# Perspectives on R&D Needs for Gas Turbine Power Generation

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# FTT Is:

- An energy and aerospace high-technology provider – specializing in development of next-generation turbomachinery
- Employer of 200+ talented professionals averaging >19 years of experience
- Lean organization – 90% perform engineering services
- A small, woman-owned business
- Headquarters: Jupiter, Florida
- Incorporated: October 1998

Quick Facts

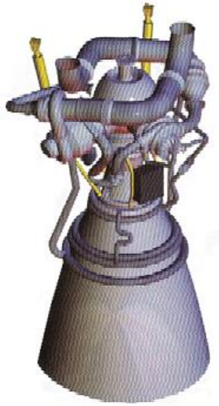
**2010**

**Employees: 210**

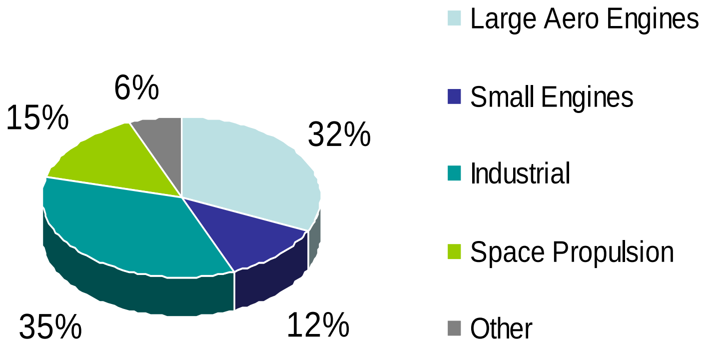
**Revenue: $30 Million**

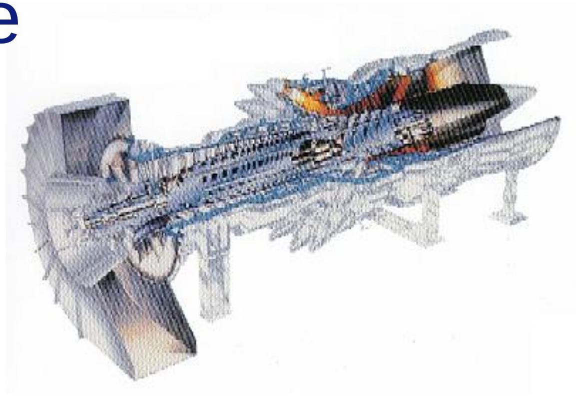
# FTT is:

## Diverse turbomachinery experience

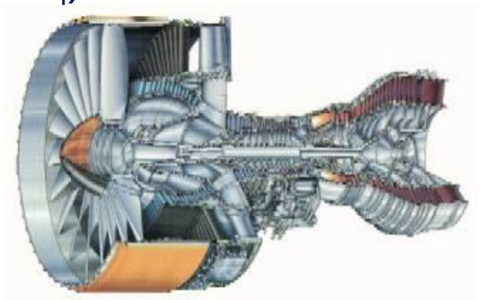


Turbopumps for
Space Propulsion
(16,000-1,000,000 $lb_f$)

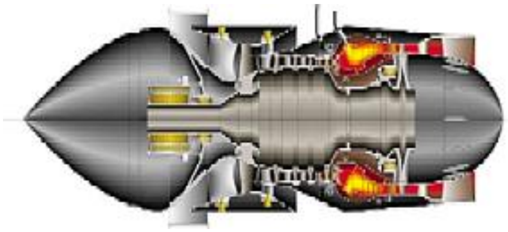


Large Turbines for
Industrial Power
(58MW-262MW)



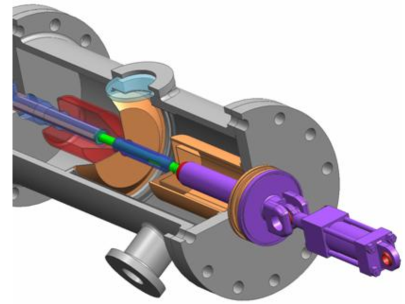
Large Turbines for Military and
Commercial Aircraft
(6,000-98,000 $lb_f$)

