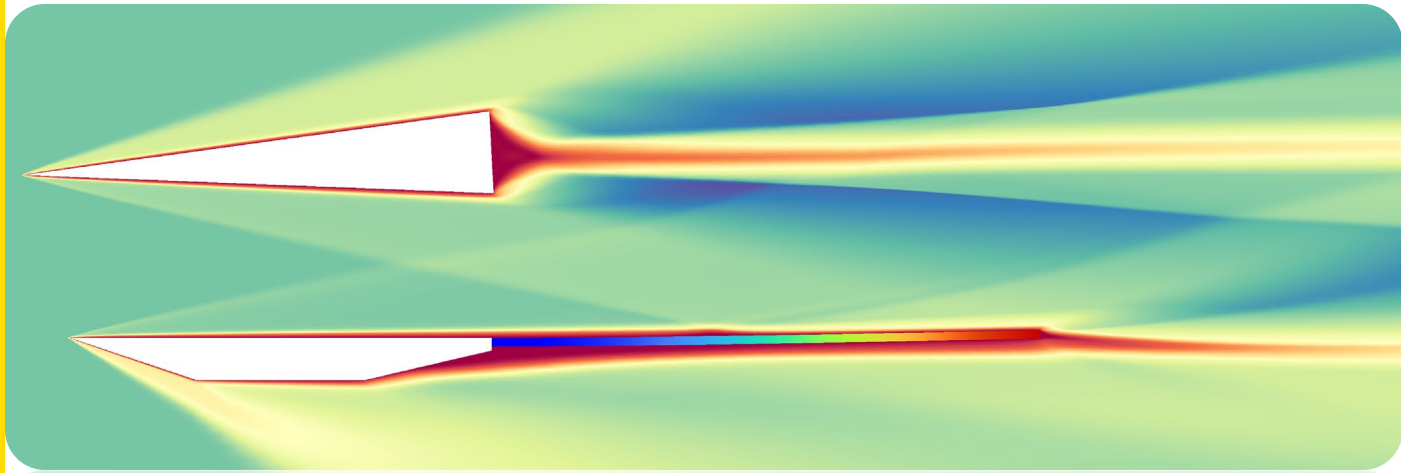
Hypersonic Multibody Aeroelastic eXperiment:

HyMAX update + UNSW

UNSW CANBERRA



Outline

- Export permits
- Simulation updates
- Experimental work
- Future plans

UNSW CANBERRA

Export permits

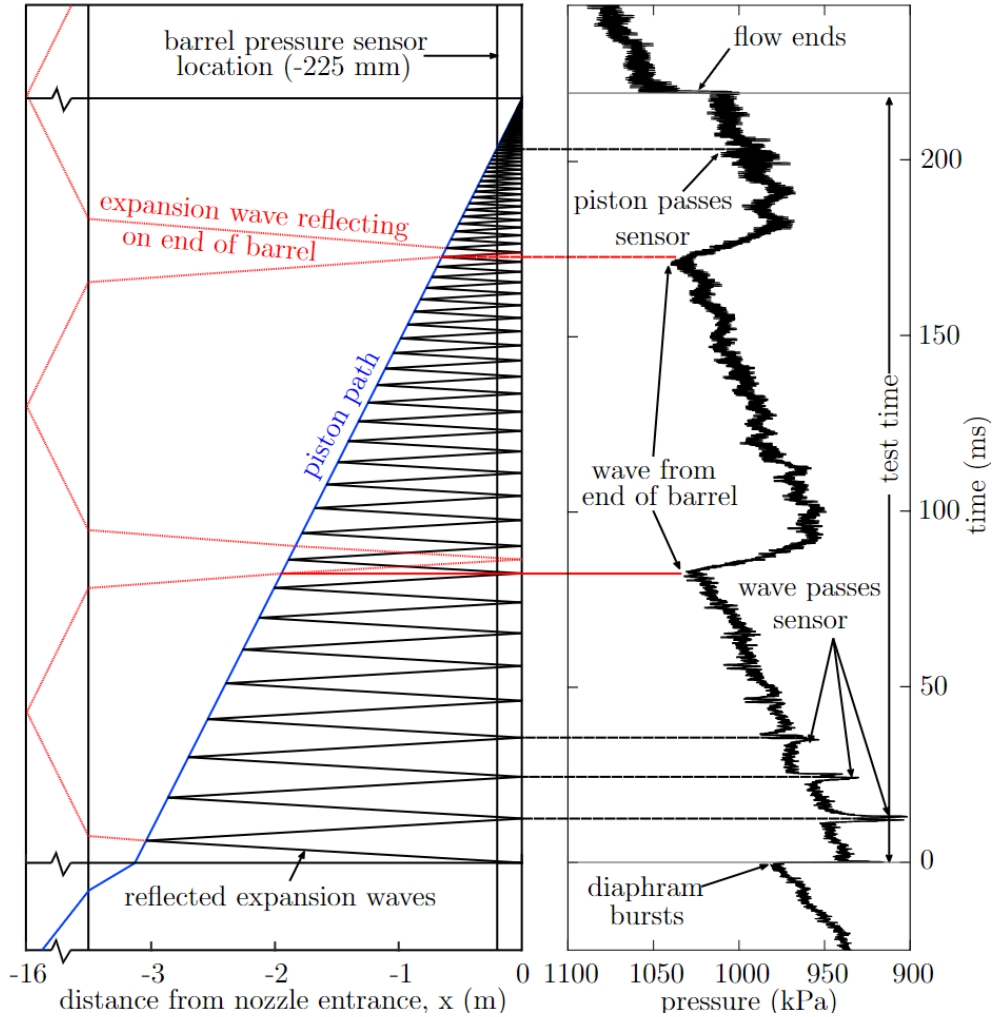
- Krishna has been working on export permits to distribute data timeseries
- Contact k.talluru@unsw.edu.au for more details
- Process will likely change come September as AUS export control is changing under AUKUS Pillar 2. Should be easier exchange to:
  - AUKUS partners;
  - Five Eyes partners;
  - Those on an approved Foreign Country List (FCL); or
  - Is clearly free exchange of clearly fundamental research.

