The Development of Open-source Gasdynamic Simulation Tools at the Centre for Hypersonics

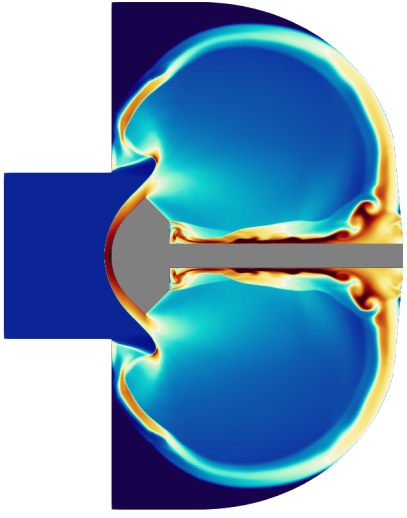
Dr. Nick Gibbons,
The University of Queensland, Brisbane, Queensland 4072, Australia

May 17, 2023

The Gasdynamic Toolkit (GDTk)

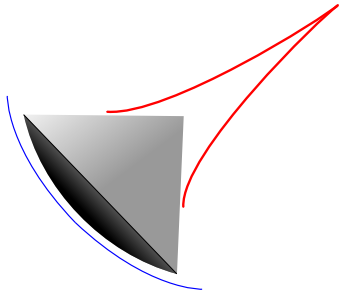
The Gas Dynamics Toolkit (GDTk) is a set of software tools for simulating high speed fluid flow, maintained at the University of Queensland, Australia.

Website: `gdtk.uqcloud.net`
Paper: `doi.org/10.1016/j.cpc.2022.108551`

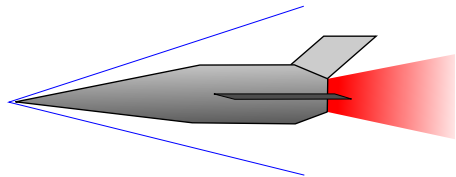


Hayabusa Aeroshell scale model in X2, by Peter Jacobs

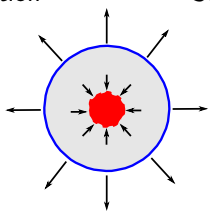
Why study high-speed flow?



Spacecraft Heat Protection



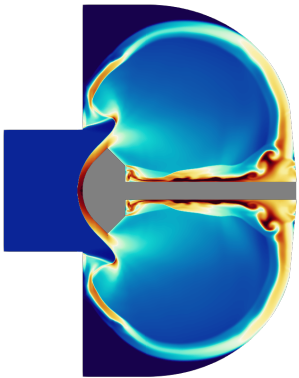
Supersonic Aircraft Propulsion



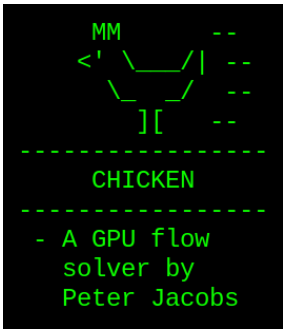
Compressible Fluid Instabilities

What's in the toolkit?

Eilmer: A general purpose CFD solver for hypersonics research.



Chicken: Experimental flow solver accelerated using CUDA.



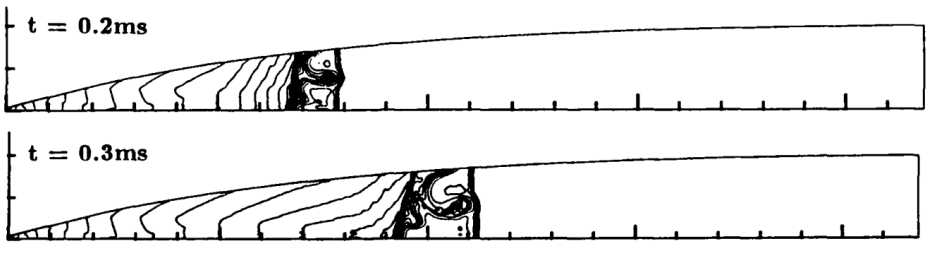
Much Else Besides:

- **Puffin**: Supersonic space marching
- **Nenzf1d**: Shock tunnel experiment analysis
- **L1d**: Full-scale Lagrangian facility simulations
- **Pitot**: Expansion tube condition design
- **ceq**: Equilibrium chemistry calculations

The Origins of Eilmer

Early work by Peter Jacobs and Rowan Gollan:

- CNS4u: Single block Navier-Stokes integrator by PJ for ICASE (1991)
- MBCNS: Multi-block version, C and custom command script (1996)
- Elmer: Hybrid code using C and Python (2004)
- Elmer 2: Back to plain C (2005)
- Eilmer 3: Massive expansion of codebase, switch to C++ (2008)



Eilmer 4 and the D Programming Language

June 2015: Eilmer 3 starts to become unmanageably large and problematically old

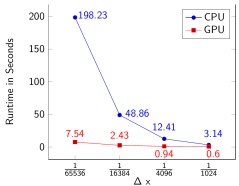
- Peter and Rowan begin porting key routines to D
- 2016: Kyle Damm joins the project, begins PhD on aerooptimisation
- 2020: Kyle and Myself begin postdoctoral fellowships as full time developers

The D programming language:

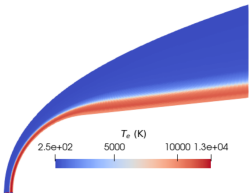
- D is a high-level compiled language designed to be a modernised improvement on C++
- Familiar C-like syntax, greatly improved compiler technology
- Redesigned high level features: Macros, templates, objects, etc.

Current Research: PhD students contributing to GDTk

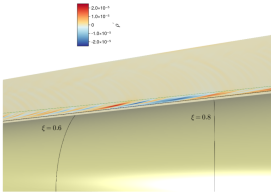
Christine Mittler: GPUs for CFD



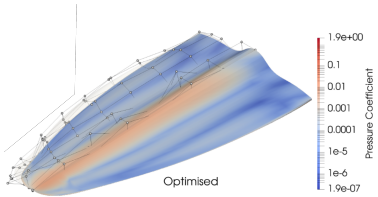
Robert Watt: Electron Transpiration Cooling



Lachlan Whyborn: Supersonic transition



Reece Otto: Aero-optimisation in 3D



Thanks!

Special thanks to:

- Dr. Anand Veeraragavan
- Prof. Vince Wheatley
- Dr. Fabian Zander
- Dr. Wilson Chan
- Dr. Chris James
- Dr. Daryl Bond
- Dr. Ingo Jahn

And many others!

Ghassan Al'Doori, Steven Apirana, Nikhil Banerji, Justin Beri, Peter Blyton, Viv Bone, Jamie Border, Arianna Bosco, Djamel Boutamine, Laurie Brown, James Burgess, David Buttsworth, Eric WK Chang, Sam Chiu, Chris Craddock, Brian Cook, Tim Cullen, Damian Curran, Jason Czapla, Andrew Dann, Andrew Denman, Zac Denman, Luke Doherty, Elise Fahy, Antonia Flocco, Delphine Francois, James Fuata, David Gildfind, Richard Goozeé, Sangdi Gu, Birte Haker, Stefan Hess, Jonathan Ho, Jimmy-John Hoste, Carolyn Jacobs, Juanita Jacobs, Chris James, Ian Johnston, Ojas Joshi, Xin Kang, Rory Kelly, Rainer Kirchhartz, Sam Lamboo, Will Landsberg, Alexis Lefevre, Steven Lewis, Yu (Daisy) Liu, Kieran Mackle, Michael Macrossan, Pierre Mariotto, Tom Marty, Matt McGilvray, Sarah Mecklem, David Mee, Carlos de Miranda-Ventura, Christine Mittler, Luke Montgomery, Richard G. Morgan, Heather Muir, Jan-Pieter Nap, Brendan O'Flaherty, Reece Otto, Andrew Pastrello, Oliver Paxton, Paul Petrie-Repar, Jorge Sancho Ponce, Daniel Potter, Jason (Kan) Qin, Deepak Ramanath, Andrew Rowlands, Jacob Sandral, Michael Scott, Umar Sheikh, Daniel Smith, Tamara Sopek, Sam Stennett, Ben Stewart, Oliver Street, Joseph Tang, Katsu Tanimizu, Matthew Thompson, Augustin Tibère-Inglesse, Pierpaolo Toniato, Matt Trudgian, Paul van der Laan, Tjarke van Jindelt, Jaidev Vesudevan, Alex Ward, Han Wei, Mike Wendt, Brad Wheatley, Ryan Whitside, Lachlan Whyborn, Adriaan Window, Hannes Wojciak, Mengmeng Zhao