Eilmer activities at Centre for Hypersonics and beyond

Rowan Gollan, Nicholas Gibbons, Kyle Damm and Peter Jacobs

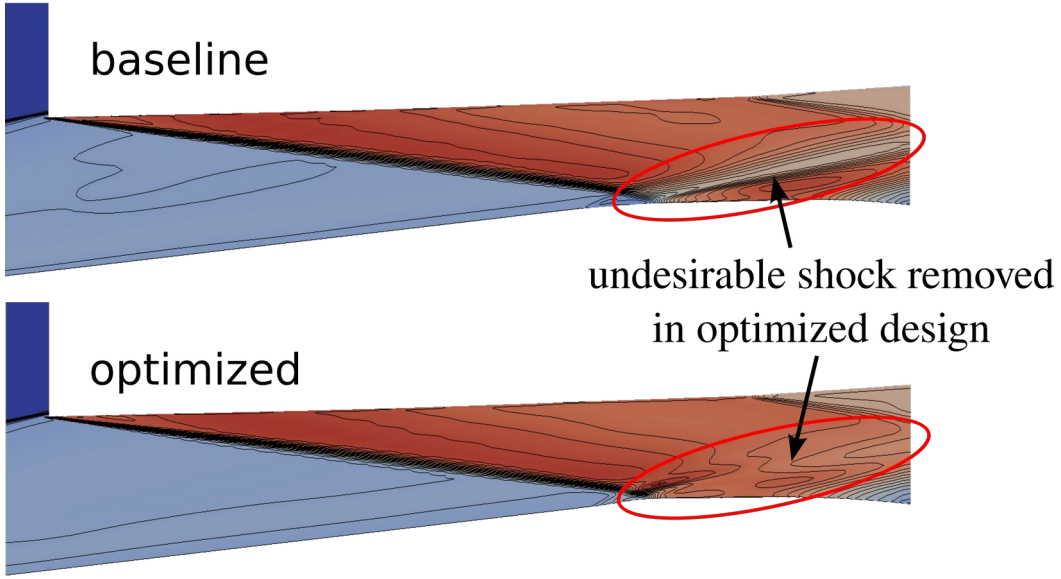
Eilmer: UQ's multi-physics hypersonic flow solver

2020-2021 news

- Official 4.0 version release in July 2021
- Jacobian-free Newton-Krylov accelerator for fluid and solid domains for steady-state simulations
- Time-accurate simulations of coupled fluid-solid domains using super time-stepping
- Generalised multi-temperature modelling capability
- Adjoint solver for CFD-based optimisation

2020-2021 outcome highlights

- Adjoint optimization of high-speed inlet
- Study on unsteadiness on double cones (JFM, 916:A5)
- Study on effectiveness of electron transpiration cooling



Damm et al. (2020) AIAA J. 58(6)
Discrete Adjoint Optimization of a Hypersonic Inlet

