



The Center for Astrophysical Thermonuclear Flashes

FLASH Verification & Validation Topics

Tomek Plewa

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An Accelerated Strategic Computing Initiative (ASCI)
Academic Strategic Alliances Program (ASAP) Center
at The University of Chicago





Outline

FLASH Center Overview

Center-specific activities

- V&V in astrophysics
- V&V in computational methods
 - Case study: shock-cylinder interaction
 - Are 2-D experiments truly two-dimensional?
 - AMR and vortex-dominated flows
 - New message from Courant, Friedrichs, & Lewy
- SQA in code development

Summary

- Changing culture in astrophysics
- Improving computational machinery



The FLASH Center

Target Applications

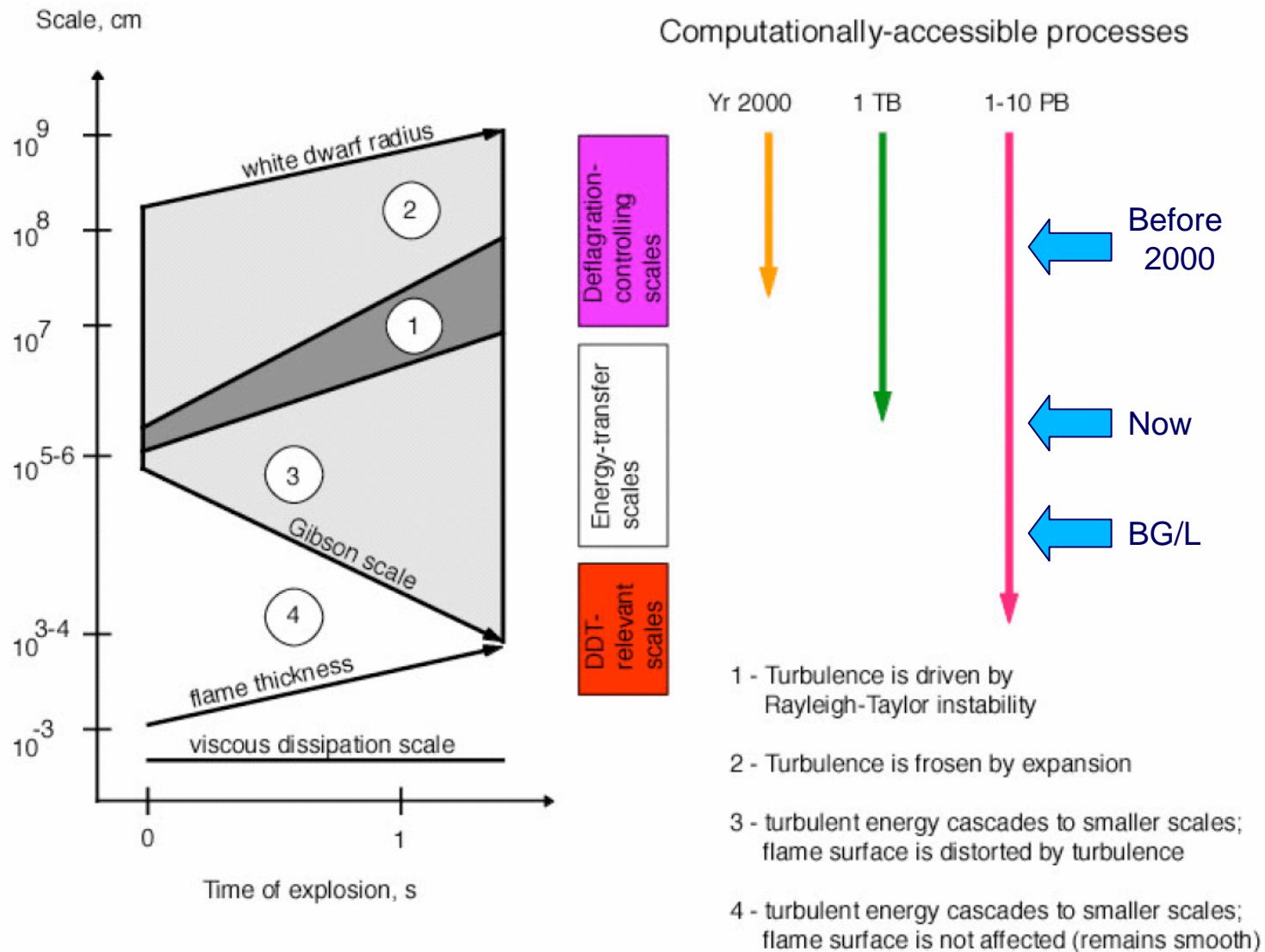
- Compact accreting stars (white dwarf, neutron star)
- Reactive hydrodynamics (DNS or subgrid model)
- Initial conditions close to hydrostatic equilibrium (self-gravity)
- Complex EOS (dense nuclear matter)