Simulation updates

- Started preliminary, heated, coupled simulations of HyMAX to explore experimental value – IFASD2024
- Immediate takeaways:
  - Detailed cold simulation needed, comparing apples to giraffes at this point
  - Deeper causal analysis
  - Identified inlet boundary condition of primary importance
    - TUSQ impulse dominated
    - Time-varying inlet flow structures including initial impulse necessary

Simulation updates

- Current plan for inlet structures:
  1. 2D unsteady simulation of tunnel. Gather field quantities at nozzle.
  2. ‘3D’ axisymmetric wedge, unsteady scale-resolved of tunnel. Gather field quantities at nozzle.
- Have barrel pressure trace to compare against.
- Likely only after diaphragm rupture
  - Piston traversal does impact pressure trace so dynamic wall needed
- Need to discus with UniSQ

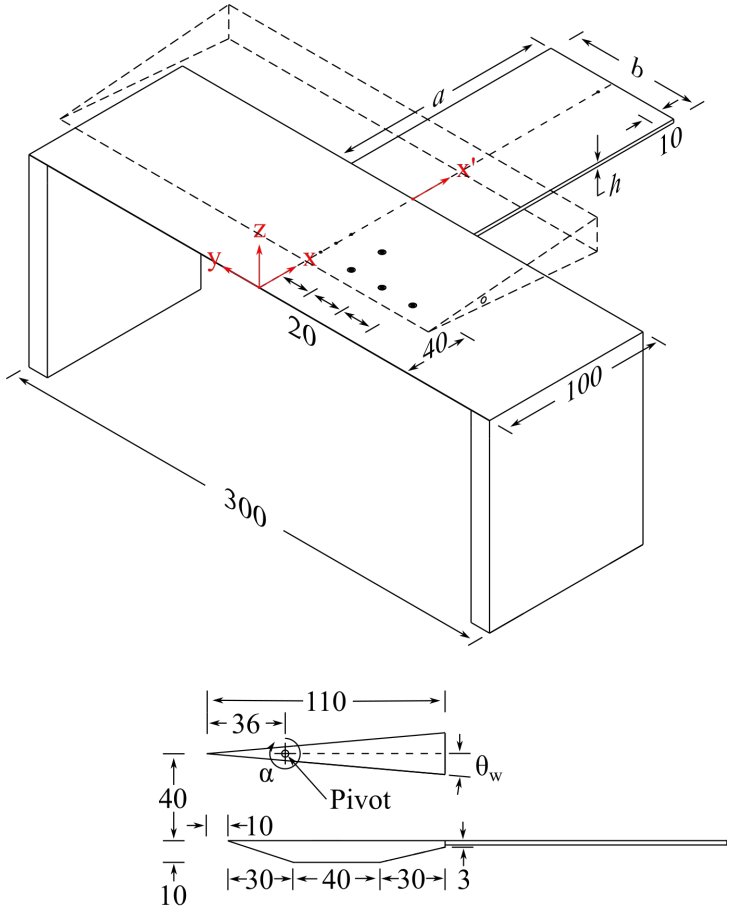


Tuten, Z. (2024), ‘*Design and Implementation of a Radiatively Pre-heated Fluid Thermal Structural Interaction Experiment*,’ PhD Thesis (pre-print)

UNSW CANBERRA

Simulation updates: Heated HyMAX – Laminar 2° SBLI

- ANSYS Fluent Intrinsic two-way FSI
  - 2D laminar fluid model
  - 2.5D projection for FEM-based structural
- Initial steady, rigid fluid solution before unsteady, compliant FSI solution
- Hot structure defined both isothermal wall-temp (fluid side), and material property (structural side)
  - RT and 350°C

