Combustor-Turbine Interactions by Using the Open National Combustion Code (OpenNCC) and the Glenn-HT Code

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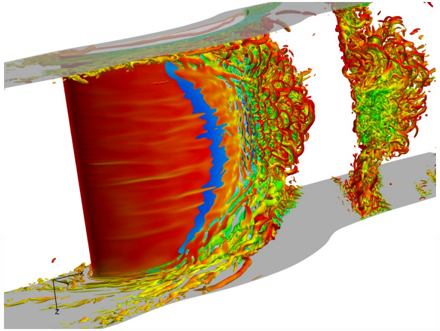
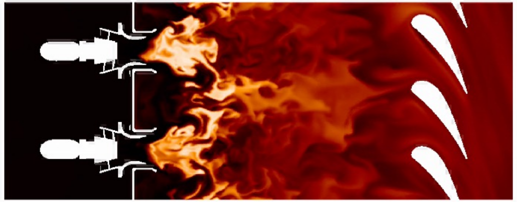
Motivation

- Designing high-pressure turbines (HPTs) for *peak* temperatures at the combustor exit ➔ More cooling air ➔Less cycle efficiency
- Designing HPTs for the *mean* exit-temperature at the combustor exit ➔ More local hot spots (hot streaks) ➔ Less gas turbine durability
- Component interactions (such as combustor-turbine) more important in compact high-OPR future engines
- Advance CFD tools to enable coupled analysis and provide design guidelines

Can we study combustor-turbine interactions while coupling two CFD codes and simulating "**unsteady**" flow fields?

