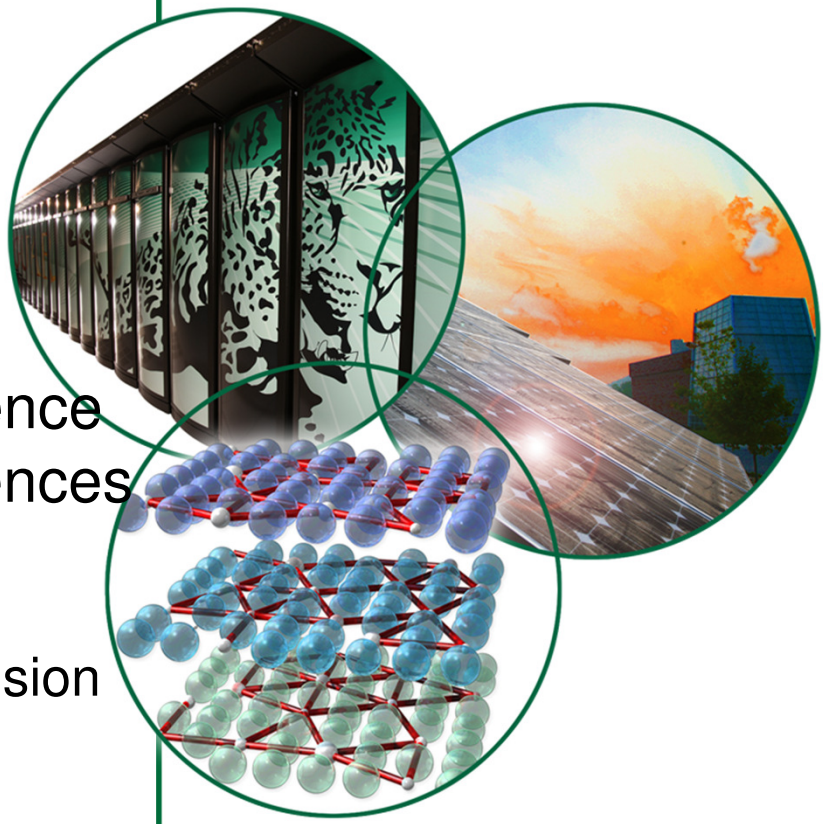
Testing, Simulating, and Profiling Designated Problems for CASL



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U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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Outline

- Introduction
- Project
- Methodology
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- References
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Consortium for Advanced Simulation of Light Water Reactors (CASL)

- DOE laboratories
  - ORNL
  - Idaho
  - Los Alamos
  - Sandia

- Academic
  - Massachusetts Institute of Technology
  - North Carolina State
  - Michigan

Consortium of Advanced Simulation of Light Water Reactors (continued)

- Industry
  - Westinghouse
  - Tennessee Valley Authority
  - Electric Power Research Institute

- 24 total partners

Virtual Environment for Reactor Applications (VERA)

- Model and simulate performance of light water reactors

- Predict with confidence
  - Coolant chemistry
  - Fuel performance
  - Neutronics
  - Thermal hydraulics
  - Structural mechanics

CASL's mission

- Reduce cost
  - Extend reactors' lifetimes
  - Run at higher power
- Reduce amount of used fuel
  - Reduce waste by enabling more efficient fuel use
- Safety
  - Enhance fuel
  - Reactor design

