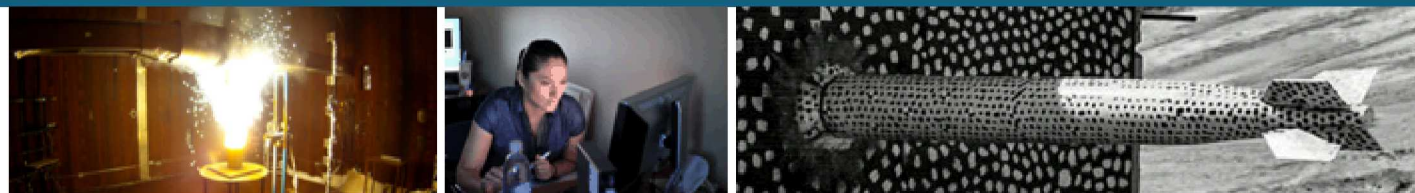


Some experiences with software engineering



PRESENTED BY

Richard Barrett



Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

ALEGRA

Simulate large deformations and strong shock physics including solid dynamics in an Arbitrary Lagrangian-Eulerian methodology

Also magnetics, MHD, electromechanics and a wide range of phenomena for high-energy physics applications.

ALEGRA code base*. (project began 1990)

C/C++ SOURCE LINES OF CODE COUNTING PROGRAM
(c) Copyright 1998 - 2000 University of Southern California, CodeCount (TM)

University of Southern California retains ownership of this copy of software. It is licensed to you. Use, duplication, or sale of this product, except as described in the CodeCount License Agreement, is strictly prohibited. This License and your right to use the software automatically terminate if you fail to comply with any provisions of the License Agreement. Violators may be prosecuted. This product is licensed to : USC CSE and COCOMO II Affiliates

The Totals

Total Lines	Blank Lines	Comments		Compiler Direct.	Data Decl.	Exec. Instr.	Number of Files	File SL0C	File Type	SL0C Definition
		Whole	Embedded							
388275	62268	72506	8267	14688	64562	174252	1241	253502	CODE	Physical
388275	62268	72506	8267	14622	32912	116441	1241	163975	CODE	Logical
5388	778	0	0	0	4610	0	68	4610	DATA	Physical

Number of files successfully accessed..... 1309 out of 1353

Ratio of Physical to Logical SL0C..... 1.55

Number of files with :

Executable Instructions > 100 = 289

Data Declarations > 100 = 48

Percentage of Comments to SL0C < 60.0 % = 697 Ave. Percentage of Comments to Logical

