Argonne NATIONAL LABORATORY

State Notation Language (SNL) Programming

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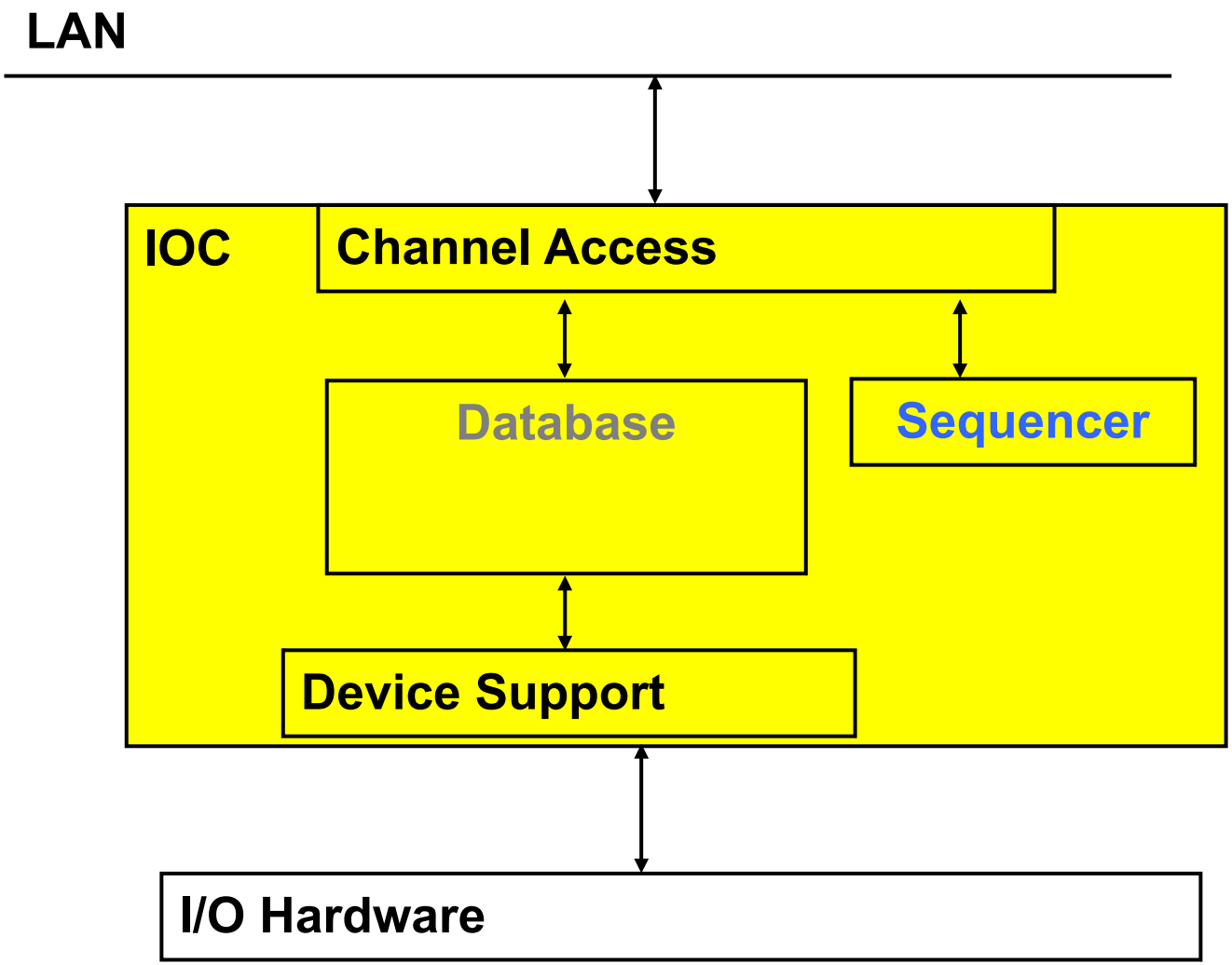
Material from many people