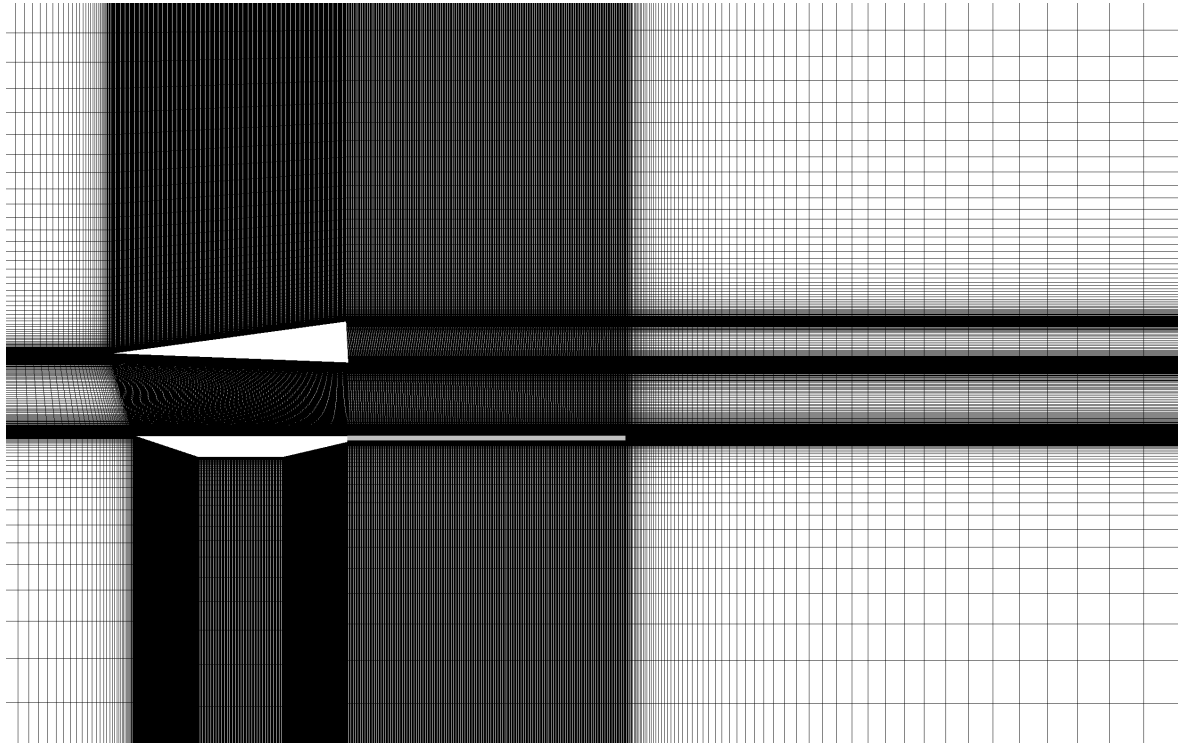


Talluru MK, McQuellin LP, Neely AJ (2023) Oscillating shock wave boundary layer interactions on a cantilever plate, AIAA-2023-3094.

UNSW CANBERRA

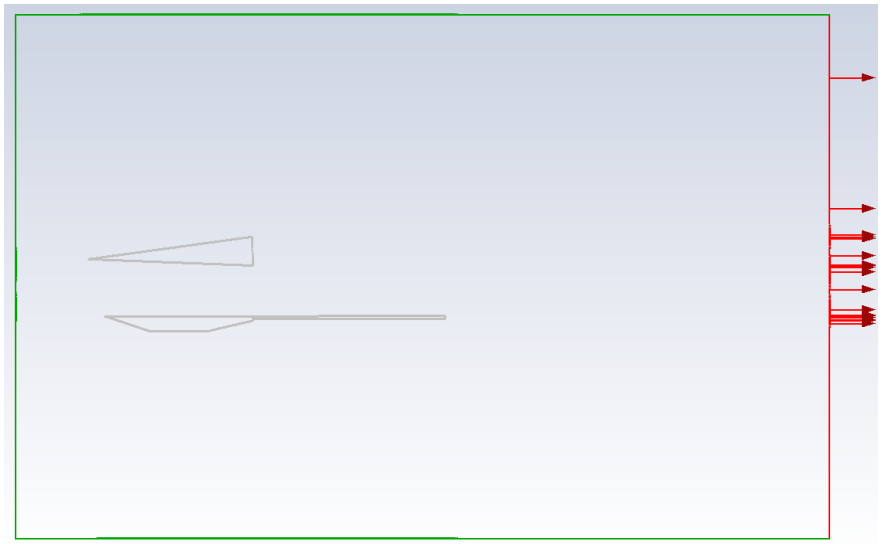
Simulation updates: Heated HyMAX – Laminar 2° SBLI

- Mesh details:
  - Structured grid, no radii, freestream aligned
  - Conformal meshes
  - 15,750 solid cells*, 431,275 fluid cells
    - Total cells: 447,025
    - Orthogonality: 0.995 ± 0.011 (1σ)
    - Skewness: 0.035 ± 0.054 (1σ)
    - AR: 23.55 ± 94.11 (1σ)
    - 1st cell height: 10 μm



Simulation updates: Heated HyMAX – Laminar 2° SBLI

- Fluid details:
  - Pressure farfield (inlet), pressure outlets (outlets), no-slip walls (all walls)
  - Density-based (ideal gas, kinetic theory viscosity)
  - Laminar model
  - Isothermal walls
  - Implicit formulation, AUSM flux-type
  - GGNB spatial gradient
  - 2nd order upwind flow
  - High speed numerics (additional relaxations and looser tolerances and limits)
  - 1st order implicit transient formulation

