Performing Multiphysics Simulations with Rocstar

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Overview

- **Rocstar code**
  - Physics modules
  - Coupling schemes
- **Producing an executable**
  - CVS checkout
  - Compiling
- **Preparing data sets**
- **Running batch jobs**
- **Visualization**
- **Data Management**

Titan gas velocity and solid deformation
Rocstar Components

- Structural Mechanics
  - Rocfrac – explicit, cracks
  - Rocsolid – implicit
  - ALE formulation
  - Large deformations

- Combustion: Rocburn
  - Burn rate at propellant surface
  - 1-D heat conduction
  - Propellant heating & ignition

- Fluid Dynamics
  - Rocflo – structured mesh
  - Rocflu – unstructured
  - Explicit, ALE formulation
  - Unsteady, compressible, viscous, turbulence, particles, smoke, radiation

- Infrastructure
  - Rocman – time stepping
  - Rocface – interpolation
  - Roccom – data transfer API
  - Rocprop – surface motion
  - Rocpanda – parallel I/O
  - Charm/AMPI – parallel libs
Explicit/Implicit Fluid Dynamics: *Rocflo*

- **Governing equations**
  - Unsteady, compressible, Navier-Stokes or Euler

- **Numerical formulation**
  - Finite volume
  - Explicit Runge-Kutta
  - Dual time stepping
  - Arbitrary Lagrangian-Eulerian (ALE) method on moving meshes
  - 2nd order central scheme
  - Roe upwind scheme

- **Code characteristics**
  - Structured, multi-block mesh
  - Plug-in modules for turbulence, Al droplets, smoke, radiation

Vortex Shedding at Joint Slot
Unstructured Mesh Fluids: *Rocflu*

- **Mesh**
  - Mixed tetrahedra, prisms, pyramids, hexahedra

- **Method**
  - Explicit, finite-volume, ALE
  - Higher order ENO scheme
  - Parallelism through Finite Element Framework

- **Extra Physics**
  - Chemical reactions for combustion in cracks
  - Particles and turbulence under development

Gas Temperature in Igniting RSRM
Explicit Structural Dynamics: *Rocfrac*

- Large strains, rotations
- Crack propagation
  - Cohesive elements allow failure
- ALE formulation
- Transient thermal solver
- Non-linear material models
  - Hyperelastic
    - Arruda-Boyce
    - Neo-Hookean
  - Non-linear constitutive laws
    - Viscoplastic
    - Porous viscoelastic
- Mixed-enhanced elements
- Stablized and mixed displacement-pressure elements

Crack Propagation in Medium With Holes
Implicit Structural Dynamics: *Rocsolid*

- Implicit formulation with full Newton iterations
- Nonlinear Kinematics (large strains, large rotations)
- Scalable parallel multigrid solver
- ALE for moving interfaces
- Nonlinear constitutive models
  - Compressible & incompressible Neo-Hookean
  - Porous viscoelastic (with void growth)
  - J2-Plasticity
- Mixed-enhanced elements
- Heat conduction
  - Obtain initial T distribution for use with T dependent burn rate
- Unstructured meshes
Interface Data Transfer: *Rocface 2.0*

Interpolates quantities across non-matching meshes

- **Constructs overlay mesh**
  - Common refinement of two meshes
  - Enables exact mass and momentum conservation

- **Minimizes errors**
  - Coefficients provide smallest least squares norm
  - Huge (> 20x) improvement over standard method (Farhat, et al., 1995)
Basic Time Stepping Schemes

- Execution: 1) all solid, 2) all fluid, 3) all combustion
- Updated interface data is passed through Rocface
- Components can adaptively subcycle
- Predictor/corrector: repeat step until solution converges
Producing a *Rocstar* Executable

Outline

1. Check out source from CVS
   - Prerequisites for new users
2. Decide whether to use charm or pure MPI
   - *Rocflu* requires charm
   - Charm for multiple partitions per CPU
3. Compile charm if needed
   - *Makecharm* utility
4. Compile *Rocstar*
   - Charm options
   - Fluid physics options
   - Executable, object code location options
Obtaining the Source Code