H.G. Hornung, R.J. Gollan and P.A. Jacobs

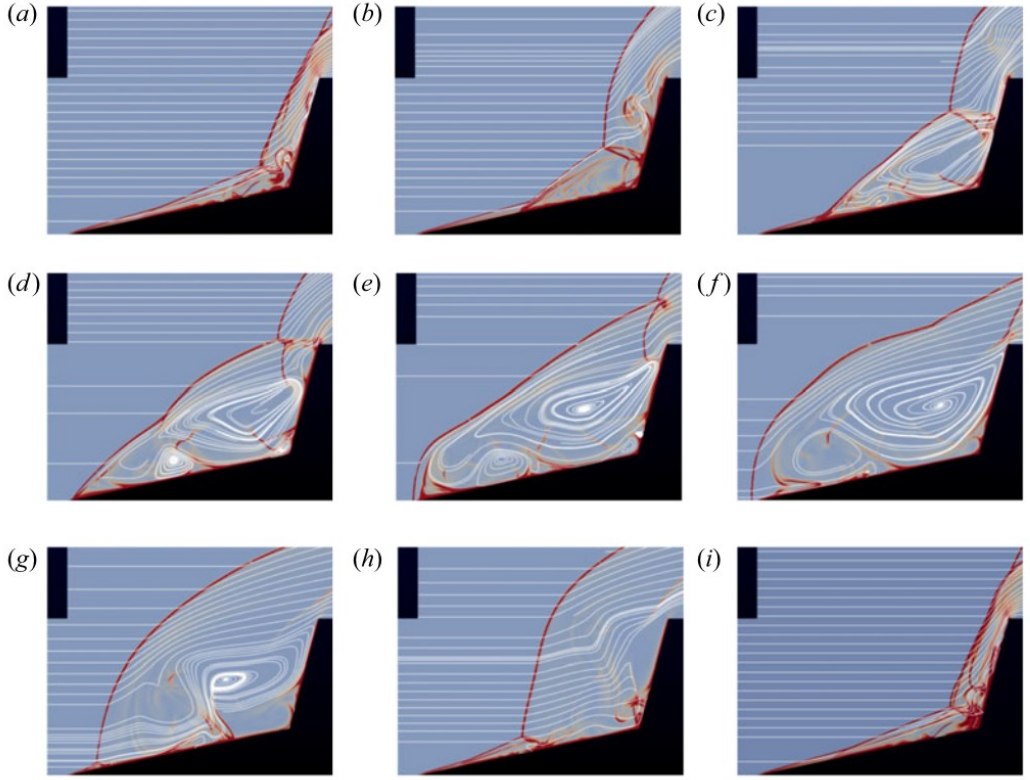


Figure 12. One cycle of the pulsating unsteadiness, condition A at location *a* in figure 3. The separation of the panels is approximately 35 μs.

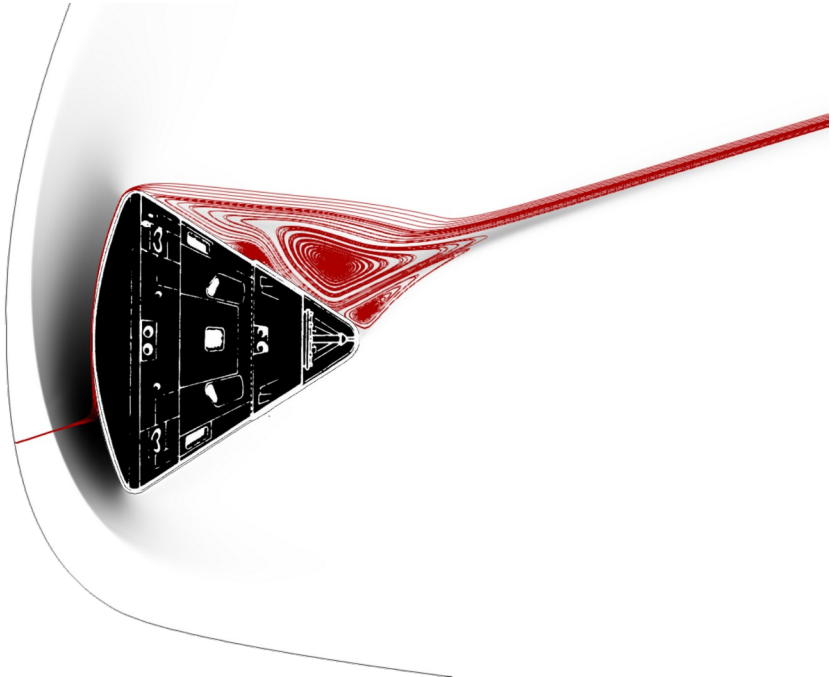
Eilmer v 4.0.0 release: what's in the box?

The University Of Queensland AUSTRALIA

```
git checkout v4.0.0
```

Capabilities/features supported in `v4.0.0`.