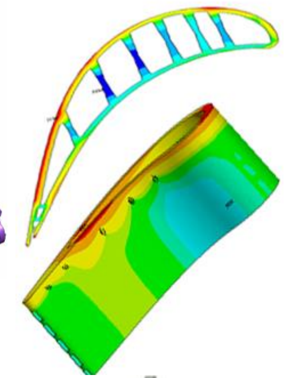


Small Turbines for
Unmanned Air Vehicles
and Distributed Power
(IHPTET,VAATE)

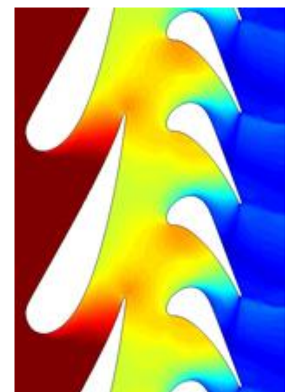
# FTT is:

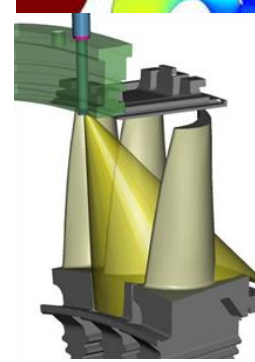
## Wide range of capabilities





- Turbomachinery Design & Analysis
  - Mechanical Design
  - Structures
  - Aerothermal/CFD/Performance
  - Combustion
  - Heat Transfer/Secondary Flow
  - Modeling & Drafting
  - Manufacturing Support
- Demonstrator Design & Development
- Testing, Instrumentation, & Assembly
- FTT Field Services
  - Outage Support
  - Technical Support
  - Reverse & Re-Engineering Services
  - Repair Engineering Services





**One-stop shop for turbomachinery needs**

# FTT is:

## Focused on innovation

- Committed to developing and protecting intellectual property
  - 523 patent applications filed and pending to date
  - 156 patents issued to date

- Proven efficient, innovative designs
  - Developed world's first highly fuel-efficient small turbofan engine turbofan engine – the FTA37F has a 40% lower TSFC than other engines in its class
  - FTT turbine efficiency improvements are saving millions of barrels of oil and millions of tons of $CO_2$ per year

# R&D Needs

UTSR research is contributing to DOE FE turbomachinery development goals

- Hydrogen turbines
- IGCC and NGCC development w/$CO_2$ sequestration
- Alternative cycles (i.e.: $SCO_2$ & oxy-fuel power cycles)

Active research

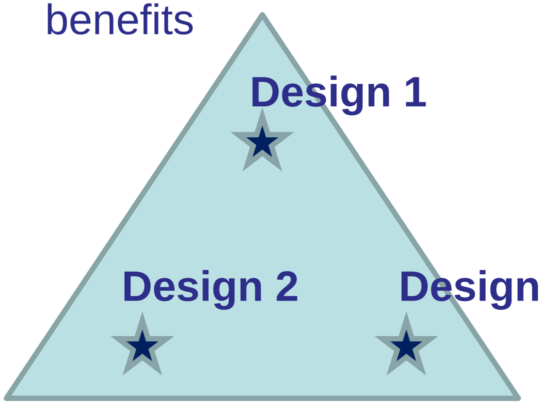
- Combustion research
  - i.e.: Flame stability, dynamics and flashback
- Aerothermal development
  - Aerodynamic and cooling system improvements for improved efficiency/durability
  - Investigation of new drivers posed primarily by use of syngas including potential effects of:
    - Increased water vapor levels
    - Deposition on turbomachinery
    - Coating degradation
- Materials and coatings

# R&D Needs

## Combustor and turbine cooling and durability

- Any cooling system design is a triad of 3 primary constituents:

**Heat load parameter (HLP)**
- Quantity of cooling flow
- TBC coating (insulation) benefits



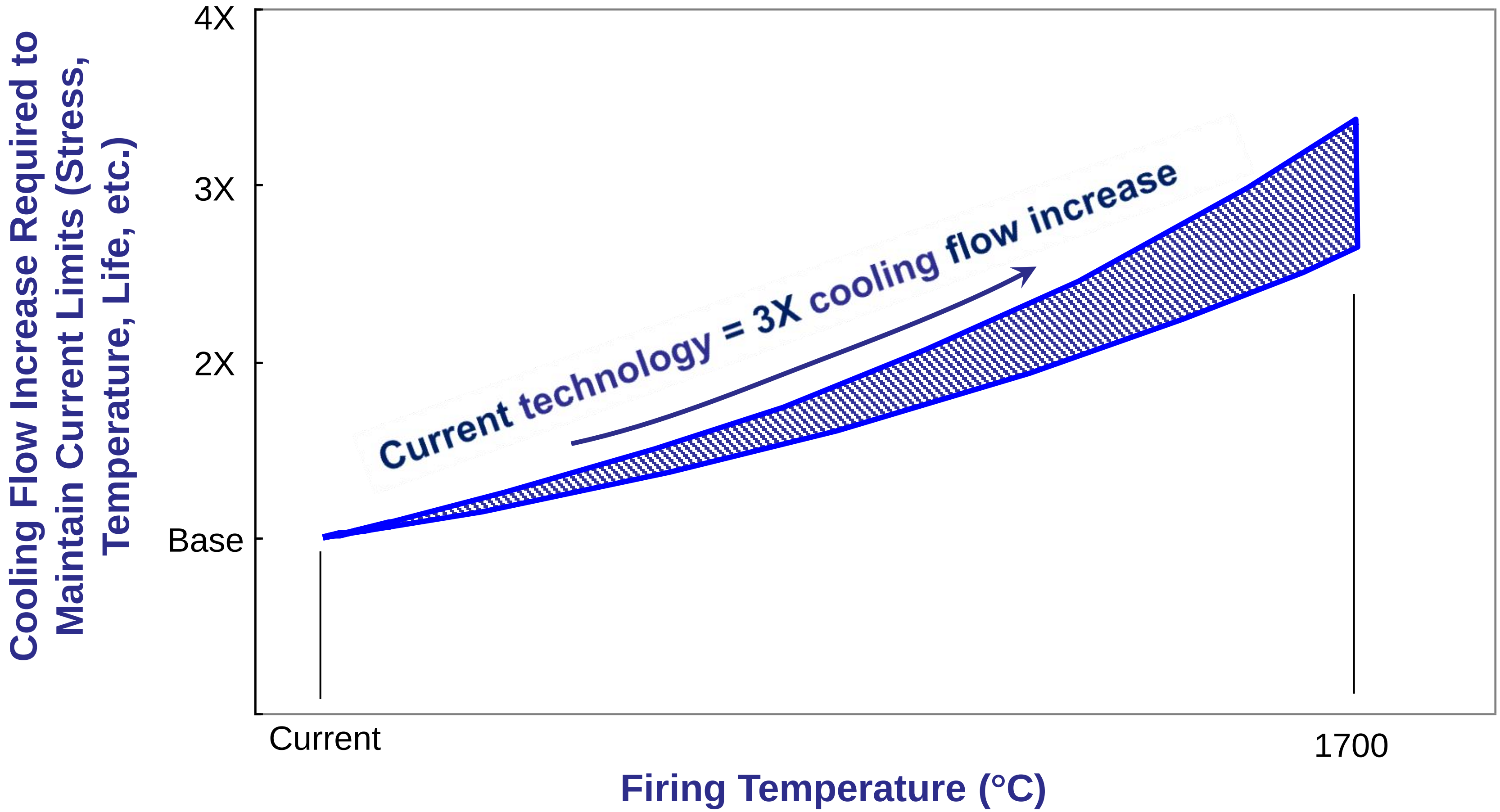

**Thermal efficiency ($\eta_{th}$)**
- How well internal cooling is done

**Film effectiveness ($\eta_{th}$)**
- How well ejected cooling flow bathes surface

Technology and design philosophy drive where any particular cooling design falls within this triangle

# R&D Needs

Use of current technology requires huge cooling flow increase to achieve turbine system goals




New technology required mitigate cooling flow escalation

# R&D Needs

Internal convection is the foundation of the cooling system

Cored castings enabled advanced internal convection cooling

- Reduced thickness of structural walls
- Increased cooling flow capacity
- Direct impingement cooling with inserted tubes and/or cast features
- Multi-pass (serpentine) cooling
- Heat transfer augmentation systems (pin-fins, turbulators, etc.)