CVS checkout

- **Prerequisites**
  - Contact Mark Brandyberry (mdbrandy@uiuc.edu) for a CSAR CVS signon and password
  - Place in .cshrc the line
    ```
    setenv CVSROOT \
    :pserver:$LOGNAME@galileo.cse.uiuc.edu:/cvsroot
    ```
  - Set up password file (one time)
    ```
    % touch .cvspass
    % cvs login
    Enter CVS password:
    ```

- **Normal check out**
  ```
  % cvs co genx/Codes
  ```
Obtaining and Building Charm

Use the genx/Codes/utilities/Makecharm utility to:

- Check out charm source from charm group’s CVS
  - Can delete/use/rename an existing charm source, (e.g., one manually downloaded from http://charm.cs.uiuc.edu/autobuild/cur/)

- Archive clean charm source in a tar file

- Choose AMPI or FEM
  - AMPI for FEM_ALONE (MPI based, 1 chunk per CPU)
  - FEM (charm’s user-level threads)

- Build charm with appropriate compilers/options

Note: on new turing, Rocstar makefiles will find system’s Charm installation automatically

Note: By default, if a charm directory is found, Rocstar will be built using FEM_ALONE
Building *Rocstar*

Compile in genx/Codes/ using gmake (make)

- **Charm options**
  - FEM_ALONE=1 (uses MPI, access to FEM framework)
  - CHARM=1 (threads, multiple processes per CPU)

- **Fluid physics options**
  - TURB=1 (*Rocflo* – turbulence models)
  - STATS=1 (*Rocflo* – collect statistics)
  - PLAG=1 (*Rocpart* – Lagrangian particles)
  - PEUL=1 (*Rocsmoke* – equilibrium Eulerian particles)

- **Multiple builds from same source**
  - PREFIX=<exe_directory> (specify executable location)

- **Separate object code directory**
  - % mkdir <obj_directory>; cd <obj_directory>
  - % <src_path>/configure --prefix=<exe_directory>

All modules compiled; load any combo at runtime
Preparing *Rocstar* Input

Outline

- Produce CAD model
  - Pro/Engineer exports IGES format
- Generate meshes, set BC flags
  - Gridgen – fluids structured/unstructured, also *Rocfrac*
  - Patran, Truegrid – often used for solids
- Check critical input parameters
  - Order of spatial differencing
  - Initial state
- Preprocess and partition
  - Use *Rocprep* on “Native Data Archives”
- Check input again!
Module Parameters that Affect Prep, I

*Rocflo*

- **<casename>.bcmp file**
  - Interacting BCs flagged with “1” at end of line

- **<casename>.inp file**
  - NDUMMY – layers of dummy cells
  - Initial state: $\rho$, $\nu$, $P$
  - Heat capacity, ratio of specific heats

- **<casename>.bc file**
  - MFRATE tells whether patch is burning initially (RocburnPY)
Module Parameters that Affect Prep, II

Rocflu

- `<casename>.inp file`
  - ORDER – determines number of dummy cells
  - Initial state: \( \rho, v, P \)
  - Heat capacity \( CP \), ratio of specific heats \( \Gamma \)

- `<casename>.bc file`
  - COUPLED tells whether patch is interacting
Rocprep

Rocstar input data preparation tool

- Native Data Archives on prandtl, new turing
  - Output from Gridgen, Patran, etc.
  - Various grids (Grid1, Grid2, …)
  - Various module input/BC/control files (Data1, Data2, …)
  - README files

- Get Rocprep from CVS
  % cvs co Rocstar/Rocprep/Codes
  - Each module’s prep tools are compiled with Rocstar

- Tasks performed with a single command:
  - Extract relevant files from archive
  - Preprocess and partition for each module
  - Construct overlay mesh for Rocface

- Example: Rocflo/Rocfrac Lab Scale Rocket
  % Rocprep –A –o 1 2 –f 1 3 –d /csar/NDAs/labscale –n 16
Rocstar Run Directory Hierarchy

