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SUPERVISORY CONTROL OF INTEGRATED CONTINUOUS DOWNSTREAM PROCSSES

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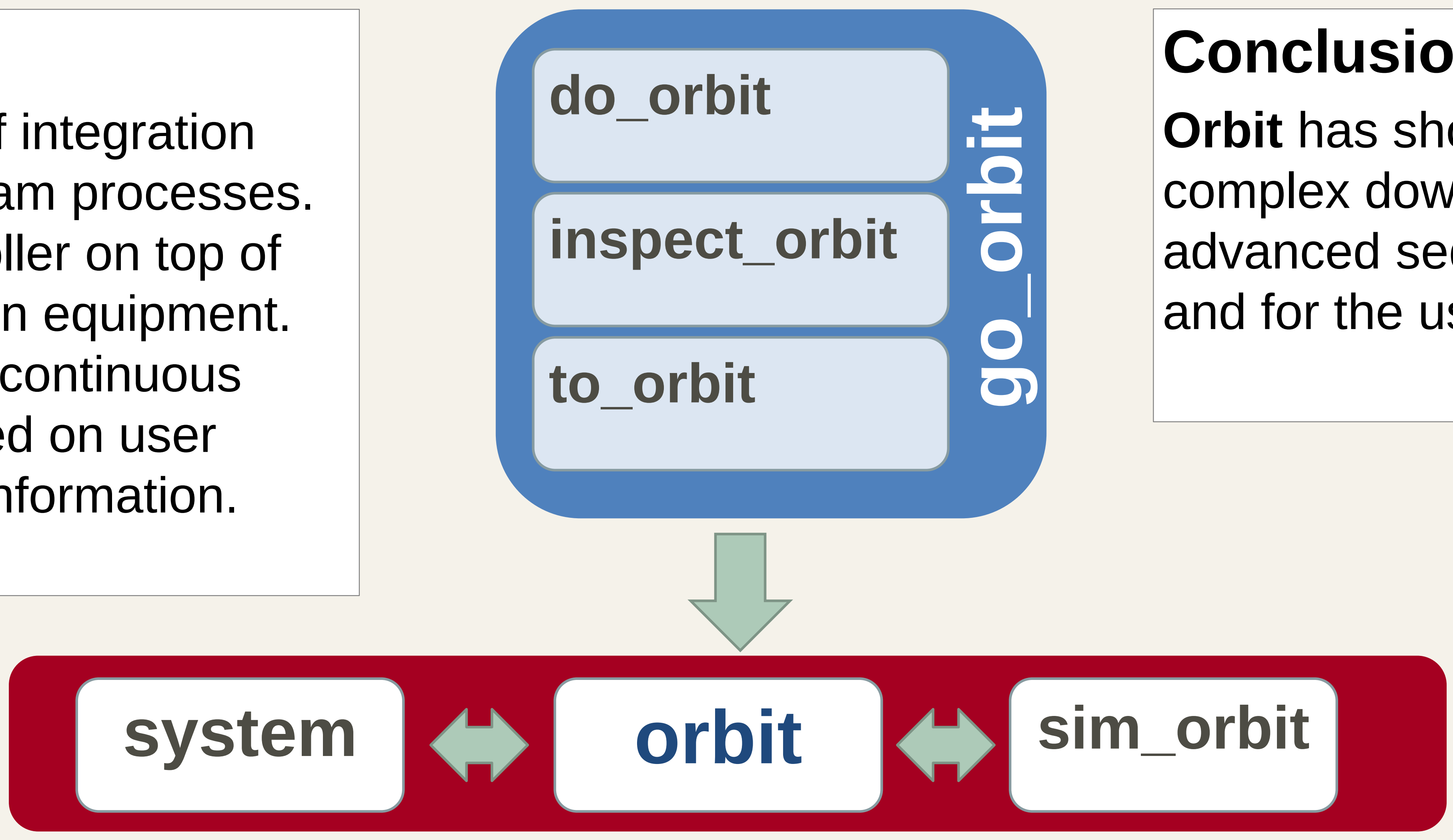
Introduction

There are industrial needs of integration and automation of downstream processes. **Orbit** is a supervisory controller on top of common available purification equipment. **Orbit** can control integrated continuous downstream processes based on user definition on a high level of information.