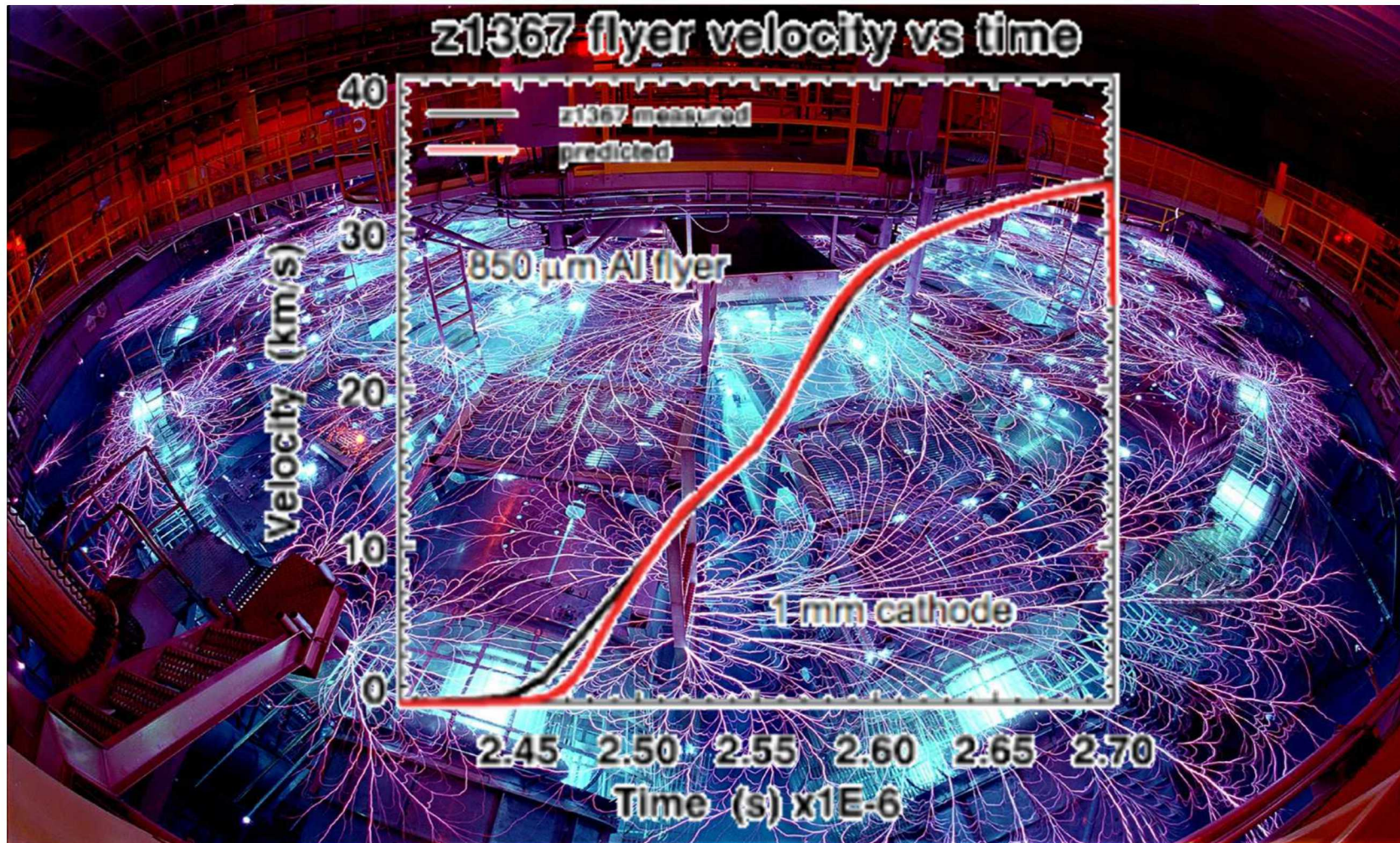
SL0C = 49.3

REVISION AG4 SOURCE PROGRAM -> C_LINES

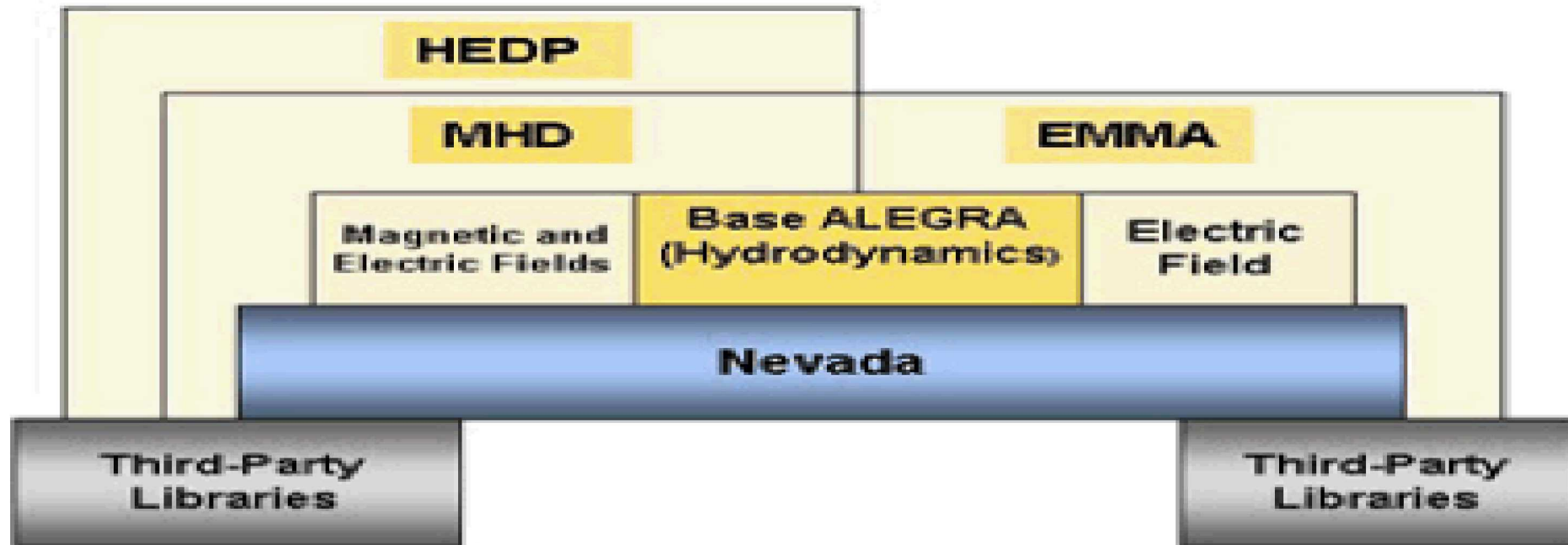
This output produced on Wed Feb 23 10:20:26 2011

* Excluding some Fortran (58k@121f), python, xml, etc, some uncounted files, and the Nevada framework.

