HIGH FREQUENCY TRANSVERSE COMBUSTION INSTABILITIES IN LOW-NOX GAS TURBINES

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Motivation

- Advances in high-temperature materials and cooling imply a push towards 65% or higher CC efficiency with low emissions → Combustion Instabilities are a challenge at this operating point
- <u>Target architecture</u> → Multi-nozzle can combustor configuration with interacting flames
  - Transverse modes are inherently high frequency and flames are no longer acoustically compact
  - Extensive research and literature to address longitudinal mode instabilities with acoustically compact flames
  - Motivates need for research into can combustor transverse modes with multiple interacting acoustically non-compact flames
- <u>Focus of the proposed project</u> → **High-frequency transverse combustion instabilities in multi-nozzle can combustor configurations.**

Research Focus

- Understand the different coupling mechanisms of high-frequency transverse instabilities in gas turbines.
  - Combined use of experiments and reduced-order modeling
- <u>Key research questions</u>:

(1) How do the conventional coupling mechanisms from low-frequency translate to high-frequency?

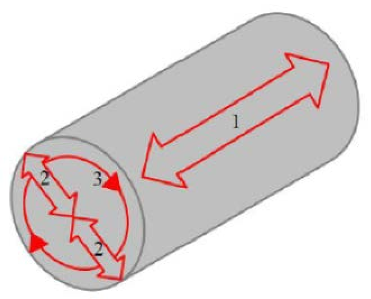
(2) How do coherent structures interact with high-frequency acoustic forcing?

(3) What are the new mechanisms that are of importance at high frequencies and what are their relative roles when compared to the conventional mechanisms?

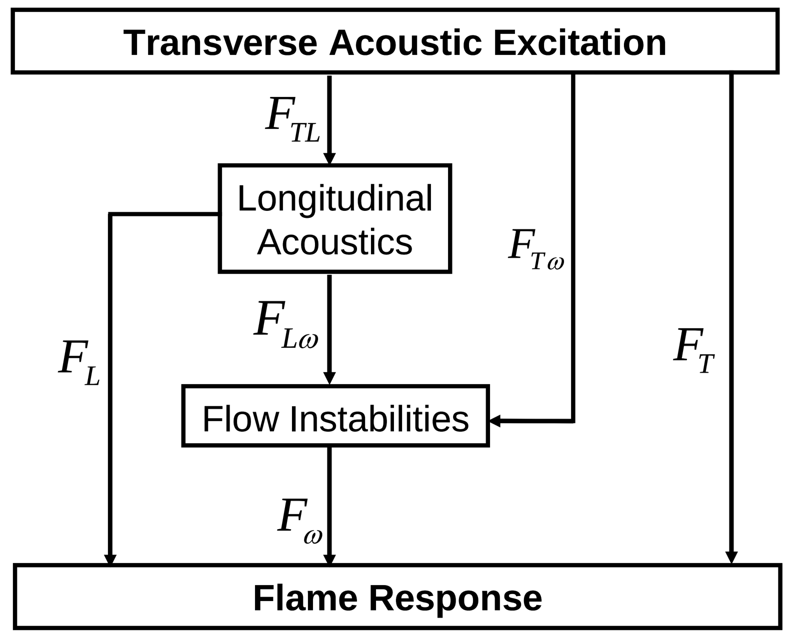
(4) How does the direct effect of pressure fluctuations influence the thermoacoustic stability of the system?

Physics

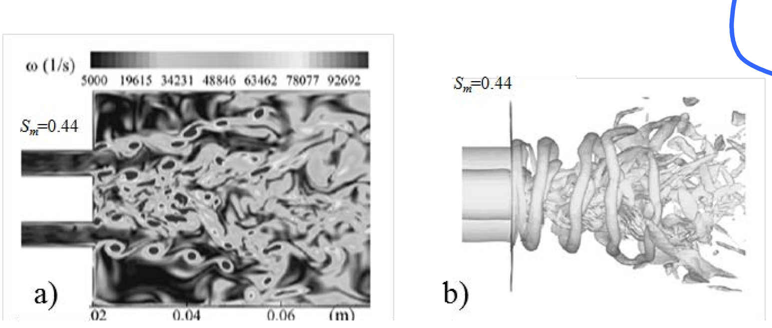
- <u>**Combustion instability**</u> → coupling between resonant combustor acoustics and heat release rate fluctuations
  - Pressure oscillations can be detrimental to hardware lifetime and emissions.
- <u>**Acoustics**</u>
  - Transverse nature of instabilities → acoustic wave motions perpendicular relative to main flow direction