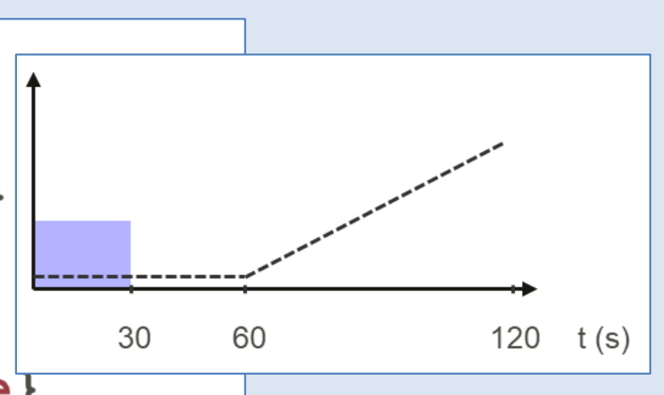


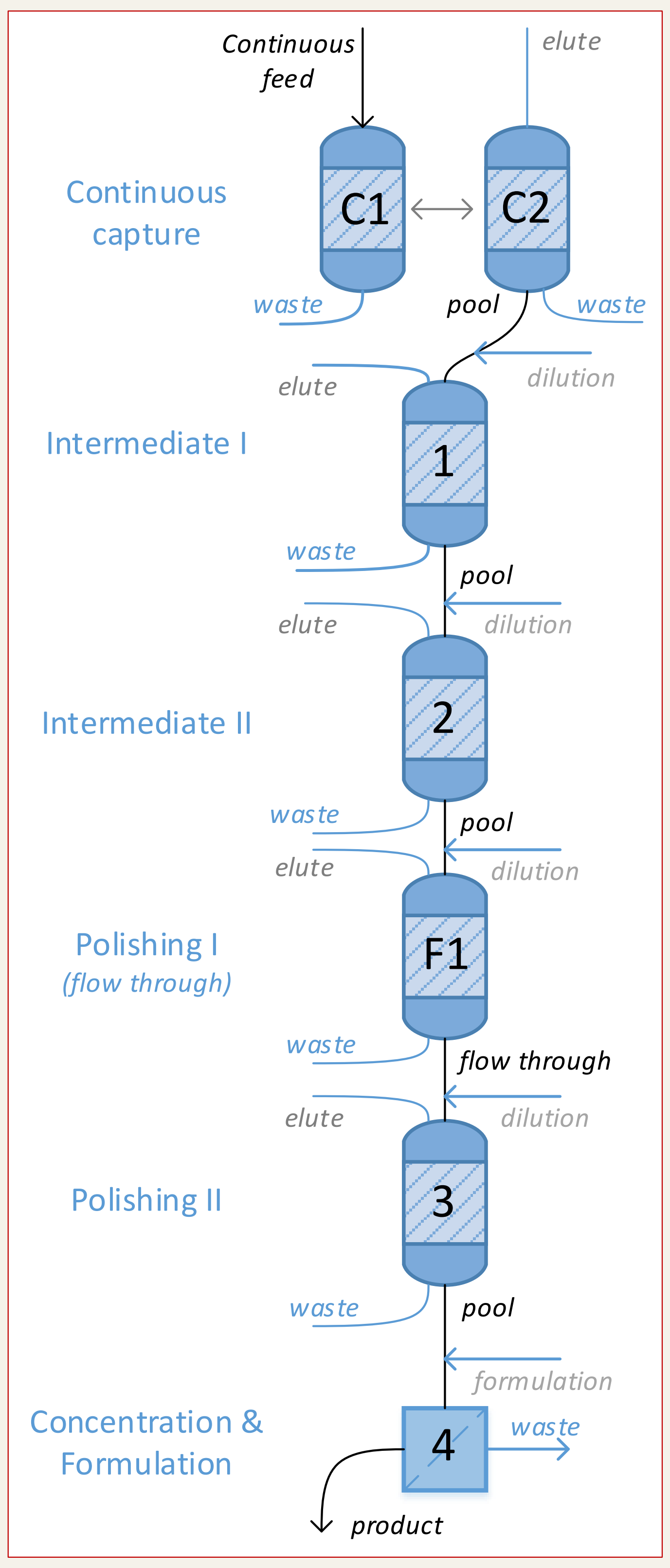
Conclusion

Orbit has shown that it is possible to define complex downstream configurations and advanced sequence structures in a modular and for the user convenient way.