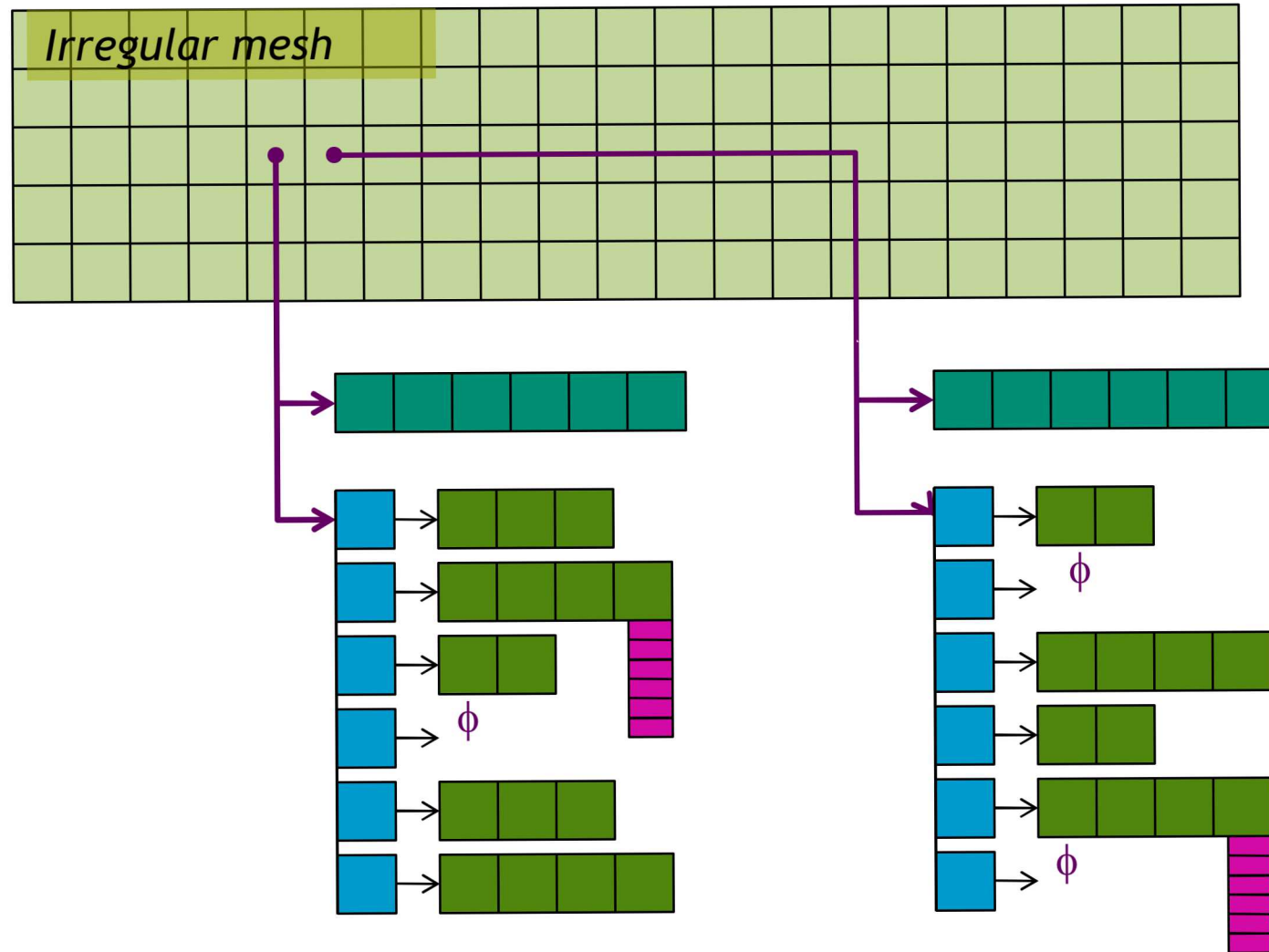
Pulsed power: Z-machine



ALEGRA framework



ALEGRA data structure



All Orders Spectral Algorithm

Simulate heating and confinement in the ITER fusion reactor using radio-frequency power

Solves a dense linear system of complex coefficients. (LINPACK)