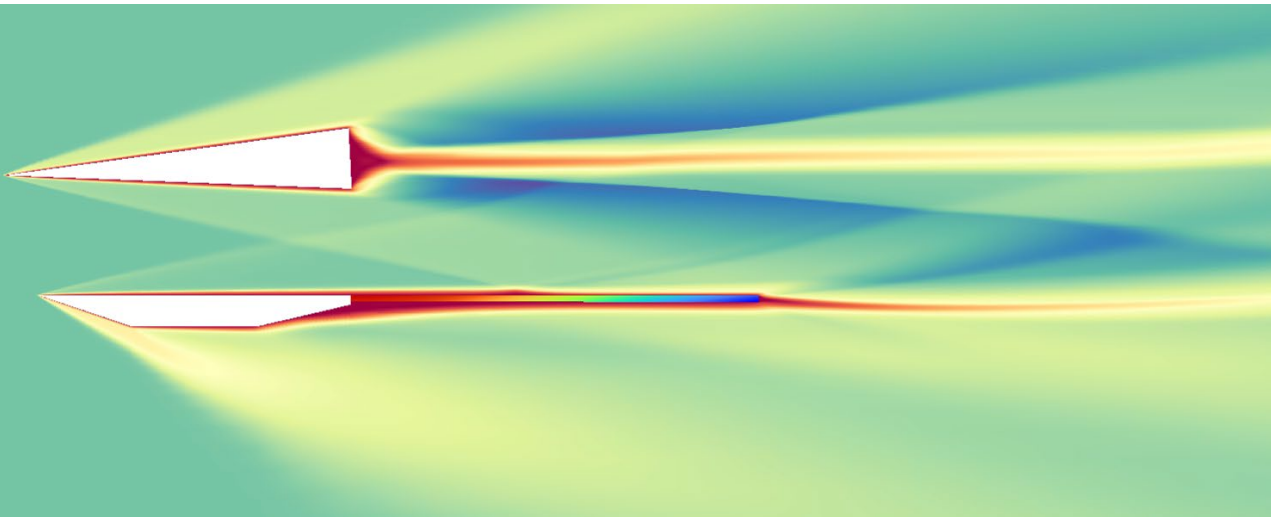


Reference Values	
Area [m^2]	0.0104
Density [kg/m^3]	0.0350703
Depth [m]	0.08
Enthalpy [J/kg]	582069.3
Length [m]	0.13
Pressure [Pa]	755
Temperature [K]	75
Velocity [m/s]	1006.566
Viscosity [kg/(m s)]	5.557898e-06
Ratio of Specific Heats	1.4
Yplus for Heat Tran. Coef.	300

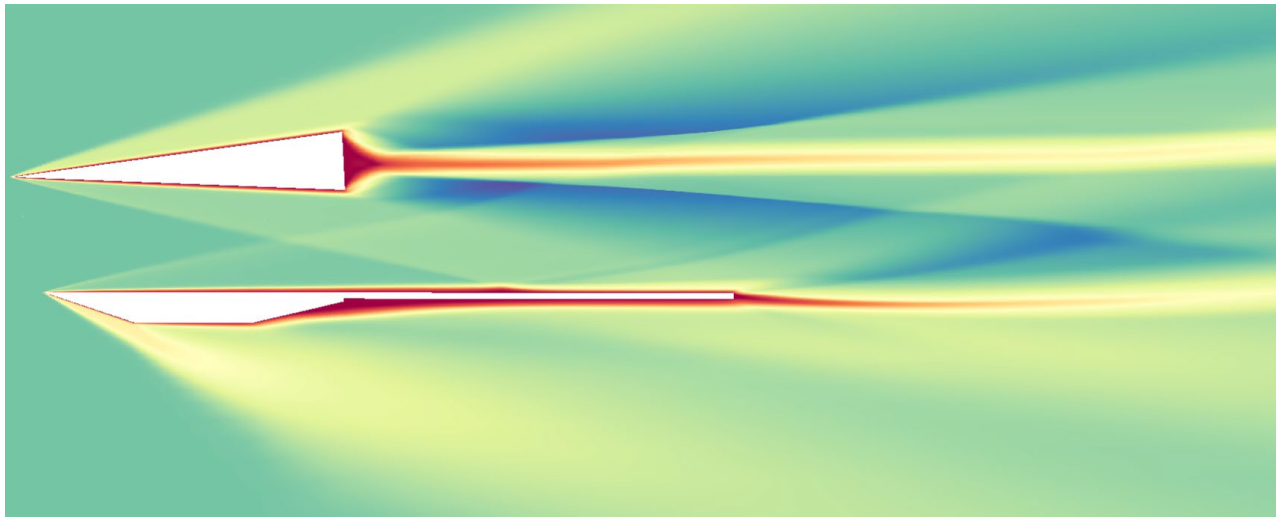
Simulation updates: Heated HyMAX – Laminar 2° SBLI

- Structure details:
  - Nonlinear elasticity (elastic updating large deflection model)
  - Thermal effects enabled
  - $\Delta T = 0$ (i.e., no thermal expansion)
  - Newmark transient formulation
- Coupling details:
  - Started from steady-state fluid solution
  - Diffusion-based smoothing (hot)*, RBF-based (cold)* for mesh motion
  - Pressure loads mapped (found out after sims viscous mapping is TUI-only additional option)