*Example of **orbit** code*

```
Load = {'Time': 30,
        'FlowRate':1
        'Inject': True}

Wash = {'Time': 30,
        'Inject': False}

Elu  = {'Time':  60,
        'Gradient': 1}

Chrom = [Load,Wash,Elu]

s.runFunc(Chrom)
```





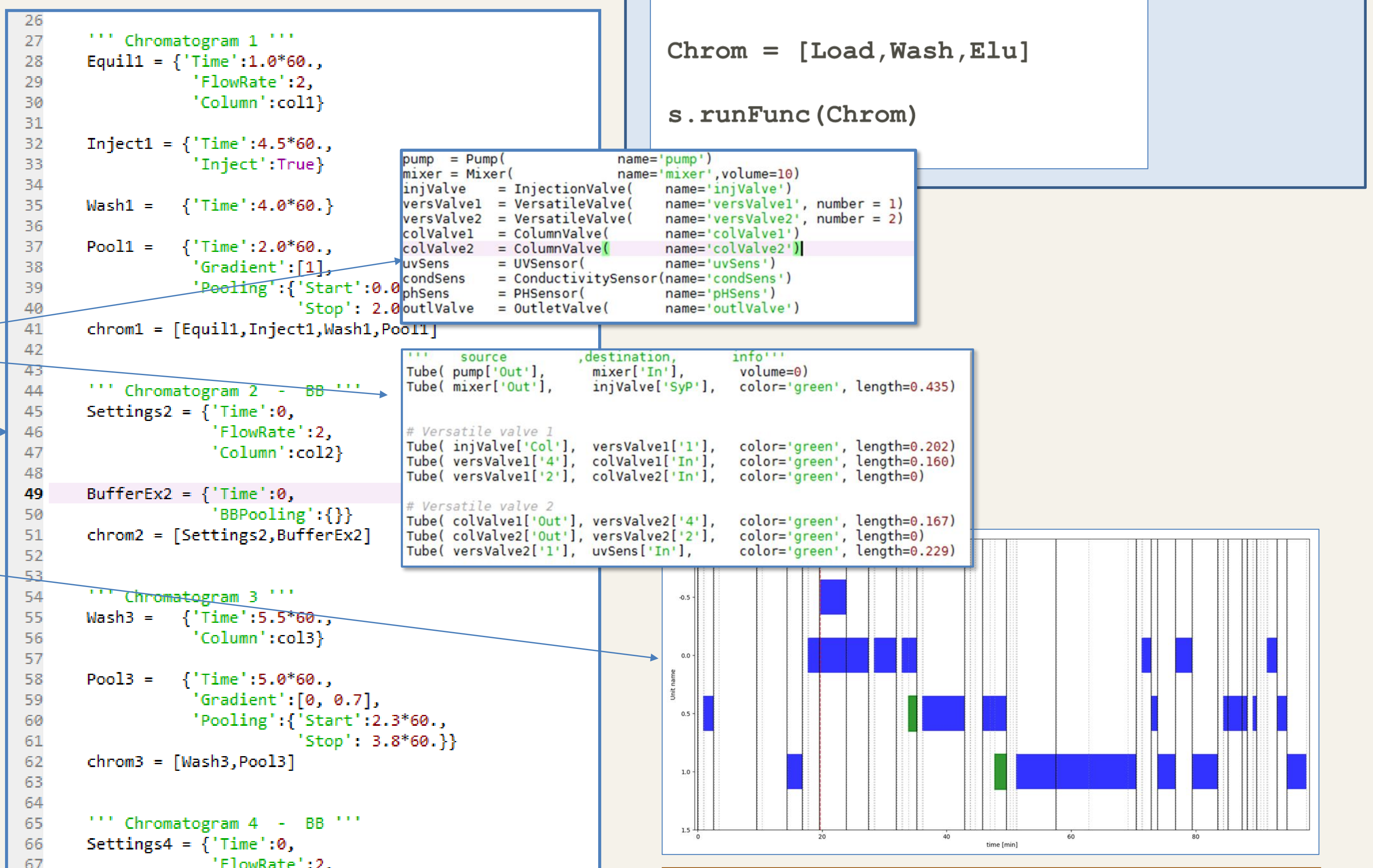
go_orbit

The **orbit** controller is automatically generated based on the design defined in **do_orbit** in two parts:

- Configuration and connections
- Overall sequence

inspect_orbit do analysis of the controller to find unfeasible operations.