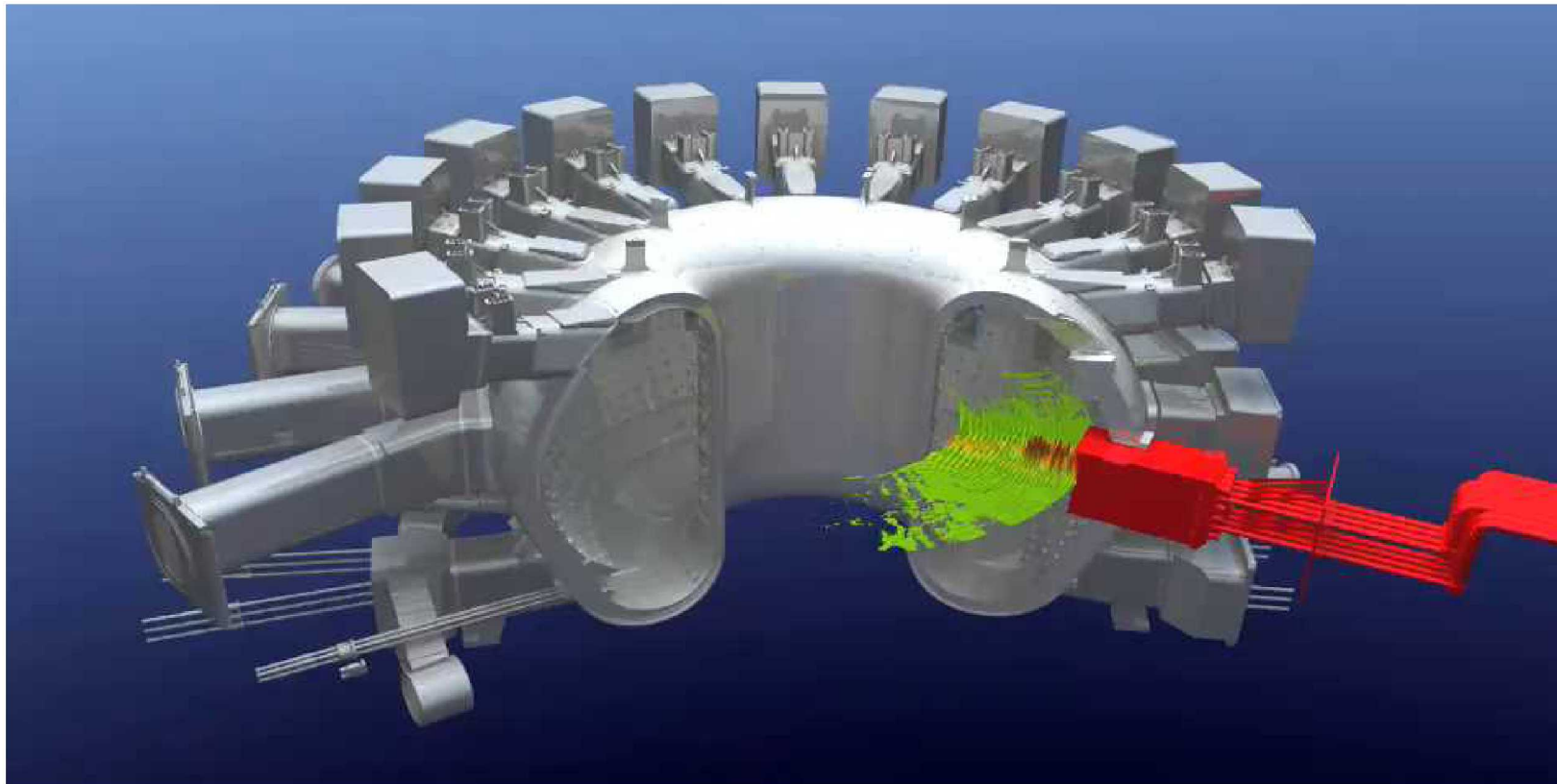
fields. For rf applications, the wave time scale is by far the fastest time scale in the system. The nonlinear response of the plasma occurs on a much slower collisional, or MHD time scale. Thus, the fields and distribution function can be separated into a time-average or equilibrium part ($\mathbf{E}_0, \mathbf{B}_0, f_s^0$), and a time-harmonic or rapidly oscillating part, [$\mathbf{E}(\mathbf{r}) e^{-i\omega t}$, $\mathbf{B}(\mathbf{r}) e^{-i\omega t}$, $f_s^1(\mathbf{r}, \mathbf{v}) e^{-i\omega t}$]. For the time-harmonic part, Maxwell's equations reduce to a generalization of the Helmholtz equation [1],

$$-\nabla \times \nabla \times \mathbf{E} + \frac{\omega^2}{c^2} \left(\mathbf{E} + \frac{i}{\omega \epsilon_0} \mathbf{J}_p \right) = -i\omega \mu_0 \mathbf{J}_{ant} \quad (1)$$

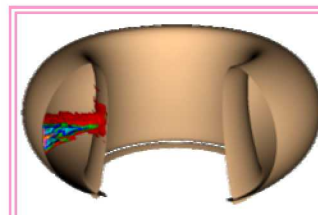
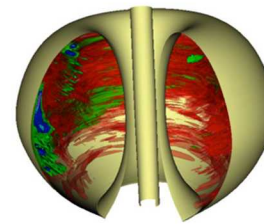
plus boundary conditions, where $\mathbf{E}$ is the rapidly oscillating part of the wave electric field and ω is the frequency of the wave. The fluctuating plasma current induced by the wave fields, $\mathbf{J}_p$ is a nonlocal, and possibly nonlinear, integral operator on the electric field [14],

$$\mathbf{J}_p(\mathbf{r}, t) = \int_{-\infty}^t dt' \sum_s \int d\mathbf{r}' \sigma(f_s^0(E), \mathbf{r}, \mathbf{r}', t, t') \mathbf{E}(\mathbf{r}', t') \quad (2)$$

where $\sigma(f_s^0, \mathbf{r}, \mathbf{r}', t, t')$ is the *plasma conductivity kernel*. The source for the waves is an externally driven antenna current, $\mathbf{J}_{ant}$,