016procs
   RocstarControl.txt
   rocstar
   Restart.txt

Rocfloo
   RocflooControl.txt
   Modin
      labscale.inp
      labscale.bc
   Rocin
      fluid*.hdf
      fluid_in*.txt
   Modout
      *.prb_0001
   Rocout
      fluid_*.hdf
      solid_in*.txt

Rocfrac
   RocfracControl.txt
   Modin
   Rocin
      labscale_*.hdf
      SurfMesh*.hdf
      solid_in*.txt
   Modout
   Rocout
      solid_*.hdf
      solid_in*.txt

RocburnAPN
   RocburnAPNControl.txt
   Modin
   Rocin
   Modout
   Rocout
      burn_*.hdf
      burn_in_*.txt

Rocman
   RocmanControl.txt
   RoccmanRocfracControl.txt
   Modout
      GENX_integ.txt
   Profiles
      GENX_timing*.txt

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Rocstar Control Files, I

RocstarControl.txt

- Coupling mode: fluid only, solid only, coupled
- Physics solvers
- Time stepping scheme, max P-C iterations
- Tolerances for P-C scheme
- Start time (>0 restarts), end time
- System time step
- Output dump interval
- Output module (Rocout)
- Surface propagation flag
- Wall clock time limit
- Performance data directory
Rocstar Control Files, II

RocmanControl.txt
- Interpolation order (temporal)
- Surface quantity to pass (pressure or traction)
- Ambient pressure load
- Solid density (fluid-only mode)
- Data transfer algorithm parameters

RocpandaControl.txt
- Number of compute nodes
- Number of I/O servers
- Method of server distribution
Physics Module Files: *Rocflo, I*

### labscale.inp

# INITFLOW

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>0 0</th>
<th>! applies to block ... (0 0 = to all)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDUMMY</td>
<td>2</td>
<td>! no. of dummy cells</td>
</tr>
<tr>
<td>VELX</td>
<td>0.</td>
<td>! velocity in x-direction [m/s]</td>
</tr>
<tr>
<td>VELY</td>
<td>0.</td>
<td>! velocity in y-direction [m/s]</td>
</tr>
<tr>
<td>VELZ</td>
<td>0.</td>
<td>! velocity in z-direction [m/s]</td>
</tr>
<tr>
<td>PRESS</td>
<td>1.E+5</td>
<td>! static pressure [Pa]</td>
</tr>
<tr>
<td>DENS</td>
<td>1.16</td>
<td>! density [kg/m^3]</td>
</tr>
</tbody>
</table>

# viscous/inviscid flow -----------------------------------------------

# FLOWMODEL

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>0 0</th>
<th>! applies to block ... (0 0 = to all)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODEL</td>
<td>0</td>
<td>! 0=inviscid (Euler), 1=viscous (Navier-Stokes)</td>
</tr>
<tr>
<td>MOVEGRID</td>
<td>1</td>
<td>! moving grid (0=no, 1=yes)</td>
</tr>
</tbody>
</table>

# reference values ---------------------------------------------------

# REFERENCE

<table>
<thead>
<tr>
<th>CP</th>
<th>1846.35</th>
<th>! specific heat coeff. at constant pressure [J/kgK]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAMMA</td>
<td>1.2144</td>
<td>! ratio of specific heats</td>
</tr>
</tbody>
</table>
Physics Module Files: Rocflo, II

# PROBE
NUMBER  1
0  0.  0.  0.        ! Use coordinates
#
! multi-physics modules: ---------------------------------------------------------
# TURBULENCE
BLOCK  0  0      ! applies to block ... (0 0 = to all)
MODEL  0          ! 0=laminar, 1=...
#
# CONPART
BLOCK  0  0      ! applies to block ... (0 0 = to all)
USED   0            ! 0=module not used
#
# DISPART
BLOCK  0  0      ! applies to block ... (0 0 = to all)
USED   0          ! 0=module not used
#
Physics Module Files: *Rocflo, III*