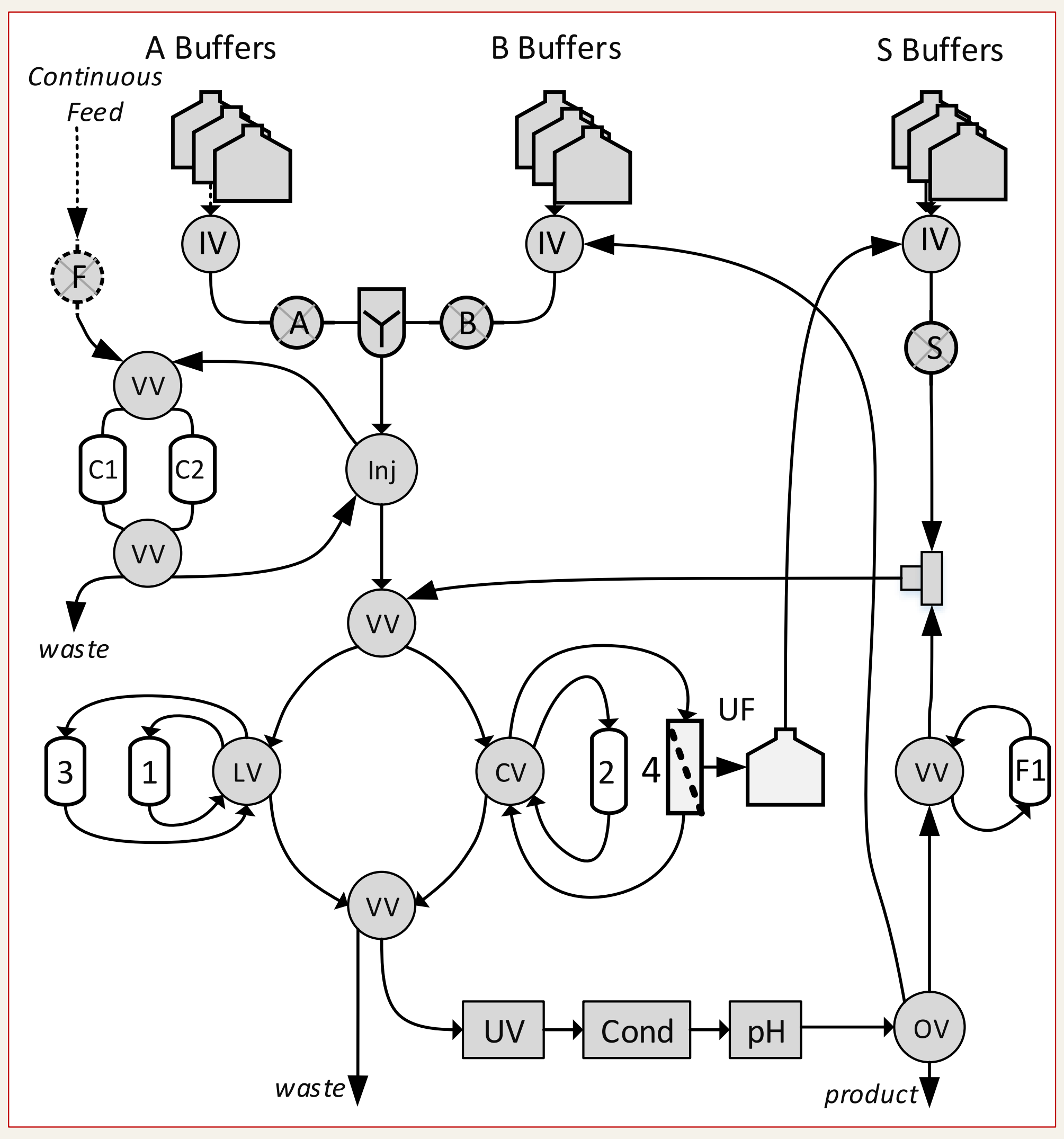
to_orbit takes the design and automatically generates the orbit controller code for sequential control based on event-action logic.



```
''' Chromatogram 1 '''
Equil1 = {'Time':1.0*60.,
          'FlowRate':2,
          'Column':col1}

Inject1 = {'Time':4.5*60.,
           'Inject':True}

Wash1 =   {'Time':4.0*60.}

Pool1 =   {'Time':2.0*60.,
           'Gradient':[1],
           'Pooling':{'Start':0.0
                      'Stop': 2.0
chrom1 = [Equil1,Inject1,Wash1,Pool1]


''' Chromatogram 2  -  BB '''
Settings2 = {'Time':0,
             'FlowRate':2,
             'Column':col2}

BufferEx2 = {'Time':0,
             'BBPooling':{}}
chrom2 = [Settings2,BufferEx2]


''' Chromatogram 3 '''
Wash3 =   {'Time':5.5*60.,
           'Column':col3}

Pool3 =   {'Time':5.0*60.,
           'Gradient':[0, 0.7],
           'Pooling':{'Start':2.3*60.,
                      'Stop': 3.8*60.}}
chrom3 = [Wash3,Pool3]


''' Chromatogram 4  -  BB '''
Settings4 = {'Time':0,
             'FlowRate':2,
             'Column':col7}

BufferEx4 = {'Time':0,
             'BBPooling':{'Next':'Waste'}}
chrom4 = [Settings4,BufferEx4]


chroms = [chrom1,chrom2,chrom3,chrom4]
guiController(s,chroms)
```

```
pump  = Pump(                 name='pump')
mixer = Mixer(                name='mixer',volume=10)
injValve    = InjectionValve(     name='injValve')
versValve1  = VersatileValve(     name='versValve1', number = 1)
versValve2  = VersatileValve(     name='versValve2', number = 2)
colValve1   = ColumnValve(        name='colValve1')
colValve2   = ColumnValve(        name='colValve2')
uvSens      = UVSensor(           name='uvSens')
condSens    = ConductivitySensor(name='condSens')
phSens      = PHSensor(           name='pHSens')
outlValve   = OutletValve(        name='outlValve')
```

```
'''     source          ,destination,       info'''
Tube( pump['Out'],        mixer['In'],        volume=0)
Tube( mixer['Out'],       injValve['SyP'],    color='green', length=0.435)


# Versatile valve 1
Tube( injValve['Col'],  versValve1['1'],    color='green', length=0.202)
Tube( versValve1['4'],  colValve1['In'],    color='green', length=0.160)
Tube( versValve1['2'],  colValve2['In'],    color='green', length=0)

# Versatile valve 2
Tube( colValve1['Out'], versValve2['4'],    color='green', length=0.167)
Tube( colValve2['Out'], versValve2['2'],    color='green', length=0)
Tube( versValve2['1'],  uvSens['In'],       color='green', length=0.229)
```