OpenNCC and Glenn HT

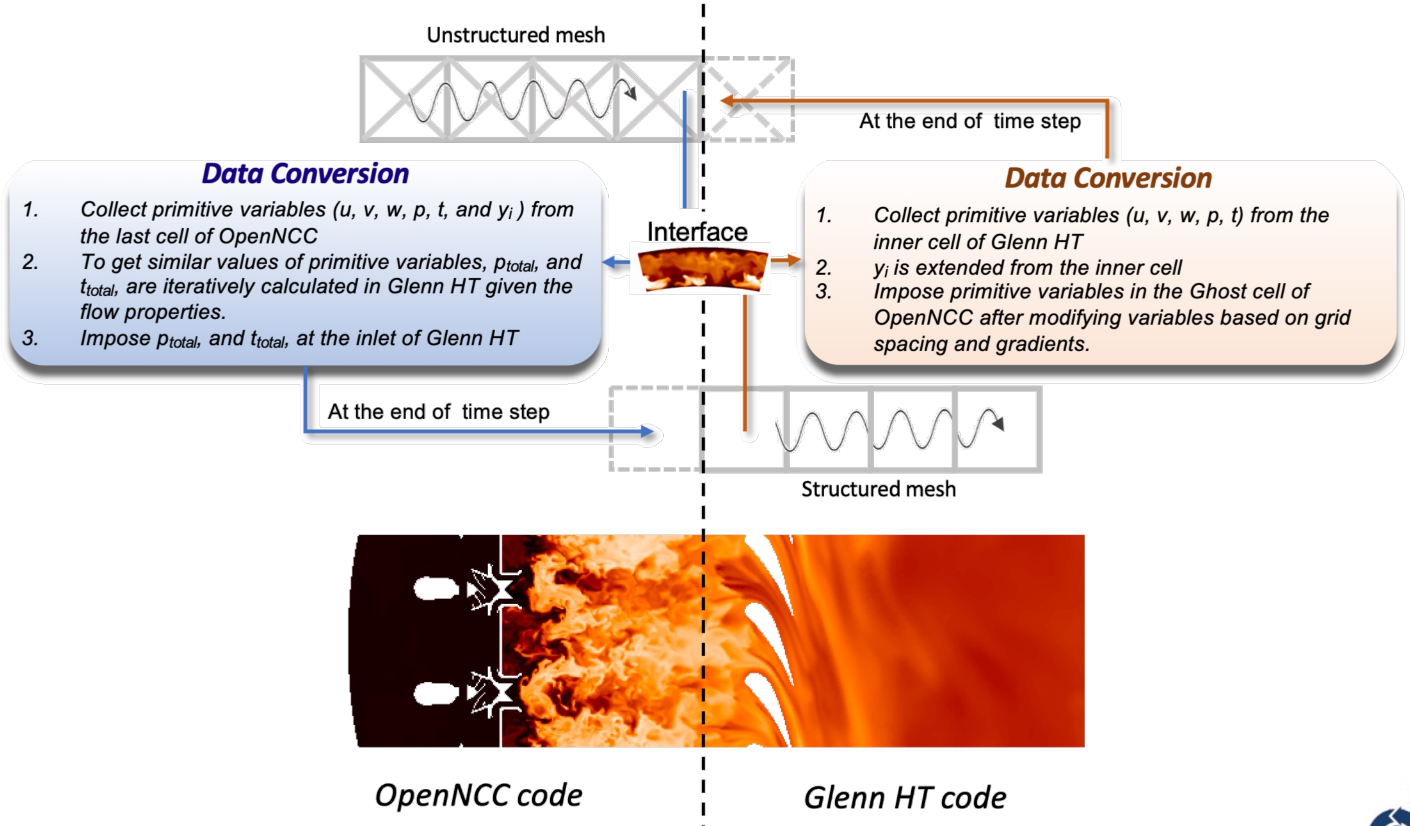




	Features	Applications
Glenn HT	Multi-block, structured, (U)RANS/LES (lots of turbulence model), flow-solid interactions, Implicit N-S solver	Turbine/compressor efficiency, Turbine cooling (conjugate heat transfer), heat exchanger performance, etc.
OpenNCC	(Un)structured, (U)RANS (2-eq. k- ε model)/LES, exp/Implicit N-S solver, spray (Lagrangian), chemical reaction	Gas/spray-fueled Combustor and preliminary turbine analysis with moving mesh, etc.

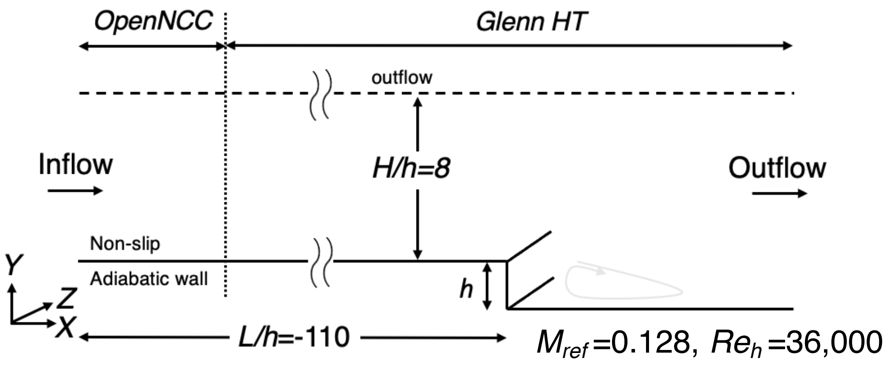
At NASA, we have been developing two in-house codes, OpenNCC and Glenn-HT, for more than two decades for many combustor/turbine applications.