U.S. DEPARTMENT OF ENERGY | Office of Science

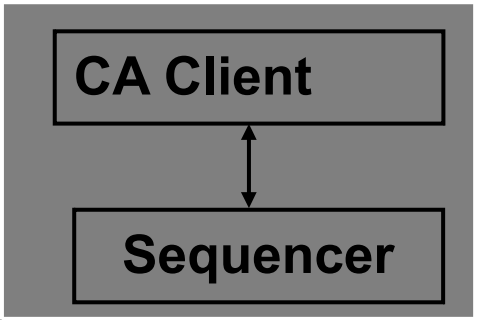
IOC

- Database: Data Flow, mostly periodic processing
- Sequencer: State machine, mostly on-demand



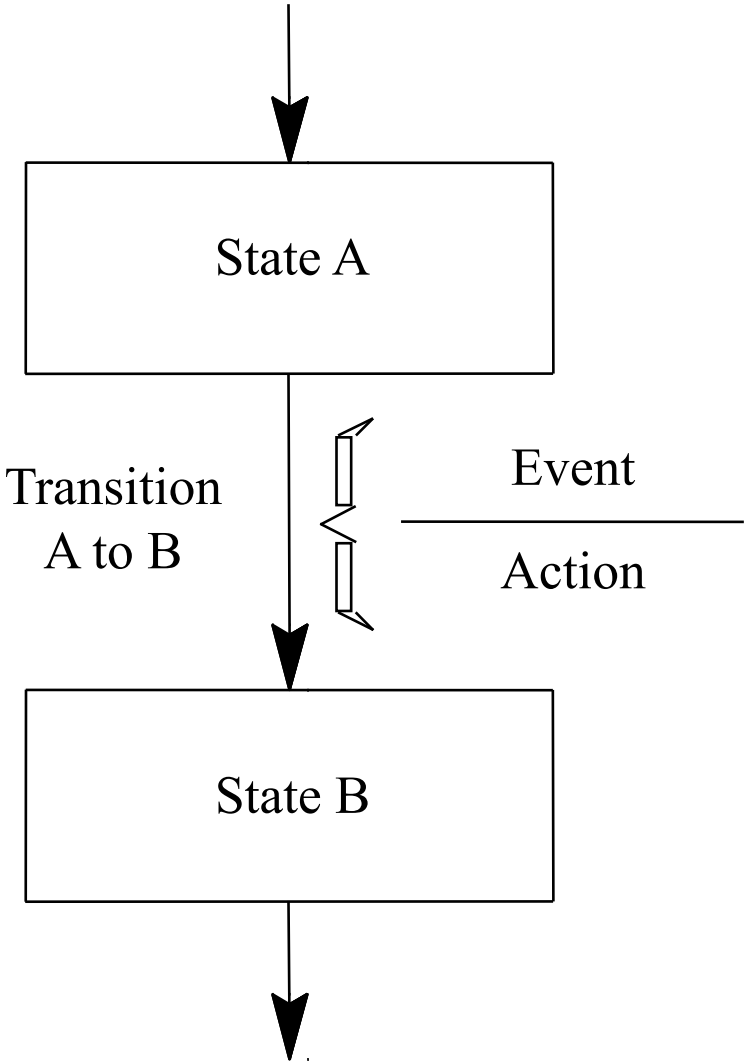
Optional:

Sequencer can run as a standalone CA-Client

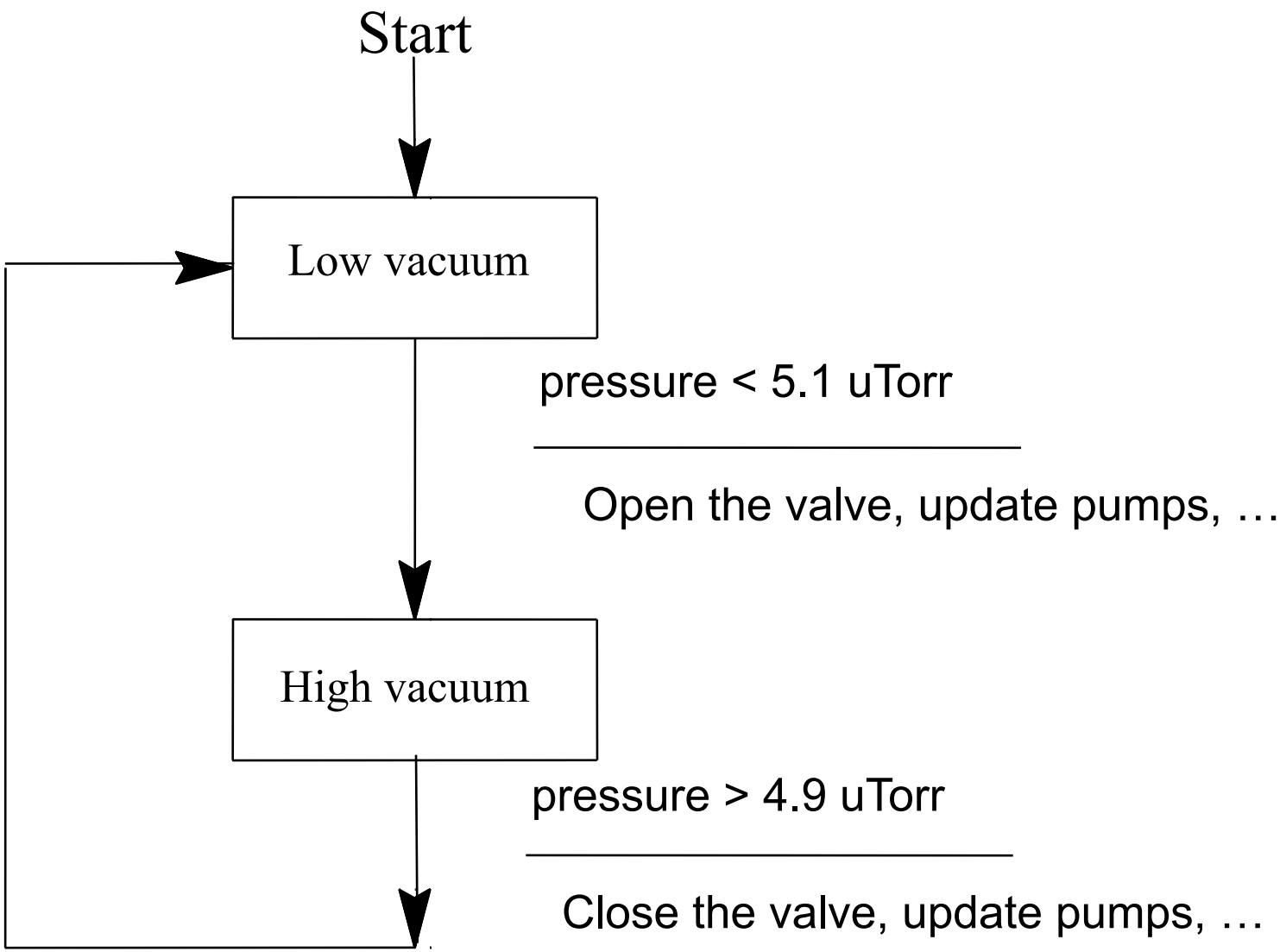


State Machines 101

- State Machine is in some State
- Events trigger transitions
- Actions are performed on transition



Example


Start
Low vacuum
pressure < 5.1 uTorr
Open the valve, update pumps, …
High vacuum
pressure > 4.9 uTorr
Close the valve, update pumps, …

Example State Notation Language

```
state low_vacuum
{
      when (pressure <= .0000049)
      {
            RoughPump = 0;
            pvPut(RoughPump);
            CryoPump = 1;
            pvPut(CryoPump);
            Valve = 1;
            pvPut(Valve);
      } state high_vacuum
}
state high_vacuum
{
    …
```