Simulation updates: Heated HyMAX – Laminar 2° SBLI



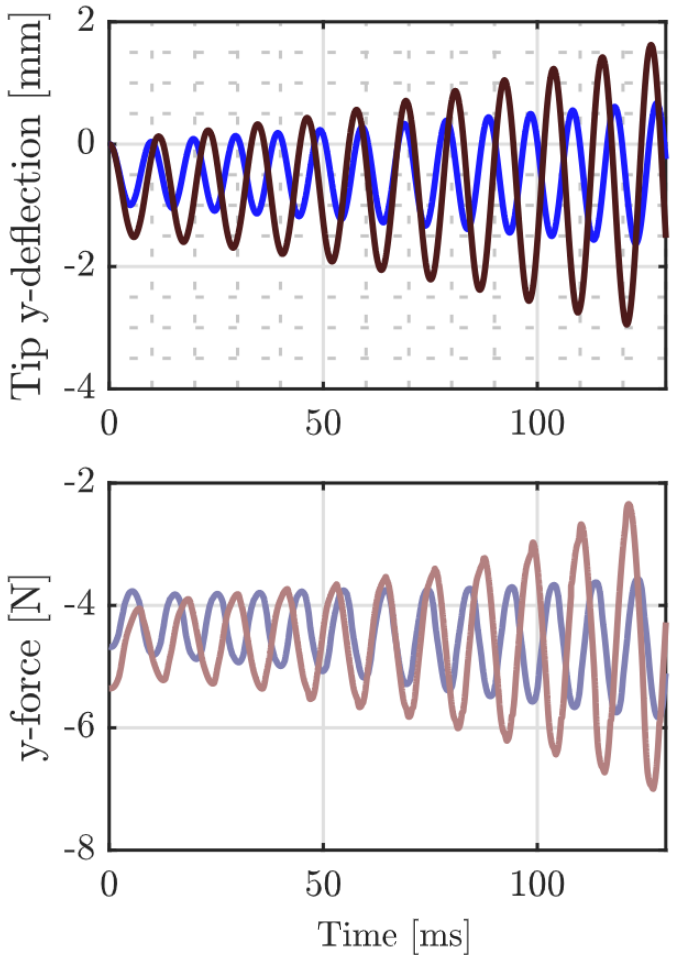
Mach contour animation, cold panel (looped, cropped)



Mach contour animation, hot panel (looped, cropped)

Simulation updates: Heated HyMAX – Laminar 2° SBLI

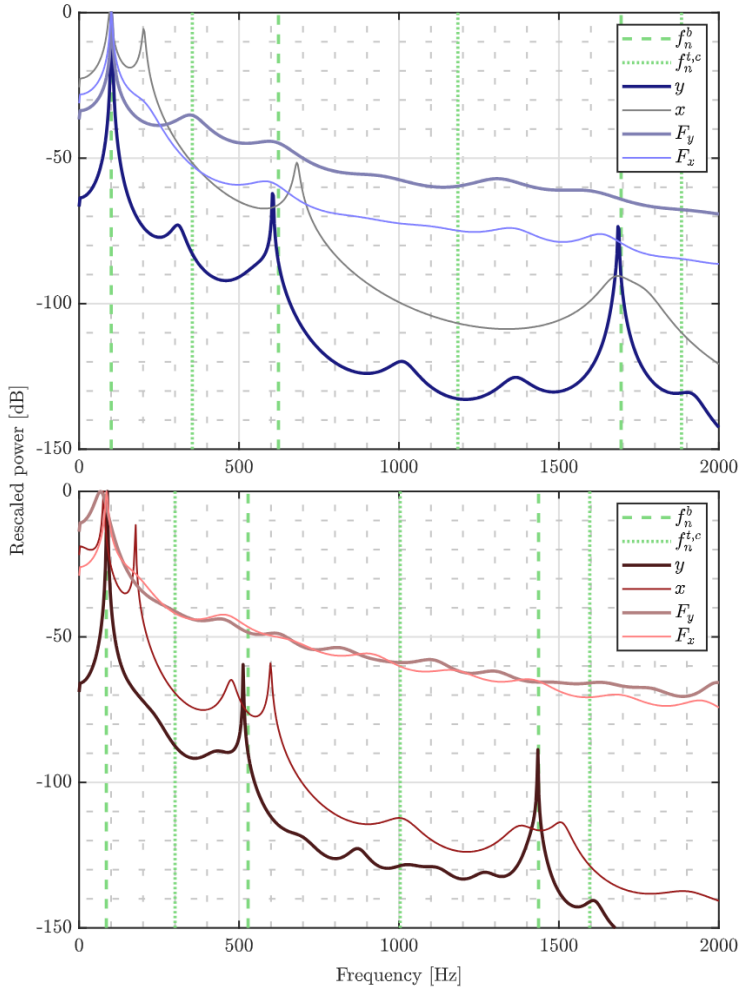
- 130 ms simulated
  - Similar to usable TUSQ flow time
  - Original simulation attempts inefficient and slow
- Both hot and cold structures show successive amplitude growth
  - Timeframe too short to determine stability
- Hot structure has greater DC bias, larger amplitudes, and is lower frequency
  - Higher loads also present
- Both hot and cold deflection generally seem quite sinusoidal (single-mode)
  - Force something starting to go on