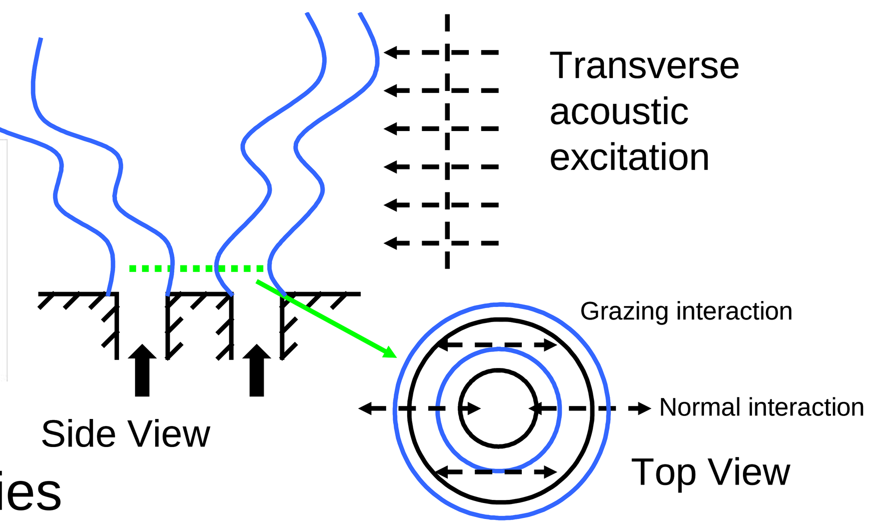


  - High-frequency → acoustic wavelength of the order of heat release zone extent

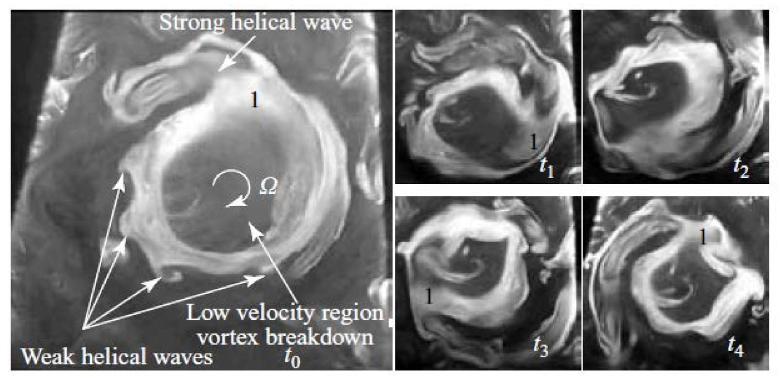


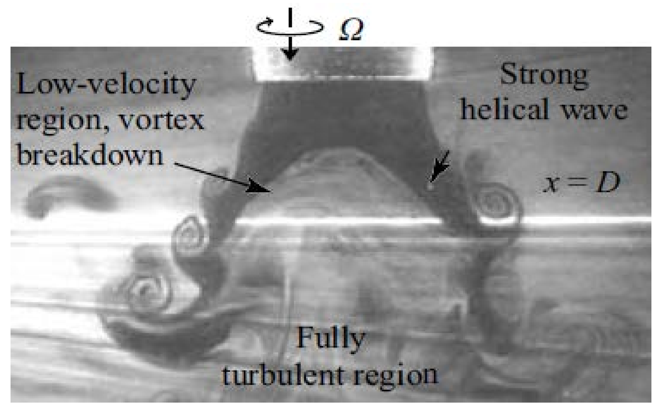
- <u>**Unsteady Flow Dynamics**</u>
  - Acoustics excites dynamical flow structures
    - Complex swirling flow features such as PVC interact with acoustics