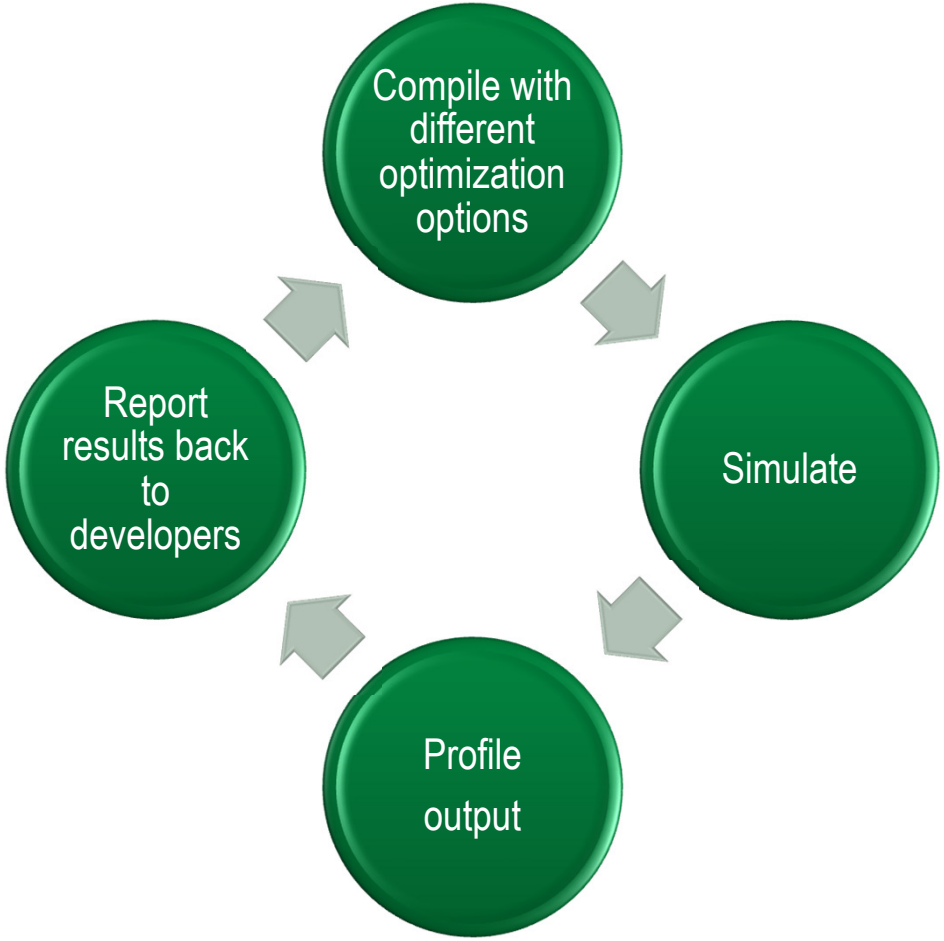
Thermal-Hydraulic Subchannel Code for Light Water Reactors Transient Analyses (COBRA-TF)

- Run designated problems
- Profile
  - gprof tool
  - Compile with -pg
- Collect
- Analyze
- Visualize
- Report back to developers

Methodology

- Optimization options
  - -O0
  - -O1
  - -O2
  - -O3

- Best option (-O3)