UNSW CANBERRA

Simulation updates: Heated HyMAX – Laminar 2° SBLI

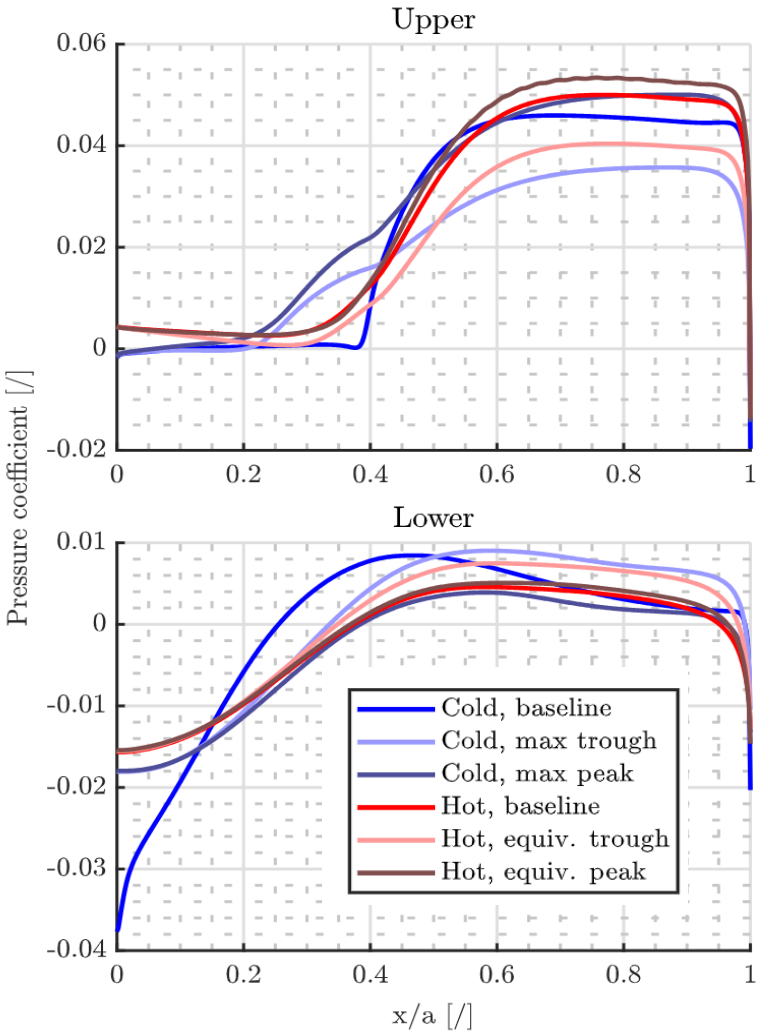
- Spectral content considered from AR-PSD
- Response **strongly** dominated by first-bending
  - Hot has slightly reduced higher mode participation
- Fluid loads reflect structural response
- Deeper relationship and causal study needed then just this



UNSW CANBERRA

Simulation updates: Heated HyMAX – Laminar 2° SBLI

- Pressure coefficient distributions considered
- Initial (from steady fluid), along with cold extrema and similar amplitude hot peak and trough assessed
- Hot wall moves pressure centre downstream (towards panel trailing)
  - Explains increase of first-mode dominance