Example: Type Ia Supernova

- Massive white dwarf
- Subgrid model for nuclear flame
- Self-gravity
- Degenerate EOS



Length scales in White Dwarf Deflagration





V&V and Astrophysics

- Verification ranging from simple analytic problems to code-code comparison.
- No direct access to experiments: use scaling laws
- Absolutely **NO** culture of validation!

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ON VALIDATING AN ASTROPHYSICAL SIMULATION CODE

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ABSTRACT

We present a case study of validating an astrophysical simulation code. Our study focuses on validating FLASH, a parallel, adaptive-mesh hydrodynamics code for studying the compressible, reactive flows found in many astrophysical environments. We describe the astrophysics problems of interest and the challenges associated with simulating these problems. We describe methodology and discuss solutions to difficulties encountered in verification and validation. We describe verification tests regularly administered to the code, present the results of new verification tests, and outline a method for testing general equations of state. We present the results of two validation tests in which we compared simulations to experimental data. The first is of a laser-driven shock propagating through a multilayer target, a configuration subject to both Rayleigh-Taylor and Richtmyer-Meshkov instabilities. The second test is a classic Rayleigh-Taylor instability, where a heavy fluid is supported against the force of gravity by a light fluid. Our simulations of the multilayer target experiments showed good agreement with the experimental results, but our simulations of the Rayleigh-Taylor instability did not agree well with the experimental results. We discuss our findings and present results of additional simulations undertaken to further investigate the Rayleigh-Taylor instability.

Subject headings: hydrodynamics — instabilities — methods: numerical — shock waves



V&V and Computational Methods

- Verification exploits elementary tests with known analytic solutions or “converged” numerical solutions (not strict but practical).
Example: advection-diffusion-reaction subgrid model for evolution of the nuclear flame.
- Access to experiments: collaborations with LANL (shock-tube) and LLNL (high-energy density laser) experiments.