# TIMESTEP
FLOWTYPE 1 ! 0=steady flow, 1=unsteady flow
TIMESTEP 1.E-4 ! max. physical time step [s]
WRITIME 2.E-2 ! time offset [s] to store solution
PRNTIME 1.E-5 ! time offset [s] to print convergence
SOLVERTYPE 0 ! 0=explicit, 1=implicit
RKSHEME 1 ! 1 - classical RK4, 2 - low-storage Wray RK3

# NUMERICS
BLOCK 0 0 ! applies to block ... (0 0 = to all)
CFL 3.0 ! CFL number
SMOOCF -0.7 ! coefficient of implicit residual smoothing (<0 - no smooth.)
DISCR 0 ! type of space discretization (0=central, 1=Roe, 2=MAPS)
K2 0.5 ! dissipation coefficient k2 (if discr=0)
1/K4 128. ! dissipation coefficient 1/k4 (if discr=0)
ORDER 2 ! 1=first-order, 2=second-order, 4=fourth-order
PSWTYPE 0 ! 0=standard pressure switch, 1=TVD type (if discr=0)
PSWOMEGA 0.1 ! blending coefficient for PSWTYPE=1 (if discr=0)
LIMFAC 5.0 ! limiter coefficient (if discr=1)
ENTROPY 0.05 ! entropy correction coefficient (if discr=1)
Physics Module Files: Rocflu

labscale.inp

# NUMERICS
CFL 3.0 ! CFL number
DISCR 3 ! Type of space discretization (1 - Roe, 2 - MAPS)
ORDER 1 ! Order of accuracy (1 - first, 2 - second)
ENTROPY 0.05 ! Entropy correction coefficient (if DISCR=1)
#
# TIMESTEP
FLOWTYPE 1 ! 0 - steady flow, 1 - unsteady flow
TIMESTEP 0.000001 ! Max. physical time step
STARTTIME 0.0 ! Current iteration
MAXTIME 0.2 ! Maximum number of iterations
WRITIME 0.001 ! Offset between iterations to store solutions
PRNTIME 0.000001 ! Offset between iterations to print convergence
#
# GRIDMOTION
TYPE 1
NITER 10
SFACT 0.25
#
Physics Module Files: *RocburnAPN*

RocburnAPNControl.txt

- **0.07696**  
  a in $rb=a*P^n$, $rb$ in cm/sec and $P$ in atm, $a_p$ (cm/sec)
- **0.461**  
  n in $rb=a*P^n$, $rb$ in cm/sec and $P$ in atm, $n_p$
- **1**  
  Maximum_number_of.spatial_nodes, _nxmax
- **2855.0**  
  adiabatic flame temperature, $T_f_{adiabatic}$ (K)
- **298.00**  
  initial temperature, $T_{o\_read}$ (K)

Rocburn_2D_Output/Rocburn_APN
Physics Module Files: *RocburnPY*

0.3912 \(a_p\) \(\text{cm/sec} = a_p \left(\frac{P}{P_{\text{pref}}}\right)^n\), \(P\) in atm

0.461 \(n_p\) \(\text{cm/sec} = a_p \left(\frac{P}{P_{\text{pref}}}\right)^n\), \(P\) in atm

34.0 \(P_{\text{pref}}\) \(\text{atm}\)

... 

2850.0 \(T_{\text{star0}}\) \(\text{adiabatic flame temperature, } T_{\text{star0}} \text{ (K)}\)

300.0 \(T_0\) \(\text{cold temperature, } T_0 \text{ (K)}\)

850.0 \(T_{\text{ignition}}\) \(\text{ignition temperature, } T_{\text{ignition}} \text{ (K)}\)

300.0 \(T_{\text{surf}}\) \(\text{surface temperature, } T_{\text{surf}} \text{ (K)}\)

560.08d0 \(\text{film}_\text{cons}\) \(\text{constant in film coefficient } [\text{W/(m}^2\text{K)}] \)

1 \(i_{\text{xsymm}}\) \(\text{axisymmetric initial burning, use } x_{\text{surf_burn}}\)

1.16200d-2 \(x_{\text{surf_burn}}\) \(\text{last surface x location burning from the onset}\)

1.d8 \(\text{press}_\text{max}\) \(\text{maximum pressure allowed to be passed in } [\text{Pa}] \)