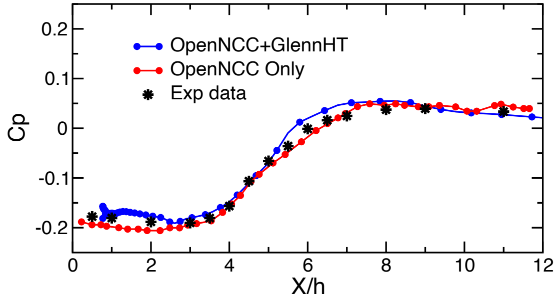
Code Coupling Methodology



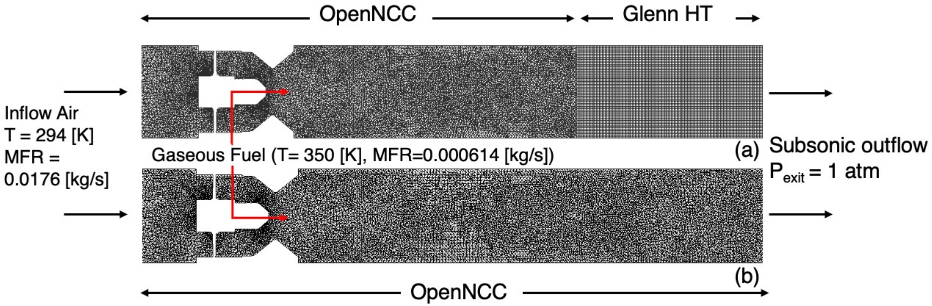
V & V of Code Coupling Methodology

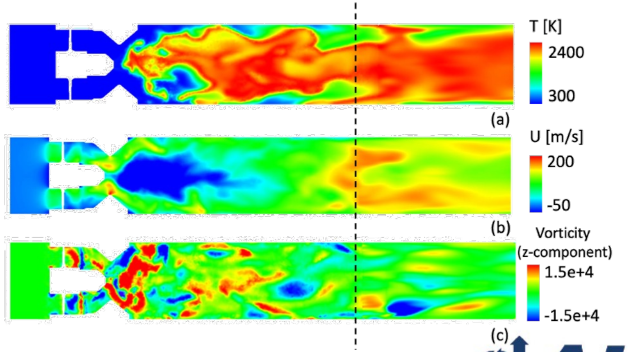
Non-reacting Flow Case (3D Backward Facing Step)



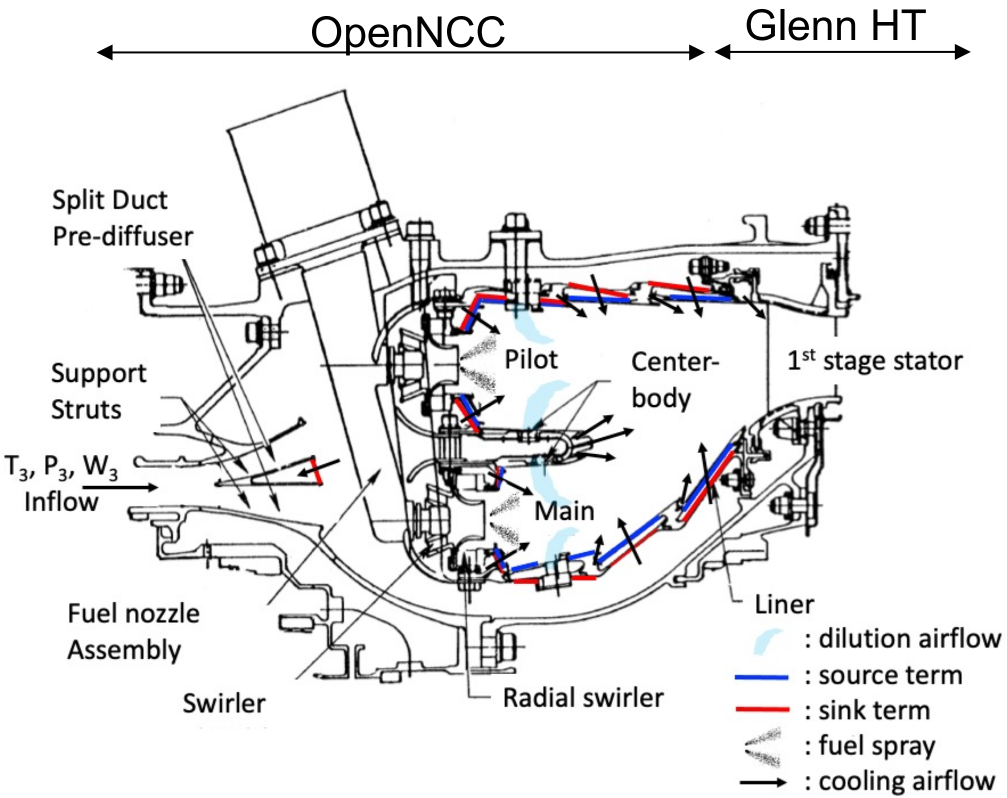


Reacting Flow Case (Lean-Direct Injection (LDI) Combustor)