- transient time-stepping
  - Euler
  - predictor-corrector
  - RK-3 variants
- local time-stepping
- grid capabilities
  - structured grids
  - unstructured grids
  - moving grid (user-defined motion and shock-fitting)
  - import GridPro format
  - import SU2 format
- parallel execution
  - with shared memory (on NUMA platforms)
  - with MPI (for inter- and intra-node execution)
- gas models
  - ideal gas
  - mixtures of thermally perfect gases
- kinetics
  - finite-rate chemistry (for thermally perfect gas mixtures)
- turbulence models
  - Spalart-Allmaras
  - k-ω
- conjugate heat transfer (coupling fluid/solid domains)
  - structured grids in 2D or 3D
- shock-fitting
- user-defined run-time customisation for:
  - initial conditions
  - boundary conditions
  - source terms
  - grid motion
- block-marching mode

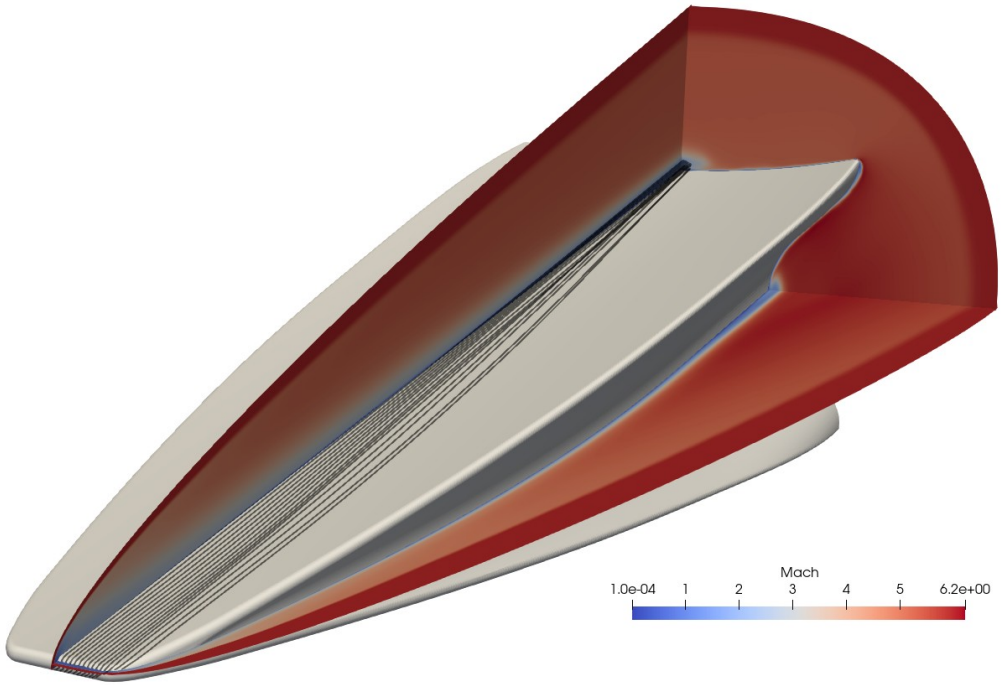


BoLT-II project: CHT RANS and DNS

*Algorithm enhancements in **Eilmer** for transient heating of BoLT-II flight vehicle:*

1) Improvements to **fluid domain** Newton-Krylov accelerator
   - Adaptive ILU preconditioner
   - Improved robustness via under-relaxation informed by a physicality check