1.d2 \(\text{press}_\text{min}\) \(\text{minimum pressure allowed to be passed in } [\text{Pa}] \)

1.0d0 \(\text{rb}_\text{max}\) \(\text{maximum burn rate allowed } [\text{m/sec}] \)

-1.0d-6 \(\text{rb}_\text{min}\) \(\text{minimum burn rate allowed } [\text{m/sec}] \)

1.d5 \(T_{\text{f_max}}\) \(\text{maximum gas temperature allowed } [\text{Kelvin}] \)

100.0d0 \(T_{\text{f_min}}\) \(\text{minimum gas temperature allowed } [\text{Kelvin}] \)

0 \(\text{TabUse}\) \(\text{use a table or not}\)

name \(\text{TabName}\) \(\text{name of table to use}\)
Physics Module Files: *Rocfrac*

*RocfracControl.txt*

*PREFIX
  labscale
**
*DYNAMIC, SCALE FACTOR = 0.25
**
** Select the 4-node tetrahedral
**
*ELEMENT,TYPE=V3D4
**
** HYPERELASTIC, ARRUDA-BOYCE or NEOHOOKINC
** Young's Modulus, Poisson's Ratio, Density, Expansion Coef.fs
**
*HYPERELASTIC, ARRUDA-BOYCE
  1
  6.585e6  0.499  1770.0  0.0
** FOR ALE:Uncomment next two lines and change Scale Factor = 0.25
*ALE
  0.15
Physics Module Files: *Rocsolid*

**RocsolidControl.txt**

Scalability test ! Title
1 1 3 4 256 ! NumElemGroup, NumMatSets, NumDof, NumMeshes, BlockSize
1 3 3 4 1.0E-3 100 ! Multigrid Variables (Gamma, NumPreRelax, NumPostRelax, NumMGMeshes, MGtol, MGMaxCycle)
1.0E-4 1000 ! PCGtol, PCGMaxCycle
JACOBI ! Preconditioner
NEWTON ! Nonlinear solver (Newton or Arc-length)
1 1.0E-4 10 ! NumLoadSteps, NewtonTol, NewtonMax
LUMPED ! MassMatrix (Lumped or Consistent)
MULTIGRID ! EquationSolver
BICGSTAB ! MeshMotionEquationSolver

**porous_viscoelastic** ! MaterialModel
propellant ! Material Name
0.929E6 3.604E6 ! ShearMod, TotalShearMod
3447E6 ! TotalBulkMod
0.305 ! TimeConstant
0.02 ! InitialProsity
1770. ! Density
b8_ld ! ElementType (b8_ld, b8_bbar, b8_ale, b8_me)
Running Batch Jobs with pj_all

- Creates batch job file to run *Rocstar*
- Supports many platforms
- Prompts for commonly changed parameters
  - Most parameters in *RocstarControl.txt*, *RocpandaControl.txt*
  - Partitions, CPUs
  - Run directory, executable directory (checks existence)
  - Gets default values from existing control files
- Edits control files automatically
- Facilitates restarts, submits dependent jobs
- New Runs
  - Renames previous run’s output directories
- Includes parameter files with screen dump
- Environment vars for *Roccom* verbosity, etc.
pj_all: Example, I

[turing-4:~/gen3/genx_charm_mpi] rfiedler% pj_all
Found rocstar, rocstar_flo, and/or rocstar_flu
To use a different executable, enter PREFIX
(full path to parent of Rocstar bin/ directory; default = /turing/home/rfiedler/gen3/genx_charm_mpi): [Enter]
Enter number of (virtual) compute CPUs (2): 16
Enter problem name (default = cylinder): labscale
Enter GEN3 run directory name (default = /turing/projects/csar/rfiedler/gen3-data/labscale/016procs): [Enter]
Enter output module (o = Rocout, p = Rocpanda, default = Rocout): [Enter]
Enter total number of physical CPUs (16): [Enter]
15 minutes will be reserved for final output
Enter total wall clock time limit in minutes (20): [Enter]
Enter program name (rocstar): [Enter]
Which fluid solver? (Rocflo = o, Rocflu = u, default = Rocflo): [Enter]
Is this run fluids only? (n): [Enter]
Which solid solver? (Rocfrac = f, Rocsolid = s, default = Rocfrac): [Enter]
Is this run solids only? (n): [Enter]
pj_all: Example, II