- Limiting factors on convection systems
  - Coolant system pressure loss
  - Thermal stress
  - Cooling of local hot spots

R&D needs:

1) What must be done to increase thermal efficiency?
2) How should improvement be measured?

# R&D Needs

## Thermal barrier coating is a complimentary cooling technology

Enhances internal cooling methods

Currently used to extent of capabilities

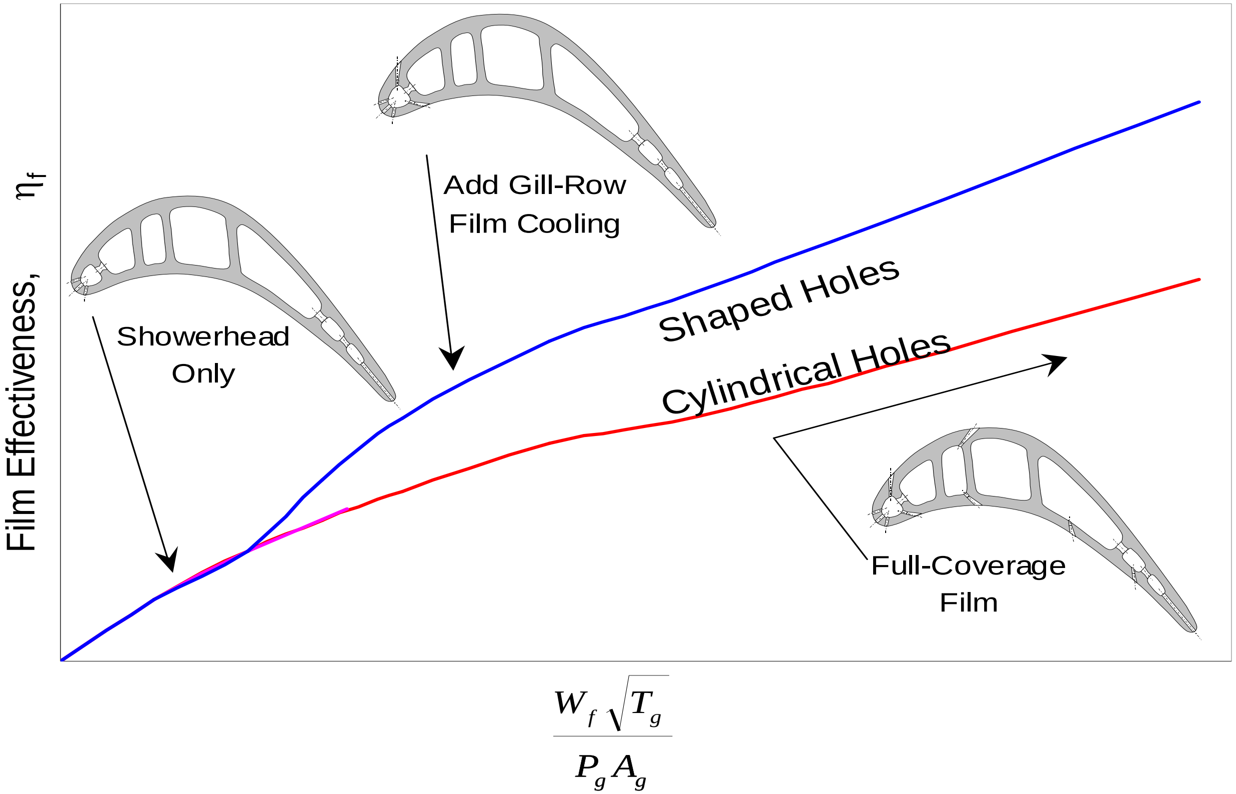
- Surface and interface temperature limits
- Spallation and erosion resistance
- Mechanical strain limitations

R&D needs:
1) Increased temperature and mechanical strain capabilities
2) Resistance to spallation
3) Low thermal conductivity?