State

Event

Action

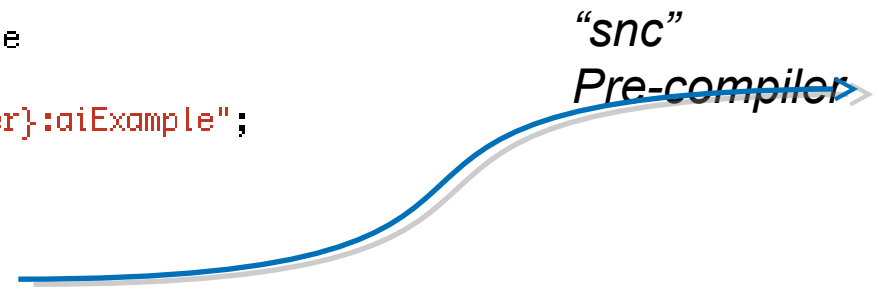
Transition

How it works

State Notation Language

```
program sncExample
double v;
assign v to "{user}:aiExample";
monitor v;

ss ss1
{
    state low
    {
        when (v > 5.0)
        {
            printf("sncExample: Changing to high\n");
        } state high
    }
    state high
    {
        when (v <= 5.0)
        {
            printf("sncExample: Changing to low\n");
        } state low
    }
}
```



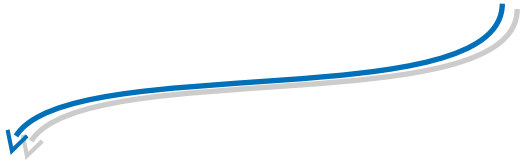
C Code

```
/* Code for state "low" in state set "ss1" */

/* Delay function for state "low" in state set "ss1" */
static void D_ss1_low(SS_ID ssId, struct UserVar *pVar)
{
# line 15 "../sncExample.stt"
}

/* Event function for state "low" in state set "ss1" */
static long E_ss1_low(SS_ID ssId, struct UserVar *pVar, short *pTransNum, short *pNextState)
{
# line 15 "../sncExample.stt"
        if ((pVar->v) > 5.0)
        {
                *pNextState = 2;
                *pTransNum = 0;
                return TRUE;
        }
        return FALSE;
}

/* Action function for state "low" in state set "ss1" */
static void A_ss1_low(SS_ID ssId, struct UserVar *pVar, short transNum)
{
        switch(transNum)
        {
        case 0:
                {
# line 14 "../sncExample.stt"
                        printf("sncExample: Changing to high\n");
```