Which combustion module? (RocburnAPN = a, RocburnPY = p, RocburnZN = z, default = RocburnAPN): [Enter]
Enter system time step (1.0e-05 1.): [Enter]
Using Time_step zoom_factor = 1.0e-05 1.
Enter number of P-C iterations (default = 1): [Enter]
Enter physical problem end time (1.0e-04): 1.0e-03
Enter output interval (1.0e-03): 1.0e-04
Enter job name (la): lab
Enter restart mode (new run = 0, restart now = 1, dependent = job ID; default = 0): [Enter]

Starting a new run from time t = 0
How many identical jobs to submit (1): [Enter]
Do you wish to view the job script? (n): [Enter]
Do you wish to submit the job(s)? (y/n/e[xempt]/[e]x[pedite]/i[nteractive]): y
qsub pjob_16p
1667.turing-server-1.turing.uiuc.edu
[turing-4:~/gen3/genx_charm_mpi] rfiedler%
### Example System Time Step, I

**DRIVER:** GENX System Time Step :  6
**DRIVER:** CurrentTime, CurrentTimeStep, ZoomFactor:  
0.500000000000000024E-04 0.100000000000000008E-04 1.000000000000000000

**ROCCOM:** CALL(0) FullyCoupled.update_solutions

Conservatively transferring from FluidBufNG.ts to SolidBuf.ts
Conservatively transferring from FluidBufNG.mdot_tmp to SolidBuf.rb

<table>
<thead>
<tr>
<th>RocFrac :: Time Step</th>
<th>Dt</th>
</tr>
</thead>
<tbody>
<tr>
<td>RocFrac ::</td>
<td>-----------</td>
</tr>
<tr>
<td>RocFrac :: 31</td>
<td>0.1692E-05</td>
</tr>
<tr>
<td>RocFrac :: 32</td>
<td>0.3385E-05</td>
</tr>
<tr>
<td>RocFrac :: 33</td>
<td>0.5077E-05</td>
</tr>
<tr>
<td>RocFrac :: 34</td>
<td>0.6769E-05</td>
</tr>
<tr>
<td>RocFrac :: 35</td>
<td>0.8461E-05</td>
</tr>
<tr>
<td>RocFrac :: 36</td>
<td>0.1000E-04</td>
</tr>
</tbody>
</table>

**RocFrac :: END SOLID STEP**
Example System Time Step, II

Interpolating from SolidBuf.u to FluidBufNG.total_disp
Conservatively transferring from SolidBuf.vs to FluidBufNG.vs
Conservatively transferring from SolidBuf.mdot to FluidBufNG.mdot

RFLO: time delta-t force-x force-y force-z mass-in mass-out
RFLO: 5.59815E-05 5.9815E-06 0.0000E+00 0.0000E+00 0.0000E+00 7.6594E-01 1.6464E-02
RFLO: 6.00000E-05 4.0185E-06 0.0000E+00 0.0000E+00 0.0000E+00 6.7040E-01 1.6633E-02

ROCCOM: DONE(0)

DRIVER: iPredCorr = 1 is done
DRIVER: Success: predictor-corrector converged at time 0.600000000000000015E-04