  - Hydrodynamic instabilities
    - Inherent to swirling flows creating non-axisymmetric flow features

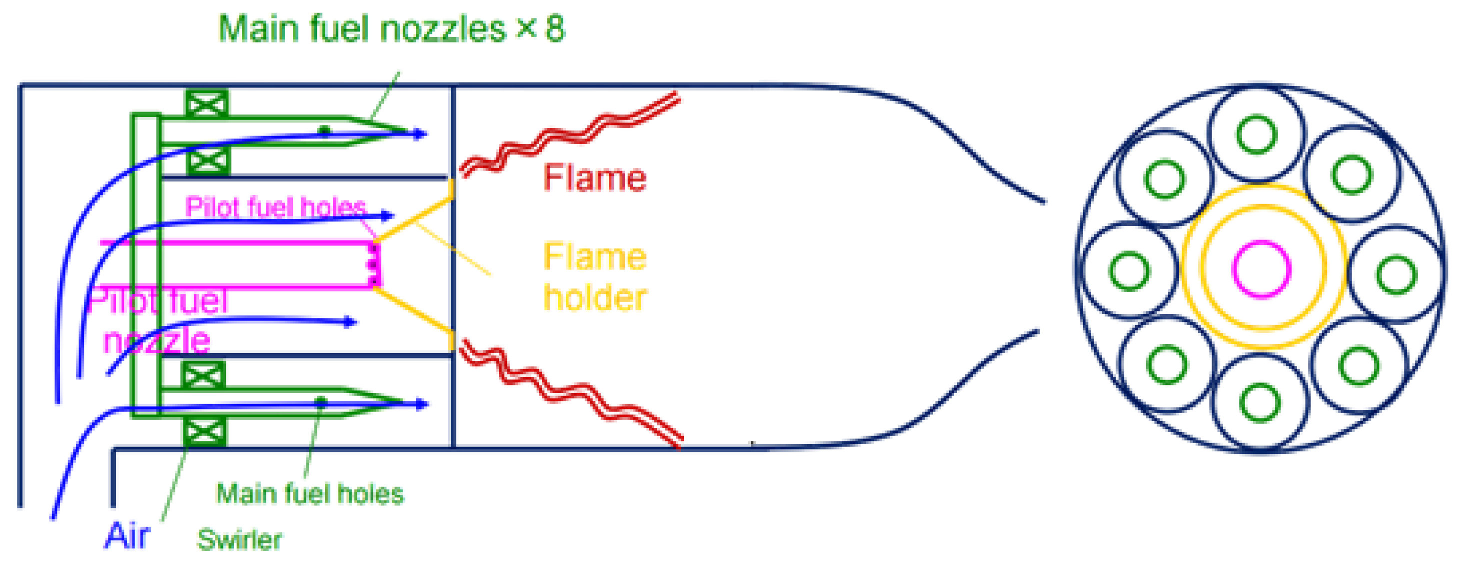




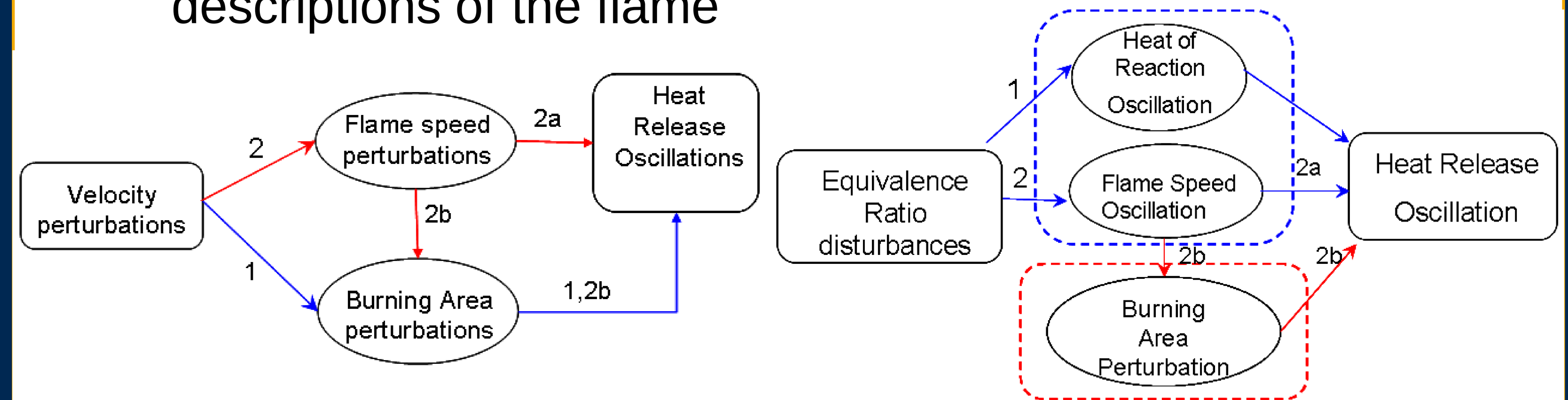
- Coupling of acoustics, flow hydrodynamics and chemical kinetics creates multiple pathways to drive heat release oscillations
  - Velocity fluctuation driven
  - Equivalence ratio fluctuation driven
  - Pressure fluctuation driven

Proposed Work

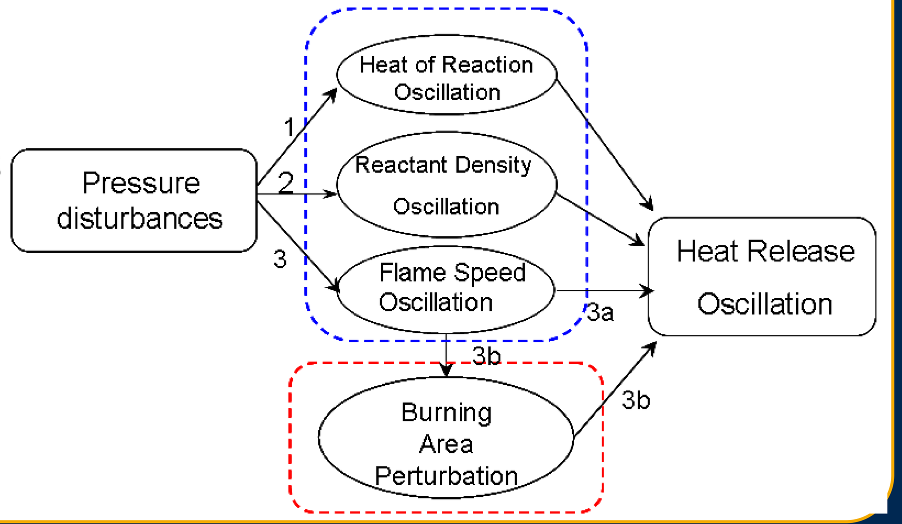
- <u>**Task: Design of Experiment for Self-Excited Transverse Instabilities (Tim Lieuwen)**</u>



  - Design a facility with realistic diameter combustor → capture accurate high-frequency transverse acoustics.
  - Multiple nozzles → capture flame–flame interactions.
  - Optical accessibility using Quartz → spatio-temporal flow and flame characterization.
  - Flexibility → multiple fuel circuits.
- <u>**Task: Reduced Order Modeling for Thermoacoustic Coupling**</u>
  - <u>Flame response (Tim Lieuwen)</u>: Using phenomenological descriptions of the flame



  - <u>Hydrodynamic stability (Tim Lieuwen)</u>: Inherent and acoustically excited flow instabilities
    - Modeled using a linearized solver that uses time-averaged measured flow information
  - <u>Kinetic coupling mechanism (Wenting Sun)</u>: Direct effect of pressure oscillations
    - Previously neglected in low-frequency studies
    - Important at high-frequencies
    - Strong function of Chemical kinetics



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