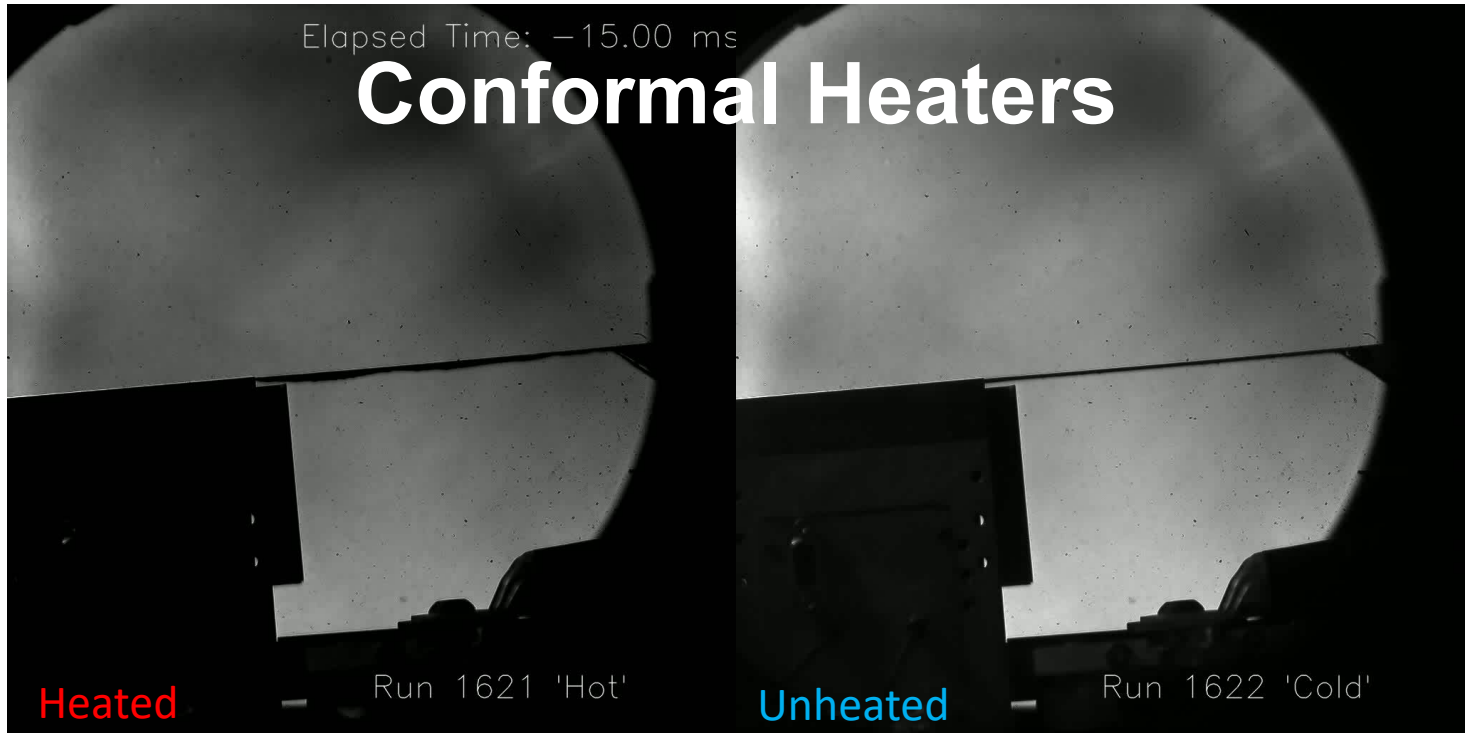


Experimental work

- No new experimental work on HyMAX case, but…
- Growing library of heated work:
  - Free-expansion heated CFCF
    - Radiative heating in TUSQ (Zach Tuten, PhD coming very soon!) completed
    - Conformal heating in TUSQ (Capt. Damon Kirkpatrick (USAF)) underway
    - Convective heating in M6-HRF (in planning for HyMAX and CFCF)
- What would make HyMAX more enticing if it were to be re-run?
  - What quantities would people like to see?
    - Onboard: Hard to change
    - Offboard: PSP, DIC, laser line-scanner, high-speed thermography, laser point-displacements
  - Any changes to explored physics, barring heat?
    - Softer material to drive large deflections

Future work

- Heated HyMAX a possibility:
  - Additively heated by radiative/conformal heater
  - Aerothermal heating
  - Challenges: limited time, manpower and funding
- Heated CFCF with SBLI
  - Run by Capt. Damon Kirkpatrick (USAF), contributing to PhD
  - Free-expansion avoiding pre-stress
  - Restricted-expansion to explore thermal buckling
  - Mechanical buckling without heat
  - Non-buckled, deformed profiles



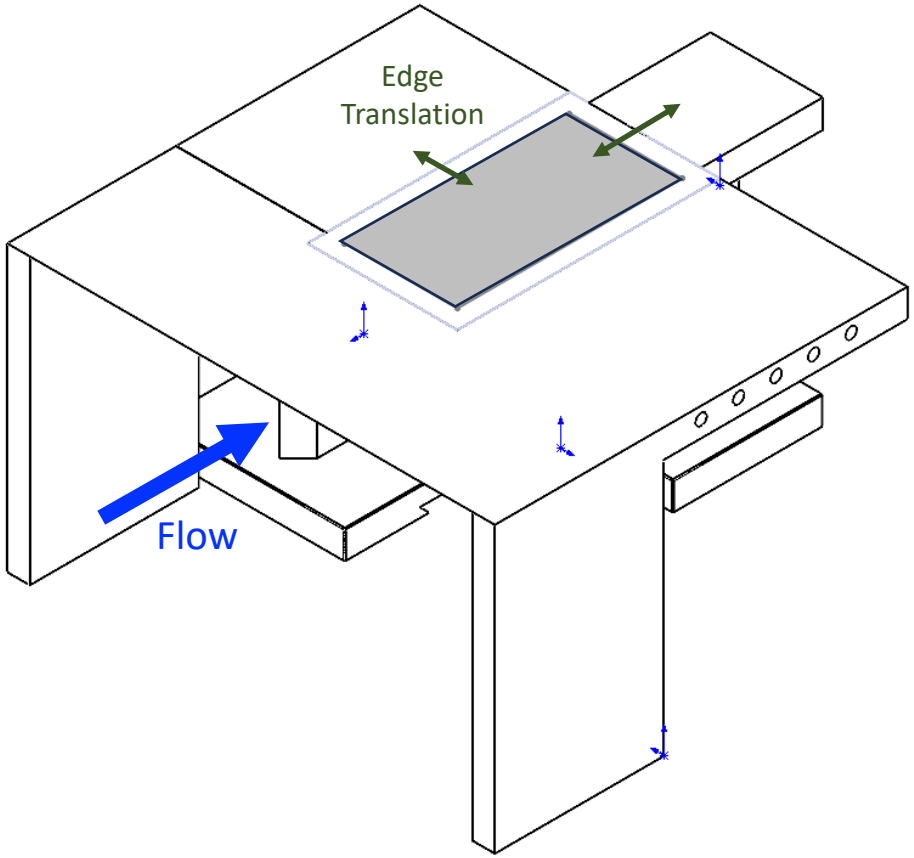
Kirkpatrick, D. (2024)