Raw flat profile output

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls  Ks/call  Ks/call  name
 45.48    765.52   765.52     1122     0.00     0.00  xschem_
 11.08    952.09   186.57 124634943     0.00     0.00  tgas_
  6.59   1063.09   111.00     1122     0.00     0.00  result_channel_
  5.84   1161.36    98.27    45936     0.00     0.00  sstemp_
  5.81   1259.22    97.86     1122     0.00     0.00  temp_
  4.23   1330.38    71.16     1122     0.00     0.00  result_
  3.52   1389.56    59.18    31416     0.00     0.00  intfr_
  2.54   1432.25    42.69     1122     0.00     0.00  heat_
  2.07   1467.11    34.86 10178784     0.00     0.00  boiling_
  2.04   1501.37    34.26     1122     0.00     0.00  gssolv_
  1.23   1522.04    20.67     1122     0.00     0.00  result_gap_
```

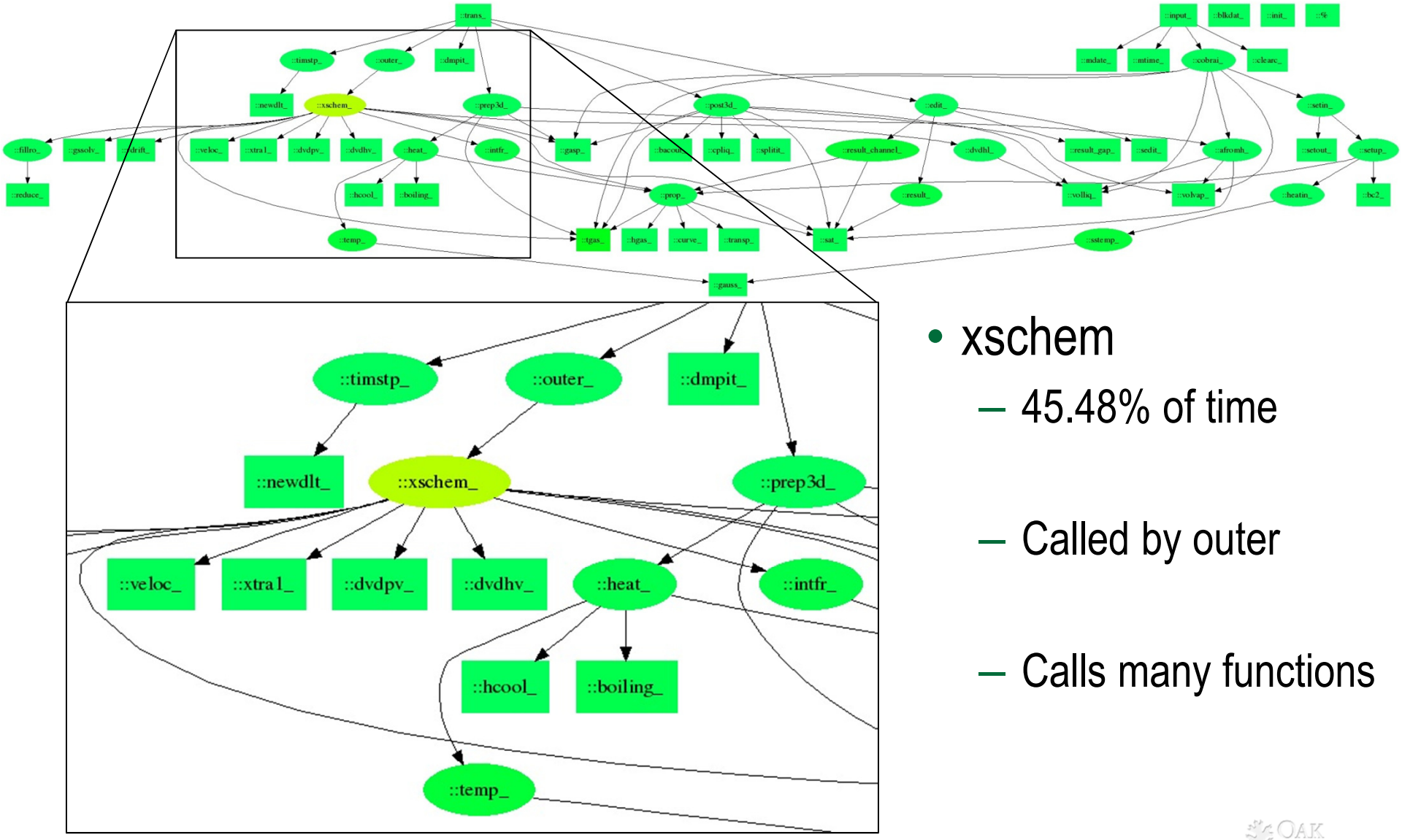
Raw call graph output