Energy Efficient Engine – GE design, 80s



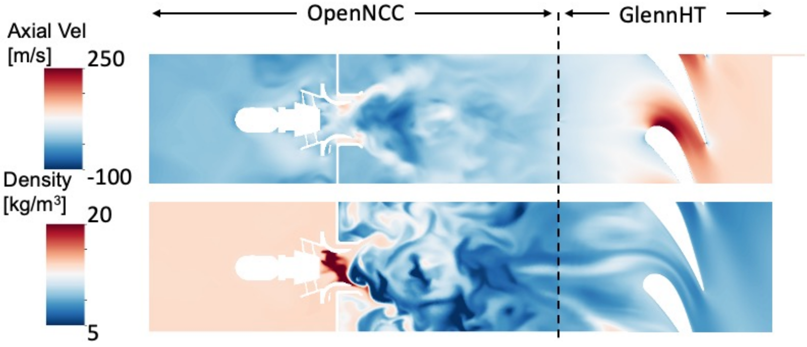
Combustor: OpenNCC

- Liquid droplets ($C_{11}H_{21}$) are injected from the main and pilot domes
- Finite-rate chemistry (2step-mechanism) for Jet-A/Air
- k-equation turbulent model
- AUSM

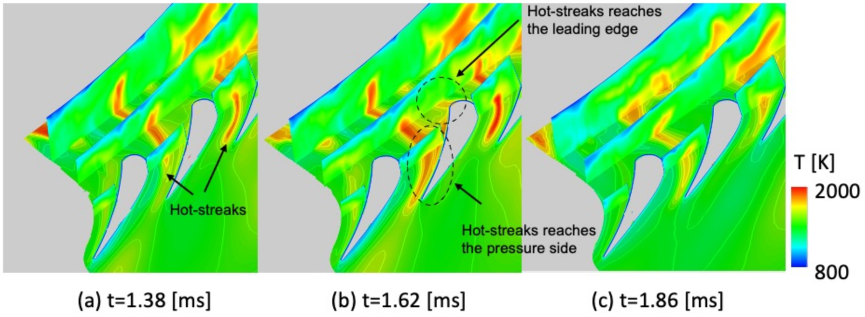
HPT: Glenn-HT

- Non-reacting flow (hot air)
- k-equation turbulent model
- AUSM

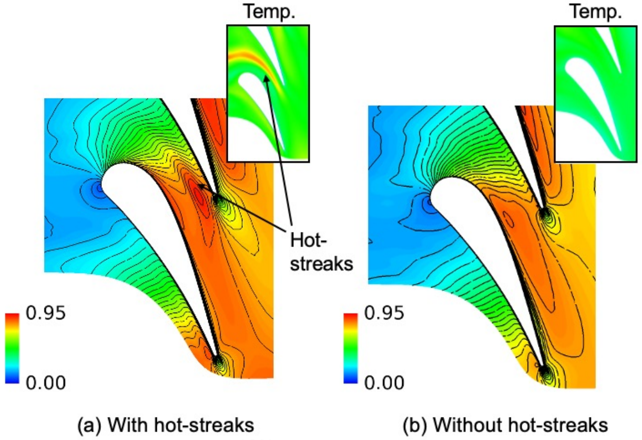
Key Results



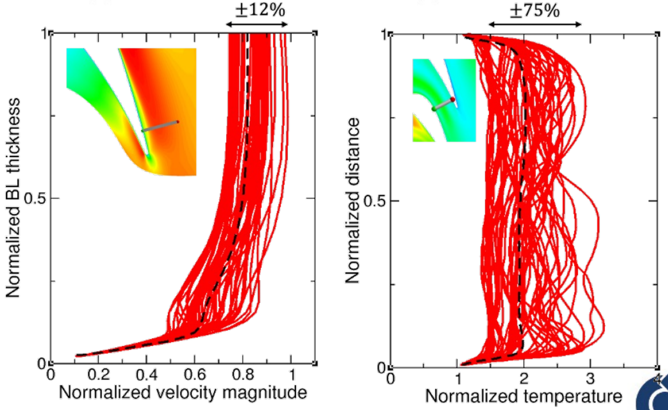
Instantaneous flow fields



Hot streak migration



"Jet" induced by hot streaks



Variations of flow fields at the passage

Conclusion

- In this study, we propose the coupling methodology of using two different CFD code and validated it against two non-reacting/reacting unsteady test cases.
- The methodology is applied to model the Energy Efficient Engine and to investigate the combustor-turbine interaction in terms of hot-streaks.
- Fully-coupled simulation using two CFD codes successfully capture unsteady flow fields and hot-steak migrations.

Thank you!

Questions?

Acknowledgement

- **Supported by NASA's Transformational Tools and Technologies project**
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- **Flow Viz was conducted with Visit (Lawrence Livermore National Labs)**

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