Object code

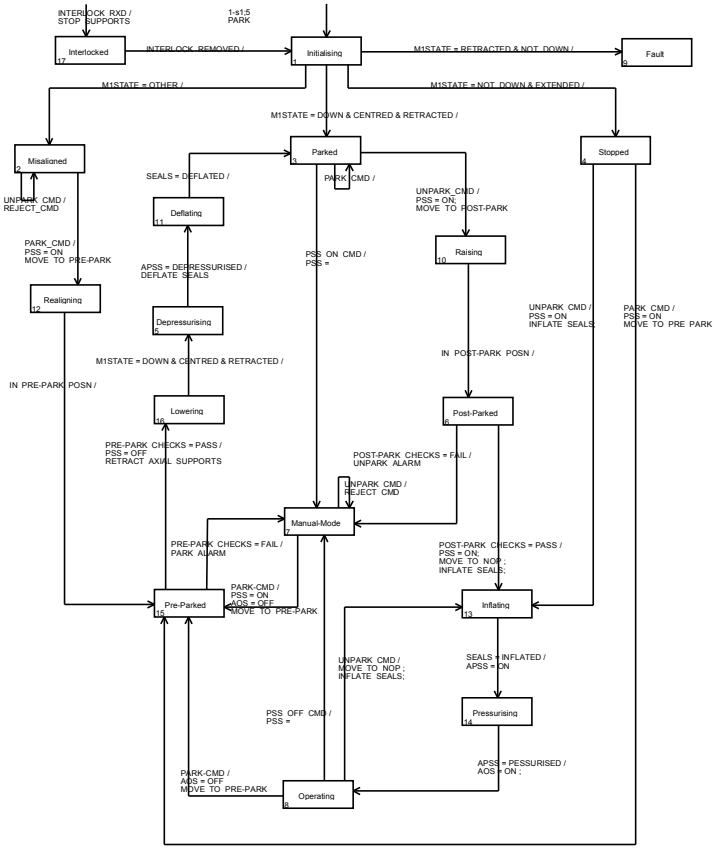
```
0000000 457f 464c 0102 0001 0000 0000 0000 0000
0000020 0001 003e 0001 0000 0000 0000 0000 0000
0000040 0000 0000 0000 0000 1738 0000 0000 0000
0000060 0000 0000 0040 0000 0000 0040 001d 001a
0000100 4855 e589 8948 f87d 8948 f075 c3c9 4855
0000120 e589 8348 10ec 8948 f87d 8948 f075 0ff2
0000140 0510 0000 0000 8b48 f845 00be 0000 4800
0000160 c789 00e8 0000 c900 55c3 8948 48e5 ec83
0000200 4820 7d89 48f8 7589 48f0 5589 48e8 4d89
0000220 48e0 458b bef8 0000 0000 8948 e8c7 0000
0000240 0000 8548 74c0 4819 458b 66e0 00c7 0001
0000260 8b48 e845 c766 0000 b800 0001 0000 05eb
0000300 00b8 0000 c900 55c3 8948 48e5 ec83 4820
0000320 7d89 48f8 7589 89f0 66d0 4589 0fec 45bf
0000340 85ec 75c0 480d 3d8d 0000 0000 00e8 0000
0000360 9000 c3c9 4855 e589 8948 f87d 8948 f075
```