ROCCOM: CALL(0) FullyCoupled.get_timestep
ROCCOM: DONE(0)
## Performance Data

**GENXTimingData0000.txt**

************** Solver times up to time step 10 since last output **************

<table>
<thead>
<tr>
<th>Function</th>
<th>#calls</th>
<th>Time(tree)</th>
<th>Time(self)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocflo.update_solution</td>
<td>1</td>
<td>0.362181</td>
<td>0.361099</td>
</tr>
<tr>
<td>Rocfrac.update_solution</td>
<td>1</td>
<td>0.115063</td>
<td>0.114022</td>
</tr>
<tr>
<td>RFC.least_squares_transfer</td>
<td>4</td>
<td>0.10477</td>
<td>0.10477</td>
</tr>
<tr>
<td>RFC.interpolate</td>
<td>1</td>
<td>0.038548</td>
<td>0.038548</td>
</tr>
<tr>
<td>FullyCoupled.update_solutions</td>
<td>1</td>
<td>0.625328</td>
<td>0.00149798</td>
</tr>
<tr>
<td>PROP.propagate</td>
<td>1</td>
<td>0.0012629</td>
<td>0.0012629</td>
</tr>
<tr>
<td>SURF.compute_bounded_volumes</td>
<td>1</td>
<td>0.00111508</td>
<td>0.00111508</td>
</tr>
<tr>
<td>BLAS.sub</td>
<td>61</td>
<td>0.000668287</td>
<td>0.000668287</td>
</tr>
<tr>
<td>FullyCoupled.update_inbuff_bc_fl</td>
<td>18</td>
<td>0.00102282</td>
<td>0.000397682</td>
</tr>
<tr>
<td>BLAS.limit1</td>
<td>24</td>
<td>0.000297546</td>
<td>0.000297546</td>
</tr>
<tr>
<td>RocburnAPN.update_solution</td>
<td>1</td>
<td>0.000272036</td>
<td>0.000258207</td>
</tr>
</tbody>
</table>

-----------------------------------------------

**Total(top level calls)** 0.625329
Output Data

- Fluids Probe files
  - labscale.prb_0001

- HDF 4
  - fluid_07.800000_0000.hdf  volume
  - fluid_gs_07.800000_0000.hdf  grid speeds (*Rocflu*)
  - ifluid_b_07.800000_0000.hdf  burning surface
  - ifluid_nb_07.800000_0000.hdf  non-burning
  - ifluid_ni 07.800000_0000.hdf  non-interacting
  - Similar solid, isolid and burn, iburn files

- Unsteady
- Quasi-Steady
Visualization with *Rocketeer*

- **Prerequisites (new turing)**
  - Place in `.cshrc` the lines
    ```
    setenv PATH "/turing/projects/csar/CSAR_Vis/v1.3.5/bin:${PATH}"
    setenv DYLD_LIBRARY_PATH 
     "'/turing/projects/csar/CSAR_Vis/v1.3.5/lib"
    ```
Rocketeer

- All data sets
  - Times, Blocks
  - Coordinates/ranges
  - Nodes/elements
  - Variables/ranges
    - Scalars
    - Vectors
    - Tensors

- Mesh
  - Blocks by color

- Quality metrics
  - Min/Max angle
  - Size, Skewness, etc.

- Surface plots

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Rocketeer

- Glyphs
  - Particles
  - Vector fields

- Isosurfaces

- 3-D mesh plots

- Opacity controls
  - Constant
  - Value-dependent

- Thresholds

- Animation
  - Output series
  - Moving camera

- Stand-alone, client/server, and batch versions
File Formats

Convert HDF to plt format

- hdf2plt
  - Builds along with rocstar in <PREFIX>/bin directory
- Need a script to convert multiple files
- Tecplot reads plt format
- Soon we’ll add CGNS as alternative to HDF 4
Managing Output Data

Utilities, Mass Storage

- **pj_all**
  - Renames previous run’s Rocout and Modout
  - Copies control and other text input files to Control_<jobid>

- **tar_input**
  - Extracts input data only

- **save_restart**
  - Extracts last output dump for restarting

- **mftp_htar/mscp_hdf**
  - Archiving/transfering files
  - Need access to storage or workstation w/o password (ssh key)
  - Transfers a range of output dumps (fluid, solid, burn)
Enhancements

- Mesh improvement: smoothing, repair, remeshing
- Rocman: more flexible time stepping schemes
- Surface propagation – face-offsetting method
- Particles and turbulence in Rocflu
- Another advanced propellant model in Rocsolid
  - Large strains and rotations
  - Debonding of AP particles
- Sliding interfaces
  - Burn propellant back along case
- GUI to help user manage all these tasks
Center for Simulation of Advanced Rockets

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