Simulation of Vortex–Dominated Flows Using the FLASH Code

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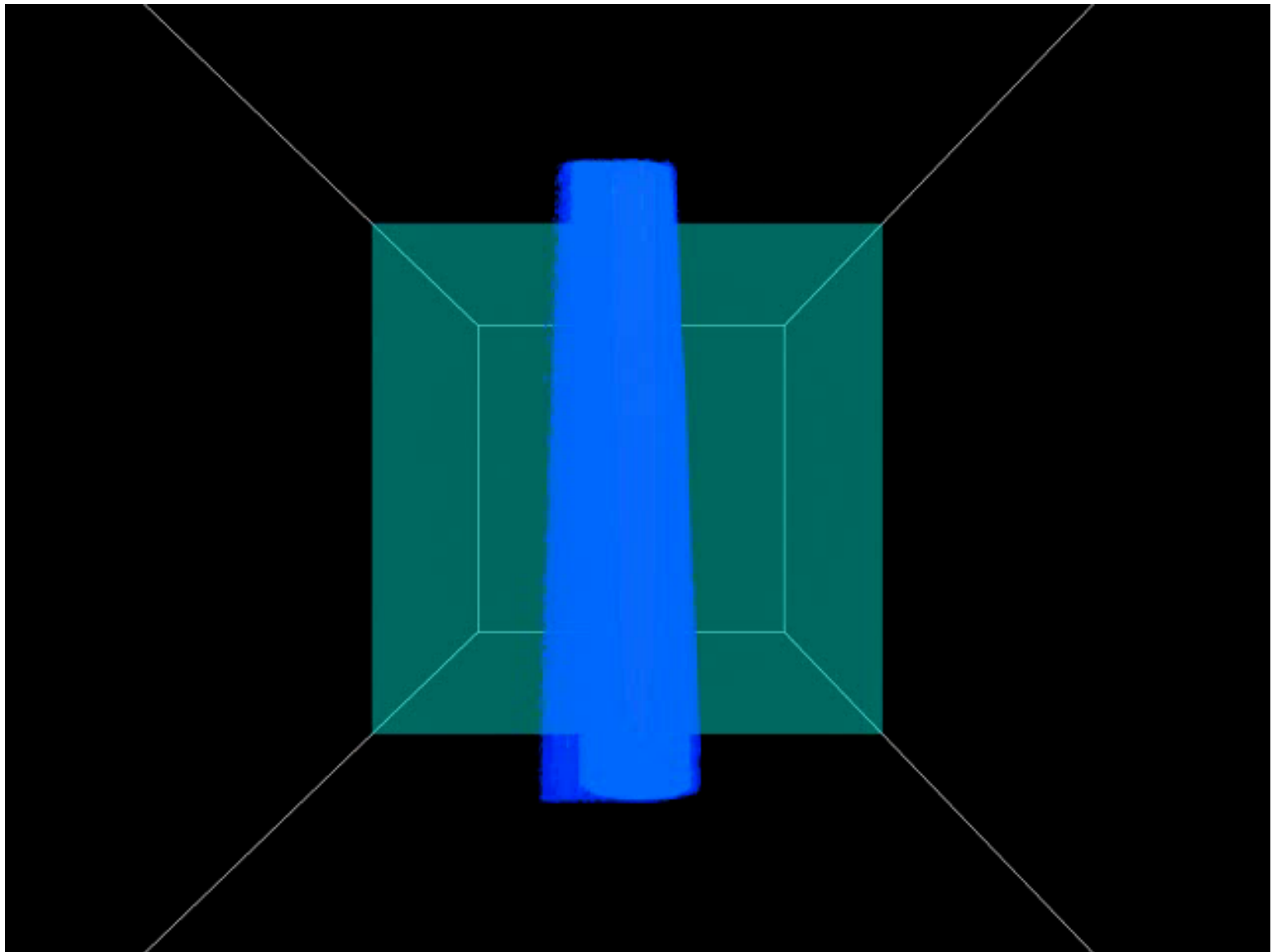
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1 Abstract

We compare the results of two–dimensional simulations to experimental data obtained at Los Alamos National Laboratory in order to validate the FLASH code. FLASH is a multi–physics, block–structured adaptive mesh refinement code for studying compressible, reactive flows in various astrophysical envi-