*AORSA simulation;
movie by Sean Ahern@ORNL*



C APPROXIMATE VALUES FOR SOME IMPORTANT MACHINES ARE:

C	IBM/195	CDC/7600	UNIVAC/1108	VAX 11/780	(UNIX)
C	(D.P.)	(S.P., RNDG)	(D.P.)	(S.P.)	(D.P.)
C NSIG	16	14	18	8	17
C ENTEN	1.0D75	1.0E322	1.0D307	1.0E38	1.0D38
C ENSIG	1.0D16	1.0E14	1.0D18	1.0E8	1.0D17
C RTNSIG	1.0D-4	1.0E-4	1.0D-5	1.0E-2	1.0D-4
C ENMTEN	2.2D-78	1.0E-290	1.2D-308	1.2E-37	1.2D-37
C XLARGE	1.0D4	1.0E4	1.0D4	1.0E4	1.0D4
C EXPARG	174.0D0	740.0E0	709.0D0	88.0E0	88.0D0

c timing on ncar"s control data 7600, basic takes about

c .32+.008*n milliseconds when z=(1.0,1.0).

c

c portability ansi 1966 standard

Some publications from AORSA

[*Simulation of High Power Electromagnetic Wave Heating in the ITER Burning Plasma*](#), E. F. Jaeger, L. A. Berry, E. F. D'Azevedo, R. F. Barrett, S. D. Ahern, D. W. Swain, D. B. Batchelor, R. W. Harvey, J. R. Myra, D. A. D'Ippolito, C. K. Phillips, E. Valeo, D. N. Smithe, P. T. Bonoli, J. C. Wright, and M. Choi, [*Physics of Plasmas*](#), (15)7, 2008

Simulation of High Power ICRF Wave Heating in the ITER Burning Plasma, E.F. Jaeger, L.A. Berry, R.F. Barrett, E.F. D'Azevedo, et al, [*Proceedings of the 49th Annual Meeting of the Division of Plasma Physics of the American Physical Society*](#), November, 2007, Bull. Am. Phys. Soc 52 (2007)

[*Global-wave Solutions with Self-consistent Velocity Distributions in Ion Cyclotron Heated Plasmas*](#), E.F. Jaeger, R.W. Harvey, L.A. Berry, J.R. Myra, R.J. Dumont, C.K. Phillips, D.N. Smithe, R.F. Barrett, D.B. Batchelor, P.T. Bonoli, M.D. Carter, E.F. D'Azevedo, D.A. D'Ippolito, R.D. Moore and J.C. Wright, [*Journal of Nuclear Fusion*](#), Volume 46, Number 7, July, 2006.

[*Self-Consistent Full-Wave and Fokker-Planck Calculations for Ion Cyclotron Heating in Non-Maxwellian Plasmas*](#), E.F. Jaeger, L.A. Berry, S.D. Ahern, R.F. Barrett, D.B. Batchelor, M.D. Carter, E.F. D'Azevedo, R.D. Moore, R.W. Harvey, J.R. Myra, D.A. D'Ippolito, R.J. Dumont, C.K. Phillips, H. Okuda, D.N. Smithe, P.T. Bonoli, J.C. Wright, and M. Choi, [*Physics of Plasmas*](#), 13, May 2006.