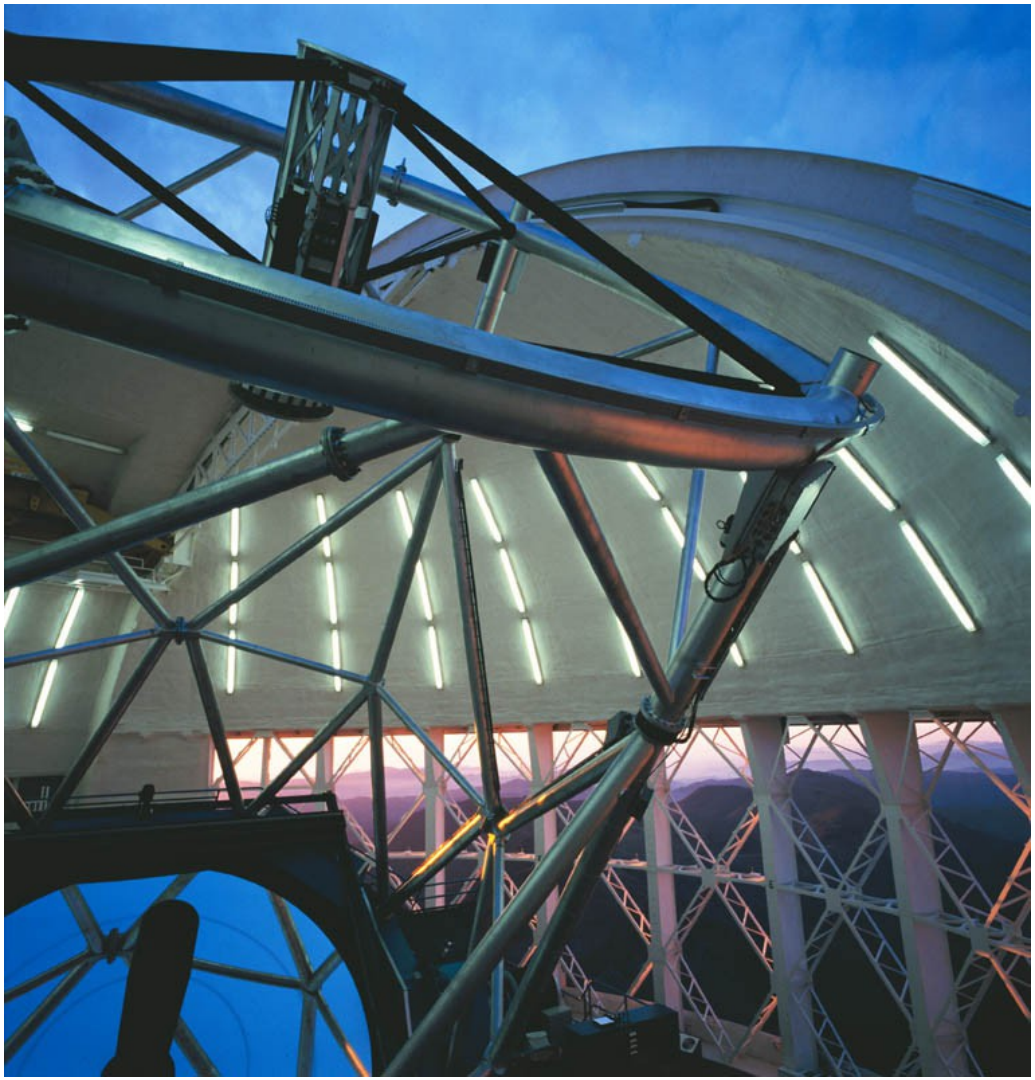
Advantage

- Compiled code. Fast.
- Can call any C(++) code
  - Use #define to create macros, …
- Easy connection to Channel Access, Records
  - Compared to custom CA client, device support, …
- Skeleton for event-driven State Machine
  - Handles threading, event handling, …

When to use the sequencer

- For sequencing complex events
- E.g. park and unpark a telescope primary mirror





Photograph courtesy of the Gemini Telescopes project

Disadvantage

- Limited runtime debugging
  - See current state, values of variables, but no details of C code within actions
- Can call any C(++) code
  - and shoot yourself in the foot
- Pre-compiler.
  SNL error
  → SNC creates nonsense C code
  → Totally cryptic C compiler messages
- Risk of writing SNL code
  1. Starts out easy
  2. Evolves
  3. Ends up as a convoluted mess

Should I use the Sequencer?

Good Reasons:

- Start-up, shut-down, fault recovery, automated calibration
- Stateful Problem
  - My SNL has 20 states, 30 possible transitions,, and little C code for each transition
- Cannot do this with CALC, BO.HIGH, SEQ, subroutine records

Bad Reasons:

- PID control, interlocks
- Warning sign:
  - My SNL code has 3 states with 2000 lines of C code
- I don't want to deal with records, I'm more comfortable with C code

If you really want to use SNL

Good manual:

http://www-csr.bessy.de/control/SoftDist/sequencer/

Implement in small steps

- Code a little
- Compile, test
- Code a little more
- Compile, test

SNL Structure

```
program SomeName

/* Comments as in C */

/* Options */

/* Variables */

/* State Sets */
```

Program Name
Used in DBD file and to start, stop and query it

SNL Options

```
option +r;
```

Make “re-entrant”.

Should be the default.
Allows running more than one copy (with different macros).

```
option -c;
```

Start right away, do *not* await connections.

Event with “+c”, the default, PVs may disconnect..