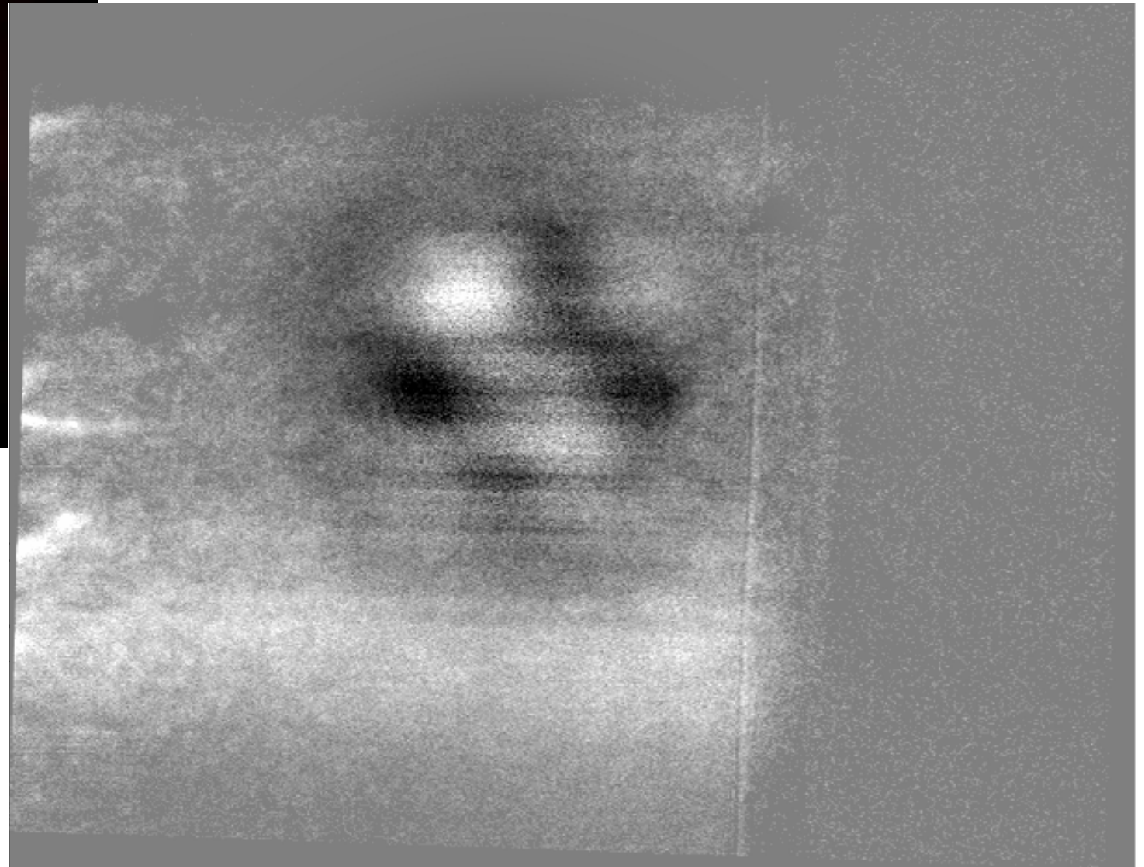
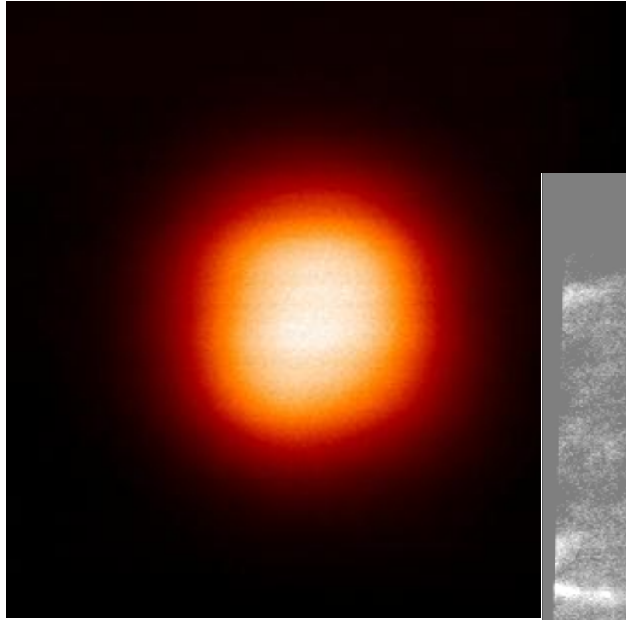