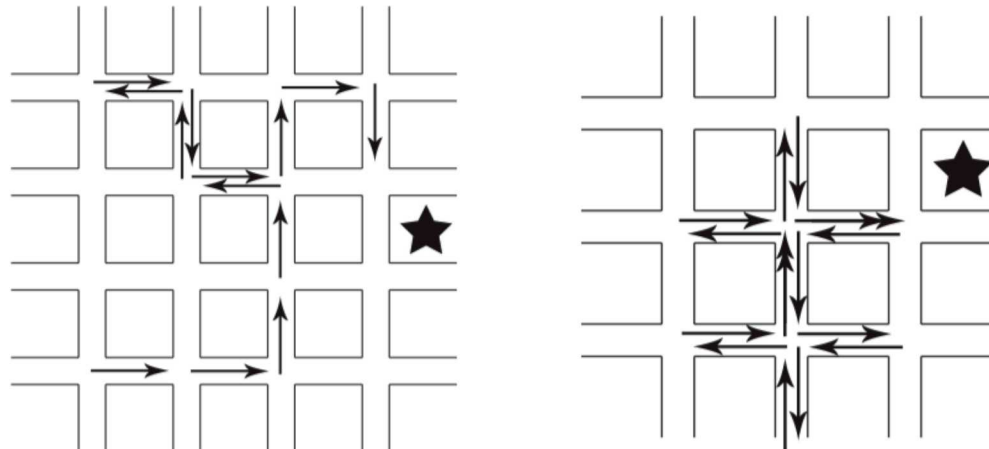
Self-consistence full-wave and Fokker-Planck calculations for ion cyclotron heating in non-Maxwellian plasmas, E.F.Jaeger et al, Invited paper, APS 2005, Denver.

[*Complex version of High Performance Computing LINPACK Benchmark \(HPL\)*](#), R. Barrett, T. Chan, E.F. D'Azevedo, E.F. Jaeger, K. Wong, and R. Wong. [*Concurrency and Computation: Practice and Experience*](#), (22)5, April, 2010 .

Boolean Satisfiability

$$(x_1 \vee \neg x_2) \wedge (\neg x_1 \vee x_2 \vee x_3) \wedge \neg x_1$$

- DPLL: a complete, “depth first”, back-tracking search algorithm
- Conflict Driven Clause Learning [CDCL96]
- Lookahead



tau profiling

TAU: ParaProf: Call Path Data n,c,1, 3,0,4 - sat6.ppk

Metric Name: TIME
Sorted By: Exclusive
Units: seconds

	Exclusive	Inclusive	Calls/Tot.Calls	Name[id]
→	27.77 0	27.77 27.498	1 917/917	.TAU application [CONTEXT] .TAU application
	0.083	0.083	2/367	[UNWIND] /home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x.0 [@] lglshtkhts [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {2652}]
	0.029	0.029	1/367	[UNWIND] /home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x.0 [@] lglnew [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {1134}]
	10.735	10.735	364/367	[UNWIND] /home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x.0 [@] lglsrz [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {1157}]
→	10.846	10.846	367	[SAMPLE] __intel_memset [{/home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x} {0}]
	5.875	5.875	191/191	[UNWIND] .0 [@] opal_memory_ptmalloc2_mremap_chunk [{/build/builddir/build/BUILD/openmpi-1.10.7/opal/mca/memory/linux/malloc.c} {3378}]
→	5.875	5.875	191	[SAMPLE] __GI___mremap [{}] {0}]
→	2.808	2.808	94	[SUMMARY] lglnpropsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c}]
→	0.801	0.801	27	[SUMMARY] lglnval [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c}]
	0.645	0.645	21/21	[UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c.2712 [@] lglnpushwch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {2739}]
→	0.645	0.645	21	[SAMPLE] lglnlwchs [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {2712}]
→	0.645	0.645	21	[SUMMARY] lglnlwchs [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c}]
→	0.616	0.616	20	[SUMMARY] lglnpushwch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c}]
	0.539	0.539	19/19	[UNWIND] .0 [@] mutex_lock [{/build/builddir/build/BUILD/openmpi-1.10.7/opal/mca/memory/linux/./sysdeps/pthread/malloc-machine.h} {64}]
→	0.539	0.539	19	[SAMPLE] __nanosleep_nocancel [{}] {0}]
	0.507	0.507	18/18	[UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c.3868 [@] lglnbcpsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {4312}]
→	0.507	0.507	18	[SAMPLE] lglnpropsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {3868}]
	0.456	0.456	15/16	[UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c.2738 [@] lglnbcpsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {4312}]
	0.034	0.034	1/16	[UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c.2738 [@] lglnprop [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {4130}]
→	0.49	0.49	16	[SAMPLE] lglnpushwch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/iglib.c} {2738}]

