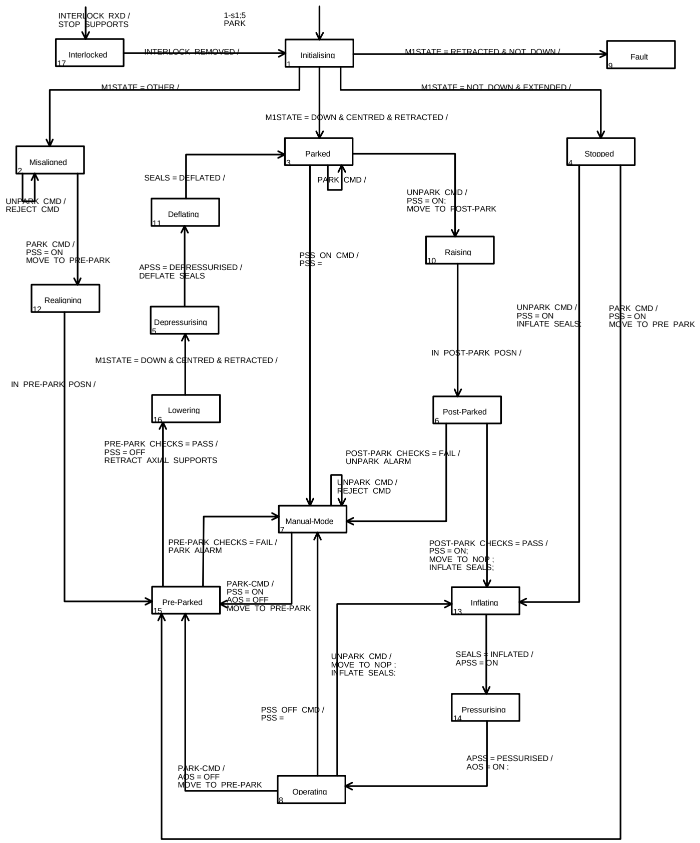
- **Access to alarm status and severity:**
  - **`pvStatus(var_name)`**
  - **`pvSeverity(var_name)`**
- **Queueable monitors -- saves monitors in queue in the order they come in -- no missing monitors.**
  - **`syncQ variableName to eventFlagname`** [optionally the length of the queue]
  - **`pvGetQ( variableName )`**
    - *removes oldest value from variables monitor queue. Remains true until queue is empty.*
  - **`pvFreeQ( variable Name)`**