Case Study: Shock-Cylinder Interaction



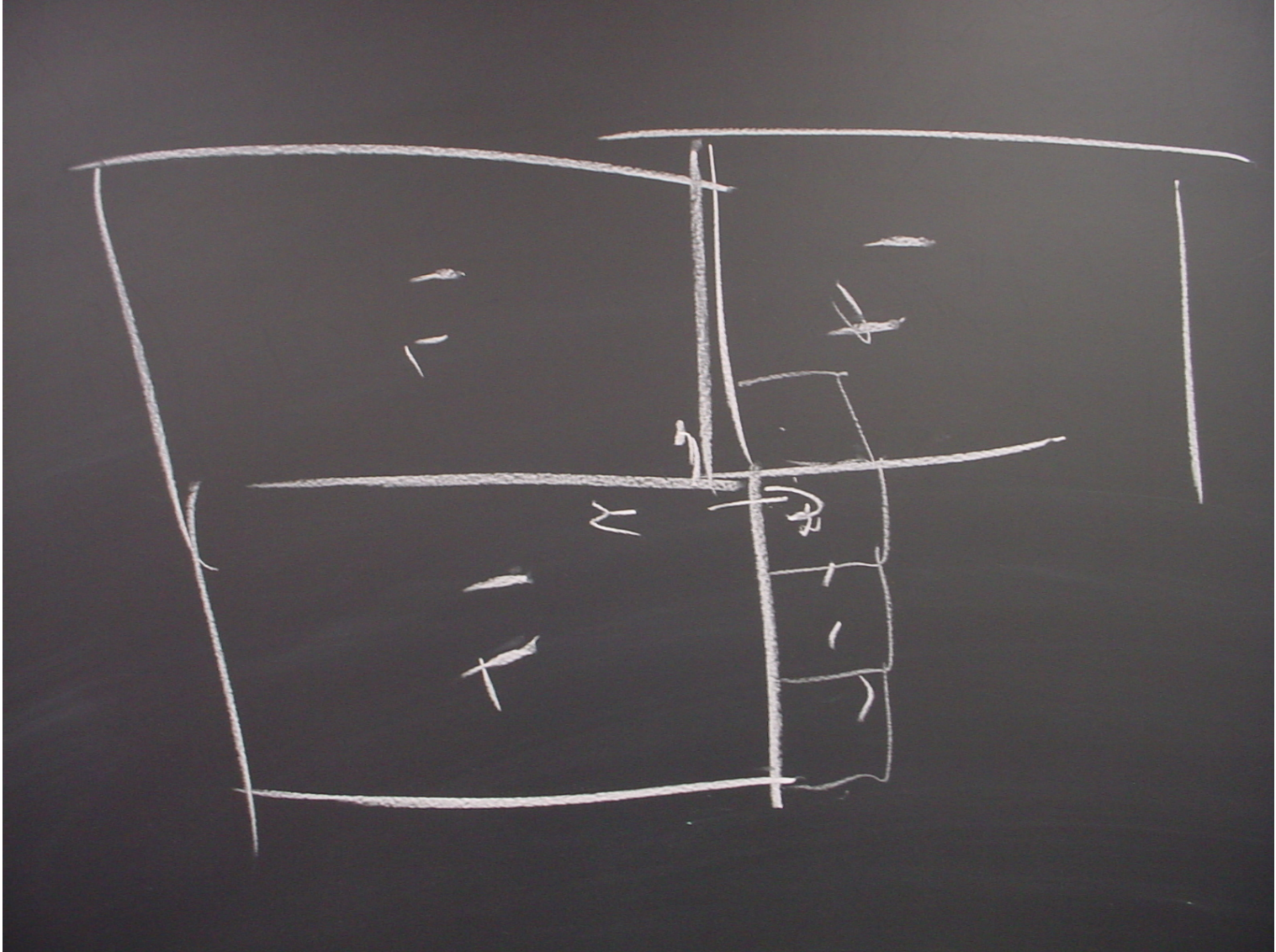


Initial Conditions: Cylinder Cross-section





FLASH Code is the AMR code





CFL dependency

CFL=0.8



CFL=0.2



Adaptive

3x3 rect

4x4 rect

4x8 rect



Software Quality Assurance

- Pure sciences rarely offer formal education or training: hands-on approach.
- SQA begins with code design: follow standards, design guidelines, specifications, etc. (FLASH2 -> FLASH3)
- Has to be a daily practice, encouraged/enforced by use of automated monitoring tools (FLASH test suite).

document on how to add a comparison test
random notes about the test suite

Tools

- Suite heartbeats NEW!
- FLASH2.3 CVS
- CVS database queries
- Issue database
- Old History of benchmark changes
- Benchmark manager
- Test source database
- Error tracker (yellow light stuff)
- Email preferences

User Comments

benchmark taralls weren't updating since move to new flash machine (as Tomek pointed out). oops. fixed.
caceres (Mon Feb 23 16:26 CST 2004)

View all (69) comments

Add comment (the input is used as raw html, so be careful with greater-than signs and things like that)

Results

Dir Log Checksums ChangeLog Environment

io]] completed with no errors
comparison[1 alt_suite/new rk3_briwju -n 1 -b comp20040226] had 1 error(s)
comparison[1 alt_suite/new_strang_briwju -n 1 -b comp20040226] had 1 error(s)
comparison[1 alt_suite/new_euler1_sod -n 1 -b comp20040226] had 2 error(s)
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		20040229	20040229	20040229	20040229	20040229
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		20040227	20040227	20040227	20040227	20040227
		20040226	20040226	20040226	20040226	20040226



Summary

- V&V is an essential component of the Center's work.
- The Center introduced V&V methodology to astrophysics, promotes and truly builds V&V-related consciousness among astrophysicists.
- Interaction with the National Laboratories, especially DP Labs, is crucial for the V&V effort (direct access to experiments, use of predictive power of the simulation tools, aiding in experiment design).
- Software Quality Assurance is a daily practice of the Center's work supported by specialized, developed in-house software and guided by design rules and custom programming standards.