tau profiling

TAU: ParaProf: Call Path Data n,c,t, 3,0,2 - sat8.ppk

Metric Name: TIME
Sorted By: Exclusive
Units: seconds

	Exclusive	Inclusive	Calls/Tot.Calls	Name[id]
→	28.086 0	28.086 27.907	1 929/929	.TAU application [CONTEXT] .TAU application
	0.137 9.298 0.04 0.046 9.521	0.137 9.298 0.04 0.046 9.521	5/308 300/308 1/308 2/308 308	[UNWIND] /home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x.0 [@] lglskrinkhts [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {2658}] [UNWIND] /home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x.0 [@] mybzero [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {25}] [UNWIND] /home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x.0 [@] lglenlwchs [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {2732}] [UNWIND] /home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x.0 [@] lglnw [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {1139}] [SAMPLE] __intel_memset [{/home/rfbarre/uncletupelo/pc3/bin/skybridge/pc3.x} {0}]
→	5.098 5.098	5.098 5.098	176/176 176	[UNWIND] .0 [@] opal_memory_ptmalloc2_mremap_chunk [{/build/buildd/build/BUILD/openmpi-1.10.7/opal/mca/memory/linux/malloc.c} {3378}] [SAMPLE] __GI__mremap [{0}]
→	4.476	4.476	152	[SUMMARY] lgpropsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c}]
→	0.97	0.97	36	[SUMMARY] lgval [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c}]
→	0.738	0.738	24	[SUMMARY] lgpushwch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c}]
→	0.641 0.04 0.681	0.641 0.04 0.681	21/22 1/22 22	[UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c.2744 [@] lgblcpsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {4318}] [UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c.2744 [@] lglna [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {5734}] [SAMPLE] lgpushwch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {2744}]
→	0.642 0.642	0.642 0.642	21/21 21	[UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c.3862 [@] lgblcpsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {4318}] [SAMPLE] lgpropsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {3862}]
→	0.631 0.631	0.631 0.631	23/23 23	[UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c.3874 [@] lgblcpsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {4318}] [SAMPLE] lgpropsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {3874}]
→	0.016 0.519 0.008 0.543	0.016 0.519 0.008 0.543	1/20 18/20 1/20 20	[UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c.2004 [@] lgclels [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {8094}] [UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c.2004 [@] lgblcpsearch [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {4318}] [UNWIND] /home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c.2004 [@] lglna [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {5734}] [SAMPLE] lgval [{/home/rfbarre/uncletupelo/pc3/TPL/lingeling_callable/lglib.c} {2004}]

Regarding software engineering

(365) If you think it's expensive to hire a professional to do the job, wait until you hire an amateur.

-- *Red Adair, oil well firefighter*

(349) It's harder than you might think to squander millions of dollars, but a flawed software-development process is a tool well suited to the job.

-- *Alan Cooper*

(358) Always code as if the person who ends up maintaining your code is a violent psychopath who knows where you live.

Corollary: I usually maintain my own code, so the as-if is true.

-- *Martin Golding*

(331) There's an old story about the person who wished his computer were as easy to use as his telephone. That wish has come true, since I no longer know how to use my telephone.

-- *Bjarne Stroustrup*

<https://www.sandia.gov/~sjplimp/quotes.html>

Thanks