Variables

int, short, long, char, float, double

```
double  pressure;
assign  pressure to "Tank1Coupler1PressureRB";
monitor pressure;
```

Map to channel

Update with channel

```
short   RoughPump;
assign  RoughPump to "Tank1Coupler1RoughPump";

string  CurrentState;
assign  CurrentState to ”{macro}:VacuumState";
```

string == char[40]

Replaced w/ macro’s value

Array Variables

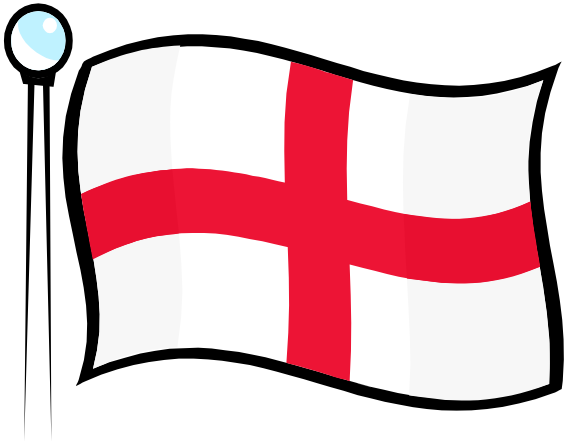
Any but ‘string’

```
double  pressures[3];
assign  pressures to
{
  "Tank1Coupler1PressureRB",
  "Tank1Coupler2PressureRB",
  "Tank1Coupler3PressureRB”
};
monitor pressures;
```

Map to channel(s!)

```
short waveform[512];
assign waveform to "SomeWaveformPV";
monitor waveform ;
```

Event Flags



a) Communicate events between state sets

b) Trigger on Channel Access updates

Declare like this:

```
evflag        event_flag_name;
```

Optionally, synchronize with monitored variable

```
sync  var_name event_flag_name;
```

State Sets

First state, name does not matter

```
ss coupler_control
{
        state initial{
                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 {
        }
}
```

Events

- Variables used in events should be ‘monitor’ed!

```
when (pressure > .0000051)
{
  /* Actions … */
} state low_vacuum

when (pressure < 0.000051  &&  whatever > 7)
{
} state high_vacuum
```

- Note that a `delay(10)` expression is not a wait for 10 seconds.
  - It means return false (0) until the state set has been in this state for 10 seconds, then return true (1).

```
when (delay(10.0))
{
} state timeout
```

Events..

Use event Flags:

```
when (efTestAndClear(some_event_flag))
when (efTest(some_event_flag))

/* Meanwhile, in other state */
when (pressure < 0.000051  &&  whatever > 7)
{
    efSet(some_event_flag);
} state high_vacuum
```

Check for connections:

```
when (pvConnectCount() < pvChannelCount())
when (pvConnected(some_variable))
```

Actions

```
when (pressure > .0000051)
{
        /* Set variable, then write to associated PV */
       RoughPump = 1;
       pvPut(RoughPump);

        /* Can call most other C code */
        printf("Set pump to %d\n",RoughPump);
} state low_vacuum
```

Action statements are almost C code. Above, `RoughPump` is a state machine variable. The SNL is transformed to

```
 printf("Set pump to %d\n", pVar->RoughPump);
```

SNC will add the “pVar->” to all state machine variables that it recognizes.

Sometimes it will be necessary to

```
%{
 /* Escape C code so that it’s not transformed */
 static void some_method_that_I_like_to_define(double x);
}%
```

Walk through the SNL from makeBaseApp –t example

- *configure/RELEASE*

```
SNCSEQ=/path/to/seq
```

- *Generated Makefile:*

```
..._SRCS += MySource.st
```

- *DBD file entry*

```
registrar(SomeNameRegistrar)
```

- *IOC st.cmd*

```
seq SomeName, "macro=value"
```

Sequencer Commands

- `seq name`
  - Start sequence program
- `seqShow`
  - List all sequence programs with their program name
- `seqShow name`
  - Detail of program state
- `seqChanShow name`
  - List variables of seq.
- `seqStop name`
  - Stop a sequence

There is more

- Support for ‘entry’ and ‘exit’ blocks
- Assign PV names within code: pvAssign(..)
- ‘Get Callback’, ‘Put Callback’
- Checking status & severity of PVs
- ‘syncQ’ to queue received Channel Access updates

Summary

- SNL very useful for State-Machine logic
- Read the SNL manual