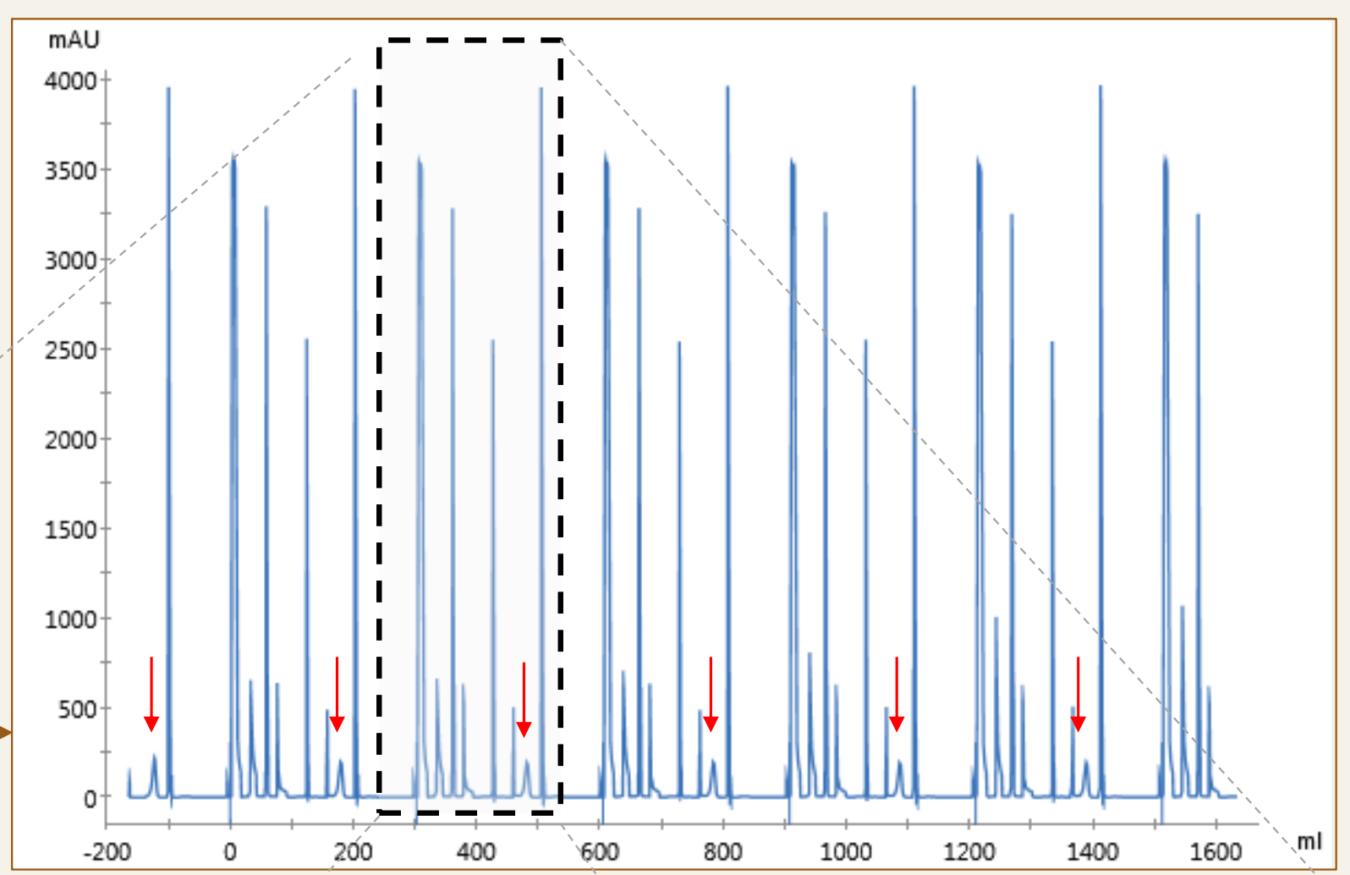
orbit

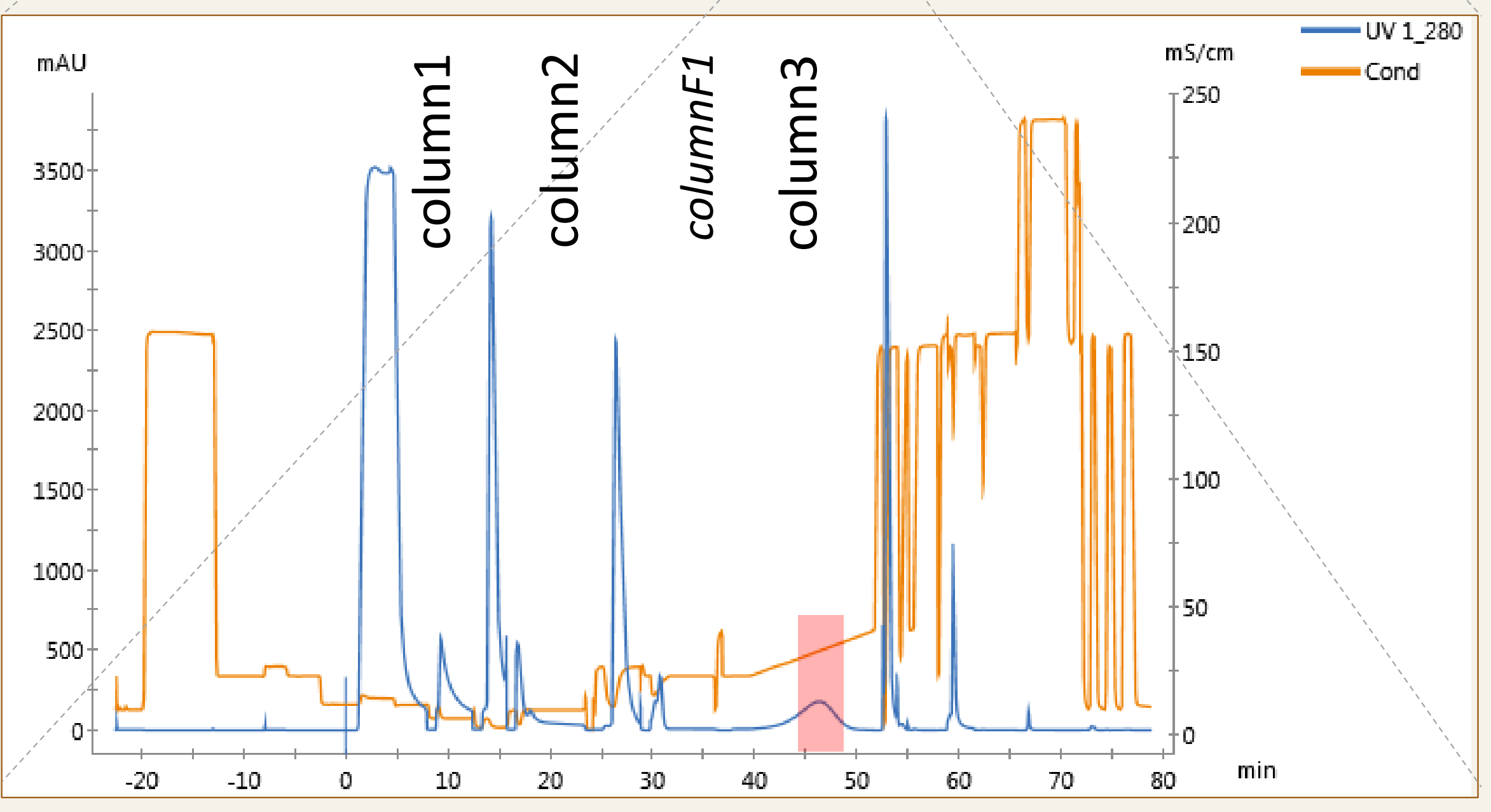
This is the actual sequential controller that executes actions based on events that is automatically generated from go_orbit.