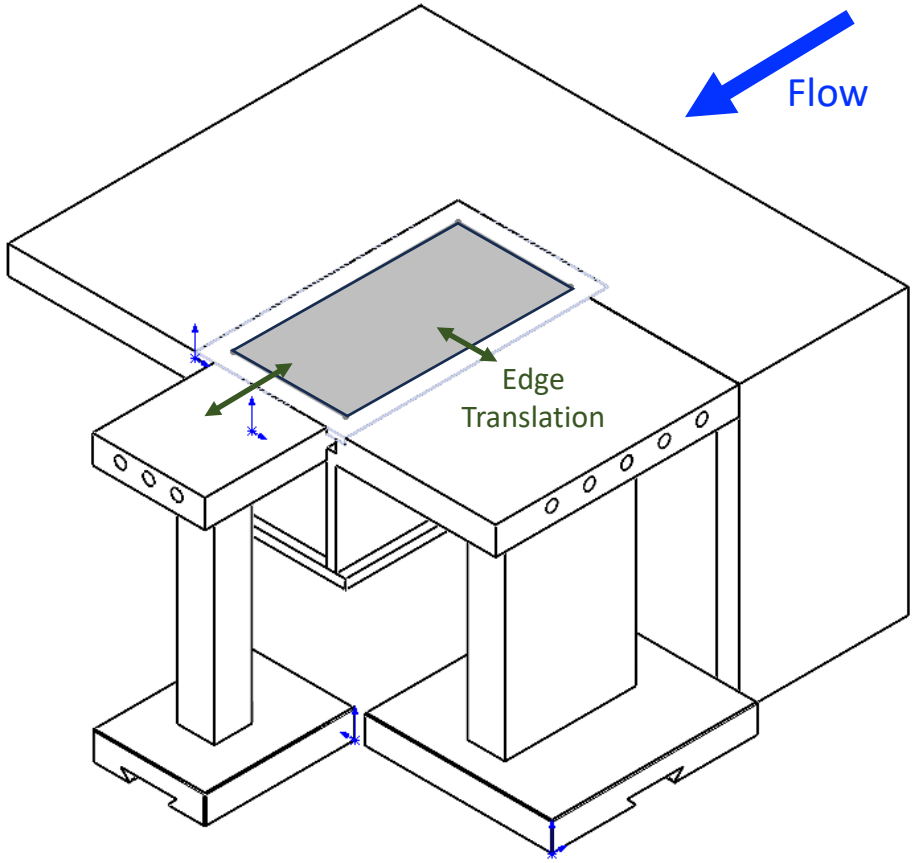
UNSW CANBERRA

Future work

- Simulations planned:
  - Hot HyMAX 10° (SciTech) and dynamic generator
  - Hot CFCF at 5° (AFMC) – short page limit problematic, but decoupled physics looked at
  - Cold comparisons needed
  - TUSQ facility simulation for inlet flow structures
  - Reassessment of HyMAX with these inlet flow structures

Future work – CCCC, variable boundary (AFOSR)

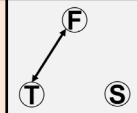
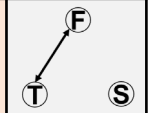
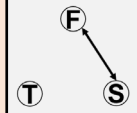
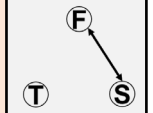
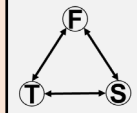
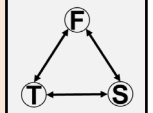
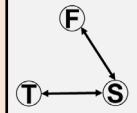
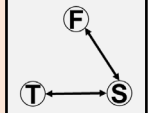
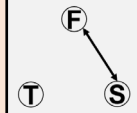
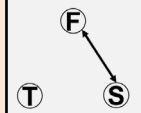
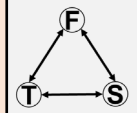
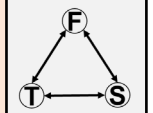
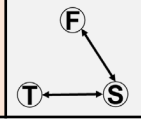
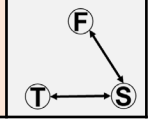




UNSW CANBERRA

Future work – CCCC, variable boundary (AFOSR)

Neely, Hoke, Dooner, Talluru, Kleine, Wild, McQuellin, Buttsworth / *Hypersonic FTSI Unit Case for a Thermally-Buckled Structural Panel* / **AFOSR FA2386-23-1-4083** PM: (Garrison Lindholm AOARD)

Unbuckled	Unstressed	Rigid	Unheated		**Buckled**	Unstressed	Rigid (machined)	Unheated	
			Heated					Heated	
		Compliant	Unheated				Compliant (machined)	Unheated	
			Heated					Heated	
			Pseudo-heated					Pseudo-heated	
	Stressed (tensile)	Compliant	Unheated			Stressed (compression)	Compliant	Unheated (mechanical)	
			Heated					Heated	
			Pseudo-heated					Pseudo-heated	

Pseudo-heated: Usage of softer material to emulate stiffness turn-down

F: Fluid
T: Thermal
S: Structure

UNSW CANBERRA