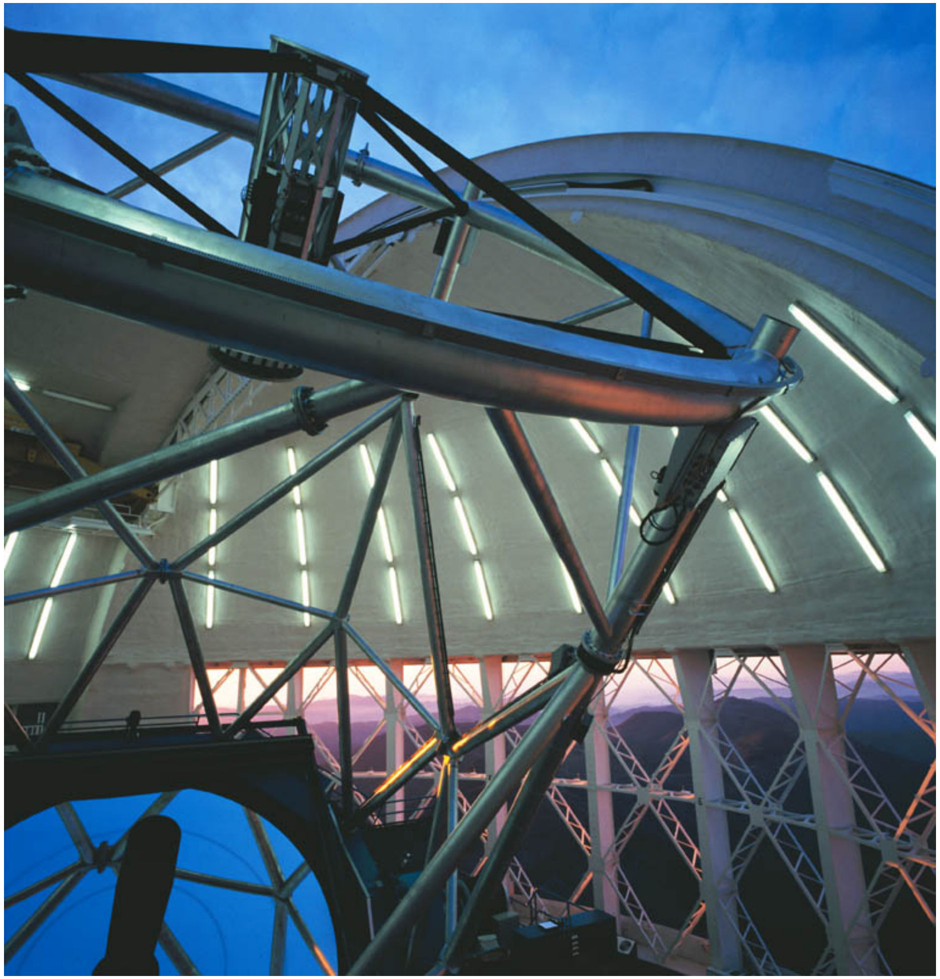
Advantages

- Can implement complicated algorithms
- Can stop, reload, restart a sequence program without rebooting
- Interact with the operator through string records and mbbo records
- C code can be embedded as part of the sequence
- All Channel Access details are taken care of for you
- File access can be implemented as part of the sequence

When to use the sequencer

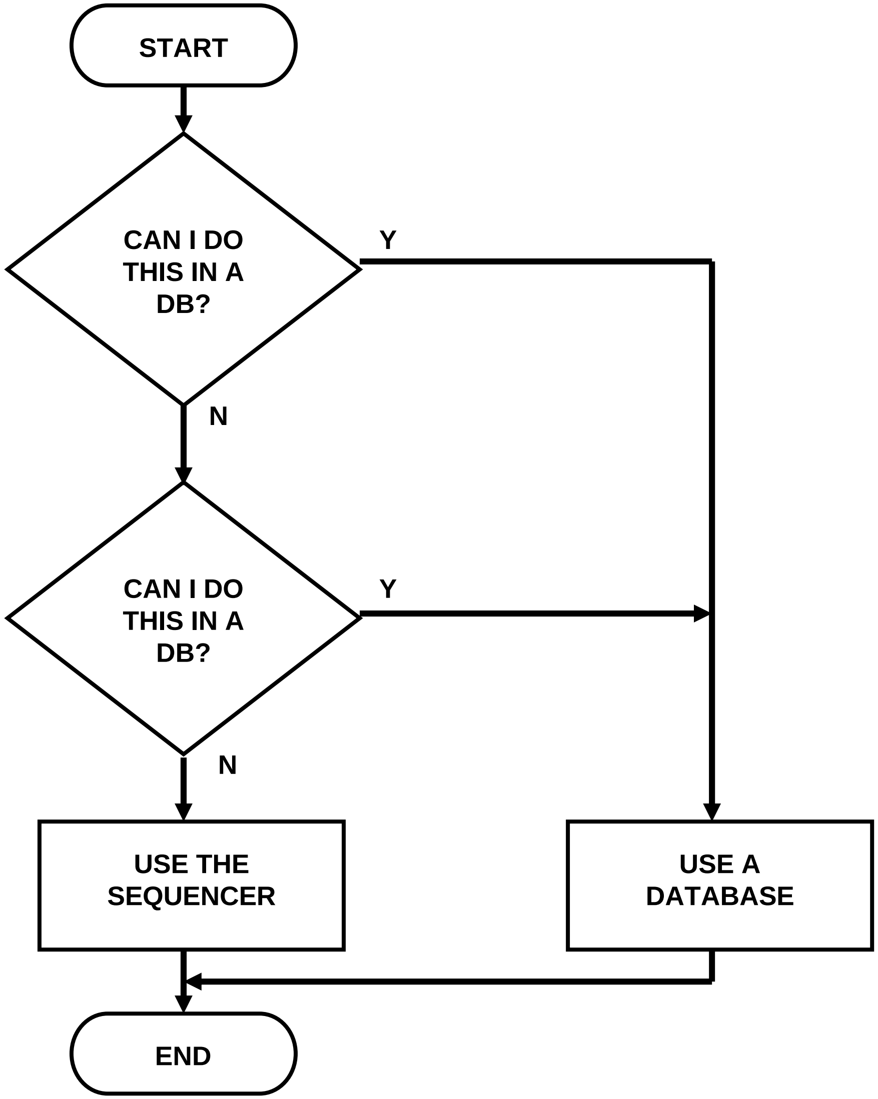
- **For sequencing complex events**
- **E.g. Parking and unparking a telescope mirror**





Photograph courtesy of the Gemini Telescopes project

Should I Use the Sequencer?



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