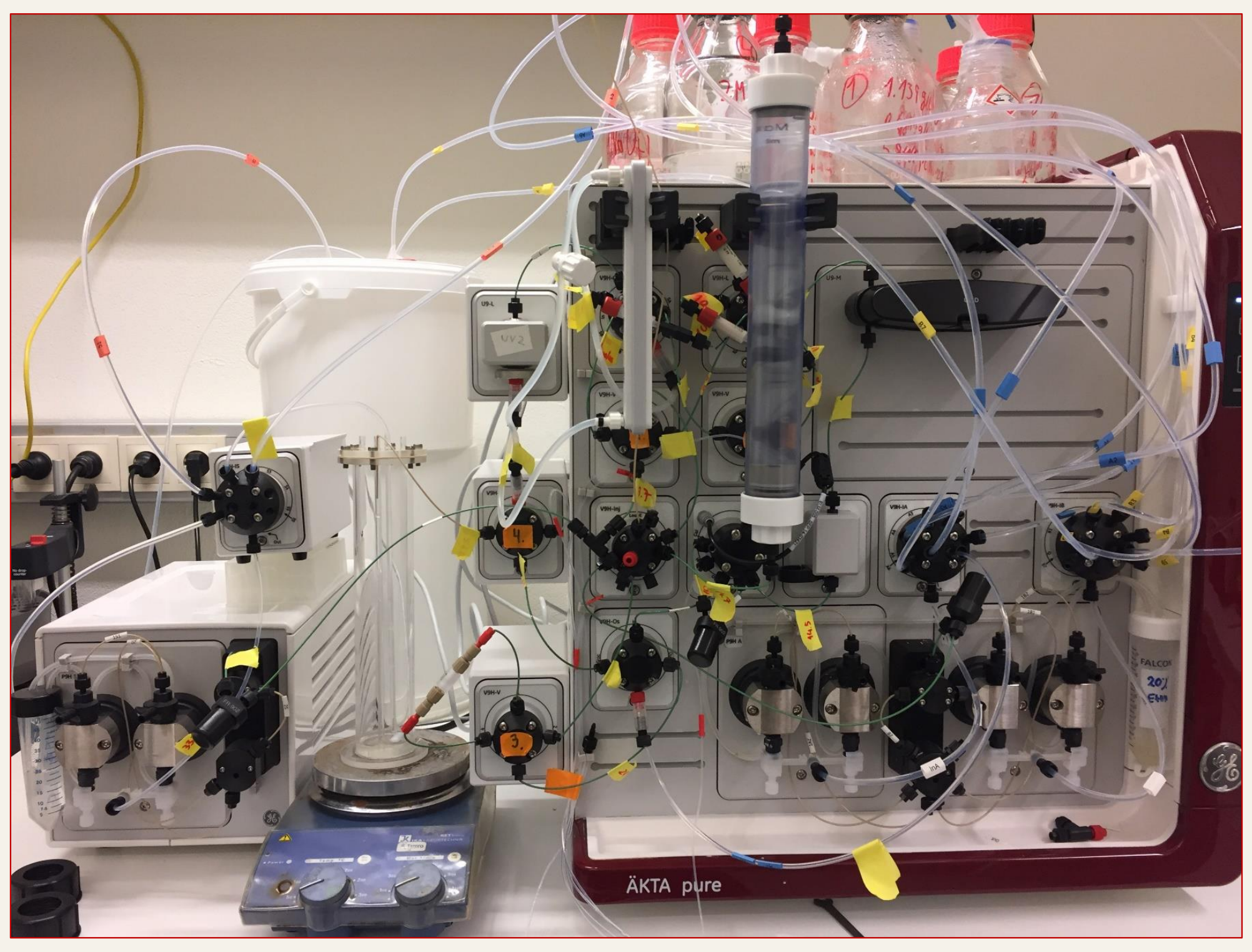
Actions are set flow rates, switch valve positions, get sensor values, start peak integration,… etc