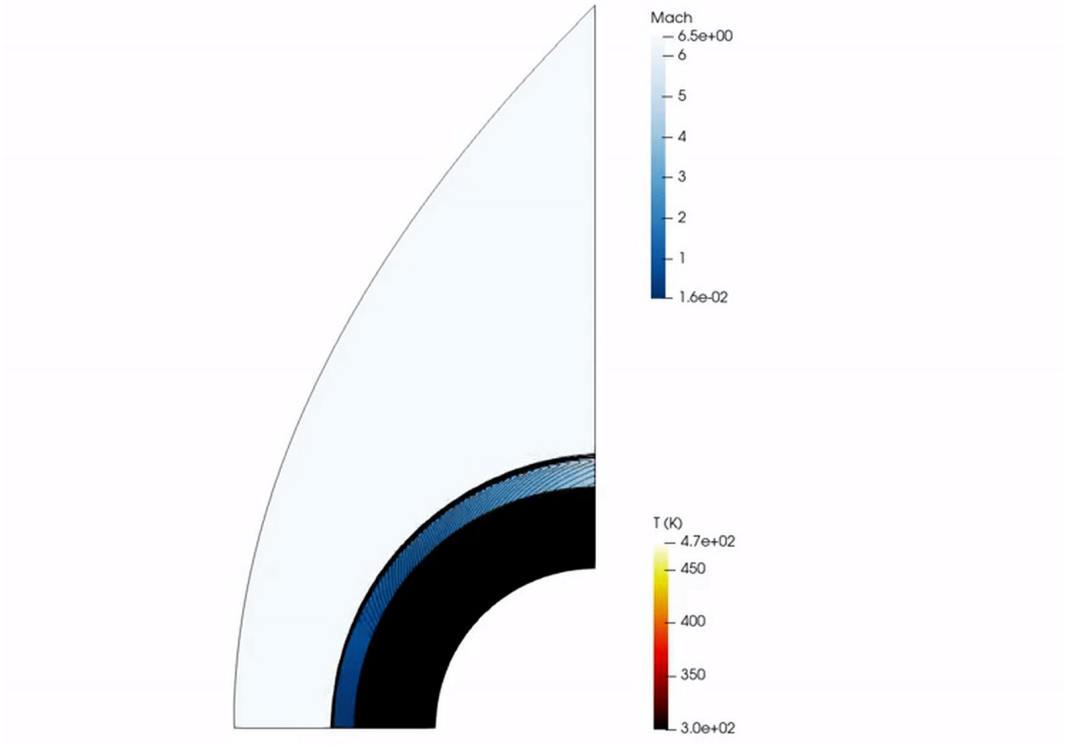
2) Improved speed of calculation for **solid domain** updates via super-time-stepping implementation