```
index % time    self  children    called     name
                                                 <spontaneous>
[1]    100.0    0.00 1683.15                MAIN__ [1]
                2.18 1582.39       1/1           trans_ [2]
                0.00   98.57       1/1           input_ [14]
                0.01    0.00       1/1           blkdat_ [45]
                0.00    0.00       1/1           init_ [53]
-----------------------------------------------
                2.18 1582.39       1/1           MAIN__ [1]
[2]     94.1    2.18 1582.39       1         trans_ [2]
                0.00  987.61    1122/1122        outer_ [4]
                2.92  300.16    1122/1122        prep3d_ [5]
                0.00  230.20    1123/1123        edit_ [7]
               15.70   45.80    1122/1122        post3d_ [20]
                0.00    0.00    1124/1124        timstp_ [47]
                0.00    0.00       2/2           dmpit_ [50]
-----------------------------------------------
              765.52  222.09    1122/1122        outer_ [4]
[3]     58.7  765.52  222.09    1122         xschem_ [3]
               59.18   56.16   31416/31416       intfr_ [11]
               34.26    0.00    1122/1122        gssolv_ [22]
               12.92   13.62 9815256/9815256     fillro_ [23]
               15.77    0.00   31416/31416       vdrift_ [26]
               14.69    0.00 9815256/124634943     tgas_ [8]
               10.32    0.00   31416/31416       veloc_ [30]
                1.80    0.00 9815256/91613230     sat_ [25]
                0.50    0.55 9815256/9815256     dvdhl_ [36]
                0.86    0.00 9815256/20357569     gasp_ [34]
                0.80    0.00 9815256/9815256     xtra1_ [39]
                0.42    0.00 9815256/9815256     dvdpv_ [41]
                0.24    0.00 9815256/9815256     dvdhv_ [43]
-----------------------------------------------
                0.00  987.61    1122/1122        trans_ [2]
[4]     58.7    0.00  987.61    1122         outer_ [4]
              765.52  222.09    1122/1122        xschem_ [3]
-----------------------------------------------
```

Improved output

%	cumulative seconds	self seconds	calls	self s/calls	total s/calls	name	Description	Called by	Calls
45.48	765.52	765.52	1122	0.00	0.00	xschem_	linearizes the momentum, continuity and energy equations	outer	intfr gssolv fillro vdrift tgas veloc sat dvdhl xtra1 dvdpv dvdhv
11.08	952.09	186.57	124634943	0.00	0.00	tgas_	Calculates vapor temperature and specific heat capacity cp of vapor	cobrai prep3d xschem post3d prop	
6.59	1063.09	111	1122	0.00	0.00	result_channel_	Prints the sub-channel results of the calculation at specified time intervals	edit	prop sat
5.84	1161.36	98.27	45936	0.00	0.00	sstemp_	calculates the steady state temperatures for fuel rods	heatin	gauss
5.81	1259.22	97.86	1122	0.00	0.00	temp_	Calculates temperature at the new time step for fuel rods and unheated conductors	heat	gauss

kProf call graph output



- xschem
  - 45.48% of time
  - Called by outer
  - Calls many functions

Results

- Simulation time
  - 3,752.26s with no optimization (-O0)
  - 2,017.99s with optimization (-O1)
    - 46.21% faster than no optimization
  - 1,709.99s with optimization (-O2)
    - 54.42% faster than no optimization
    - 15.26% faster than -O1
  - 1,683.15s with optimization (-O3)
    - 1.56% faster than -O2

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Conclusion

- Best optimization option -O3
- 45.48% of time spent at xschem
- 11.08% of time spent at tgas

Summary

- Simulate designated problems
- Profile with different optimization options
- Results
  - Collect
  - Analyze
  - Compare
- Report results to developers

Future work

- Profile memory use during simulations
  - Valgrind
  - Simulation took about 2.5 hours to run
  - 1,683.15s of CPU time (~28 mins)

- Different simulation problems
  - Input files

References

RDFMG (2012). A Thermal-Hydraulic Subchannel Code for Light Water Reactors Transient Analyses

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Questions