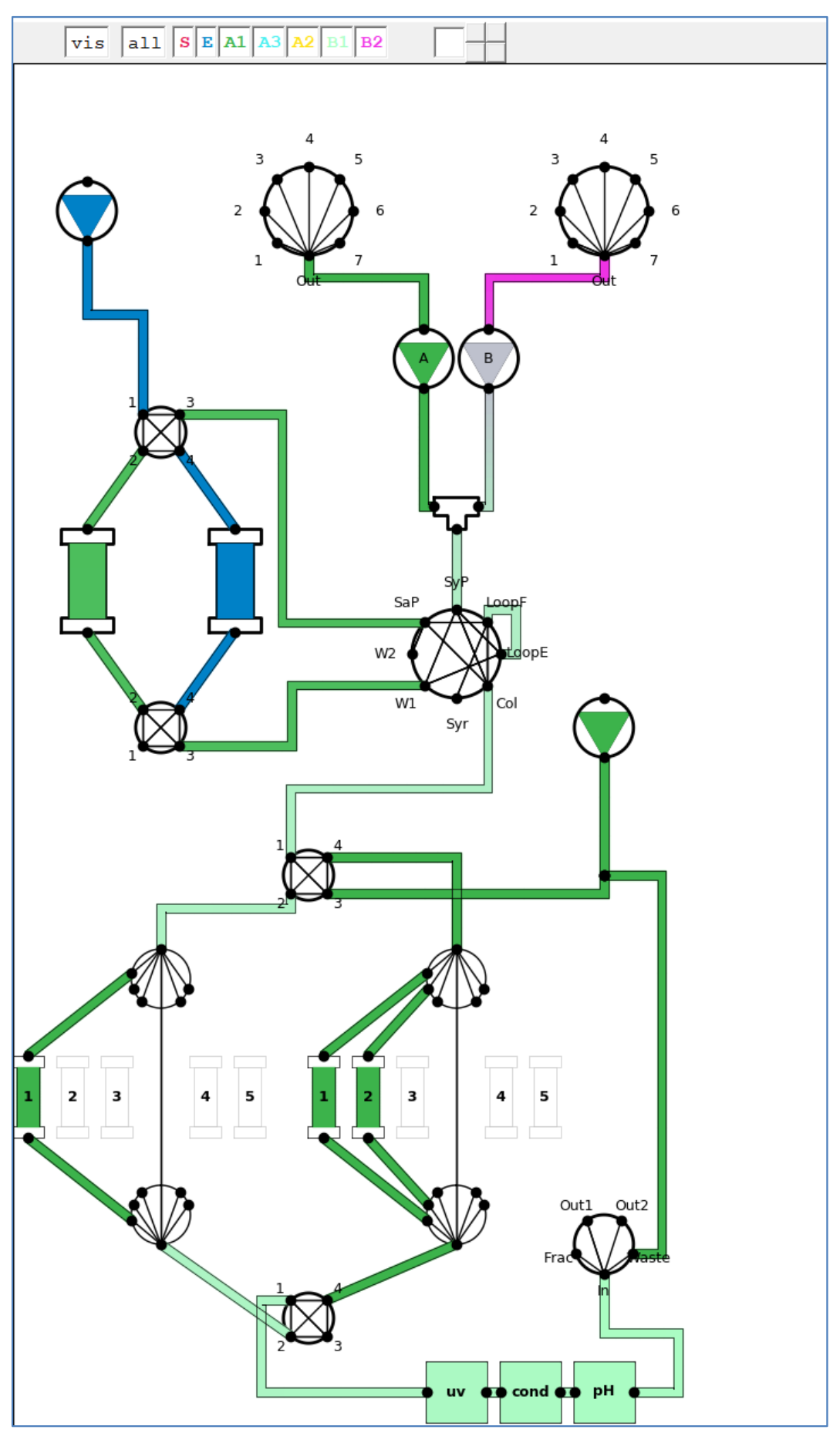
Events are often a given time. Other events are sensor values or peak integration value.

The orbit controller run autonomous.









sim_orbit

A system simulator based on automatically generated information from orbit: i) the configuration, ii) control sequence and iii) a model library of all units available.

The simulator makes it possible to estimate the performance of the sequence:

- Buffer flow path and consumption
- Cleaning of complete configuration
- Check of complete cycle

Acknowledgement

novo nordisk

Modelon

VINNOVA

PiiA Process Industrial IT and Automation

PIC Process Industry Centre

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