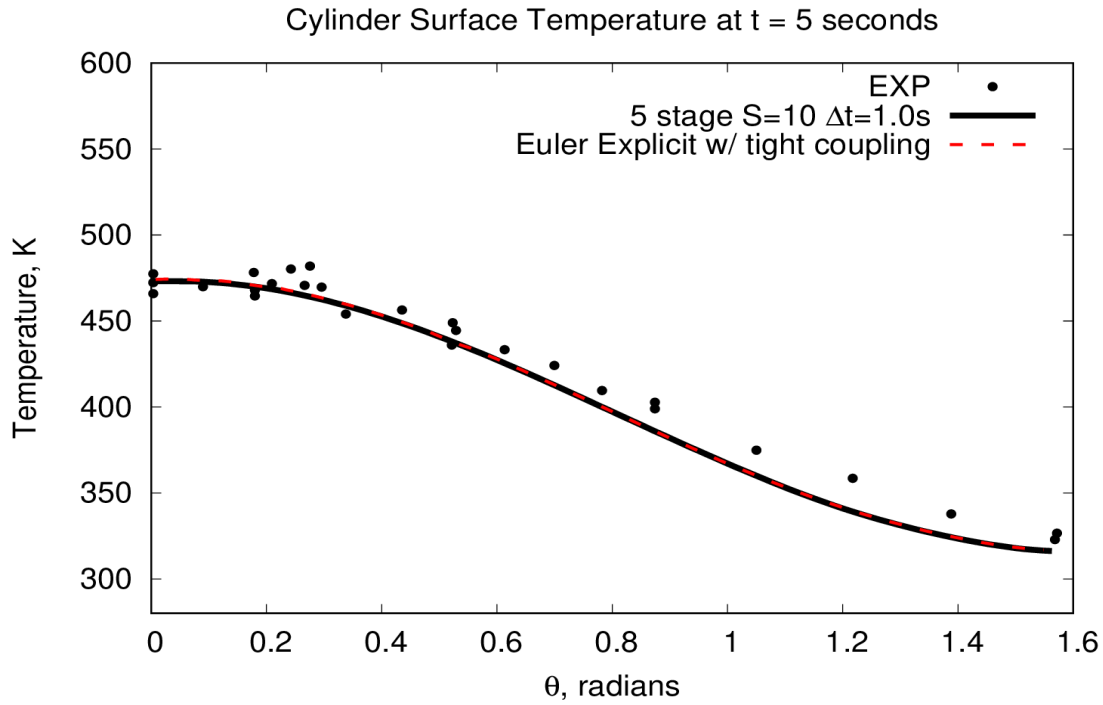


Conjugate heat transfer: validation

Test case:

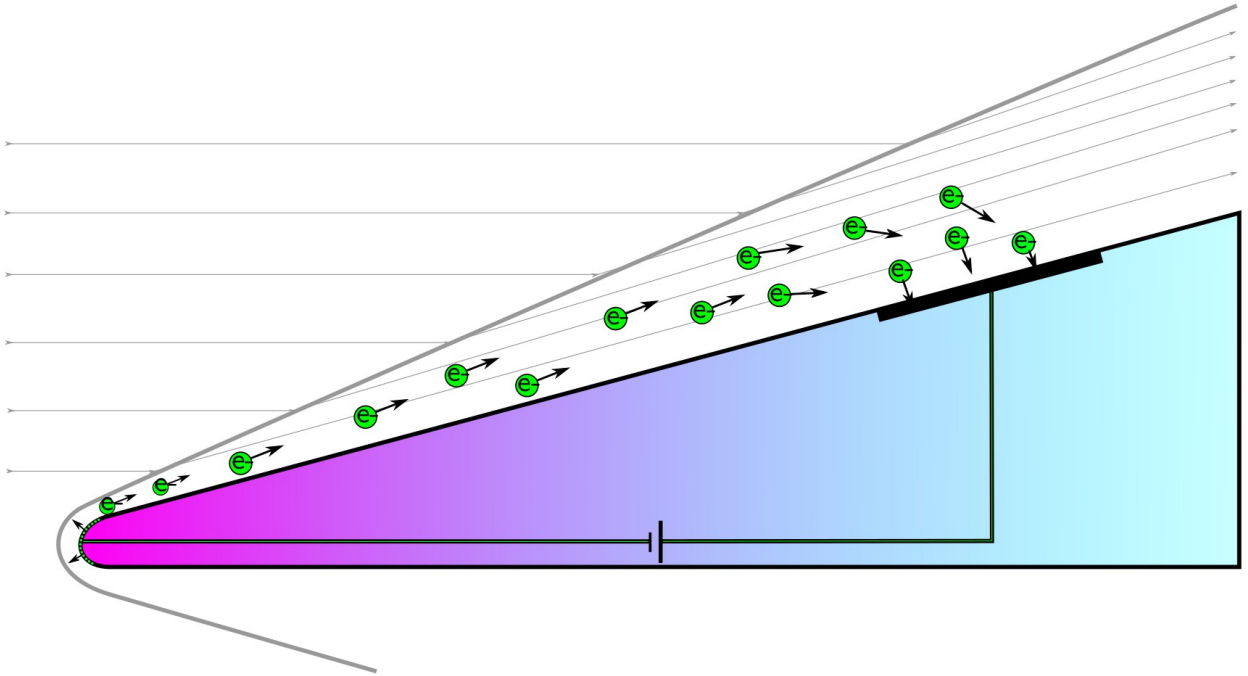
- **Mach 6.5** air flowing over a **hollow cylinder**

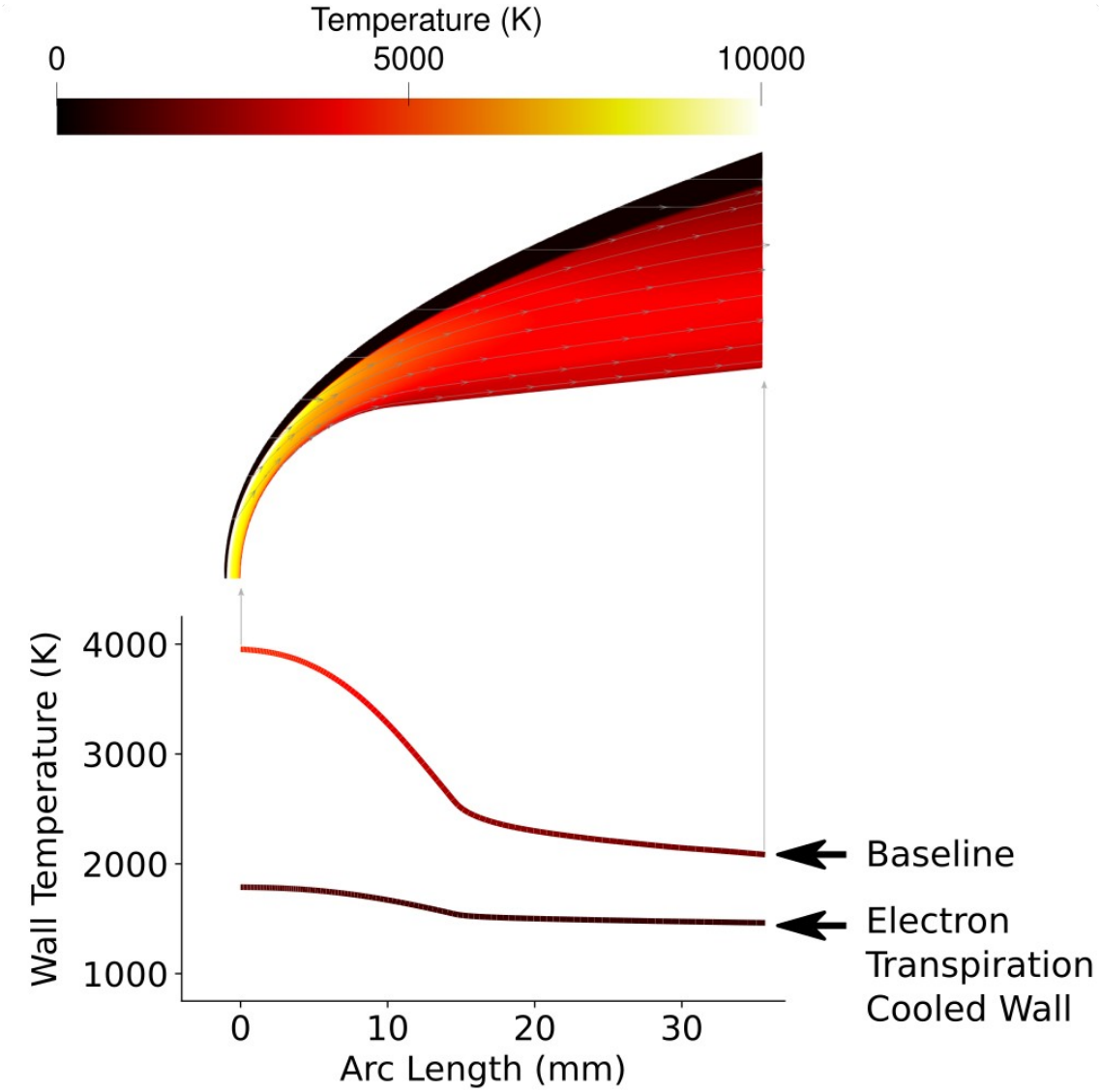




Method	Wall-clock (s)	Speed-up
Euler	917	1
STS (S=3)	223	4.1
STS (S=5)	125	7.3
STS (S=10)	41	22.3
STS (S=100)	4	229.2

Simulation of electron transpiration cooling





Gibbons et al. (2021) ASCEND Paper
Flight Regime Limits of a Hypersonic Vehicle using Electron Transpiration Cooling

ETC: will my vehicle melt?