# R&D Needs

## Film cooling technology advancement

## - Shaped holes perform better than cylindrical holes




R&D needs:

1) What geometries perform better than shaped holes, if any?
2) How should film cooling benefits be measured/compared?
3) What is needed to optimize film cooling within the context of a real cooling design?

# R&D Needs

## Approach to innovation

### Memorable quotes:

- Give me 1000 monkeys and I can solve any problem - anonymous
- Inventions don't just happen. They are made by working on problems – anonymous

### "Designer" -vs- "Analyst" philosophy:

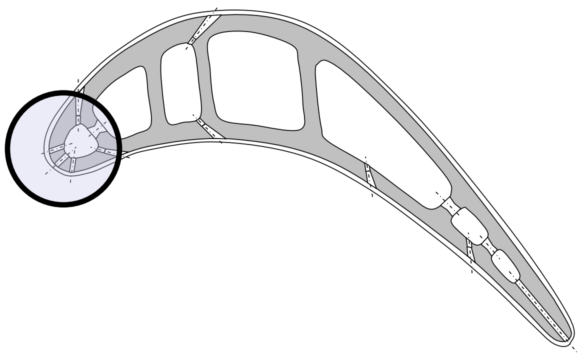
- The "analyst" uses the tools at hand to find a solution (i.e.: sizing an orifice for a particular flow by <u>iterating</u> on flow area until the desired flow falls out)
- The "designer" uses their engineering knowledge and expertise to solve problems (i.e.: sizing an orifice for a particular flow by solving the engineering equations for flow area)

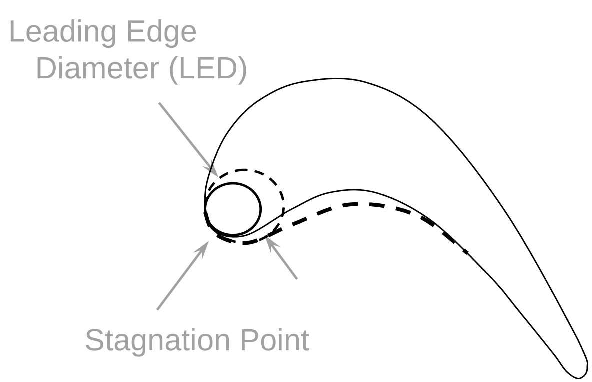
# R&D Needs

## Approach to innovation – case study

### Problem:

- Cool leading edge of turbine blade below … without a showerhead



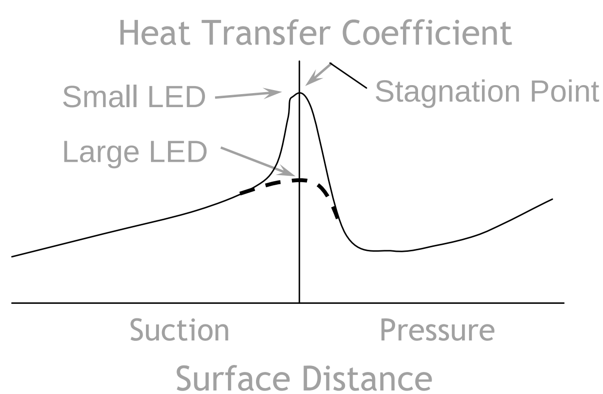



### Analyst: Can’t be done!

- External heat transfer coefficient is too high with sharp leading edge
- Internal/external surface area ratio limits internal convection heat transfer

### Designer: If L/E diameter is increased:

- External heat transfer coefficient can be decreased
- Internal/external surface area ratio more conducive to



# Summary

- The UTSR program is:
  - Performing turbine systems research which is critical to meeting DOE FE turbomachinery development goals
  - Promoting industry/academia collaboration
- New opportunities for technology development and understanding exist
  - System-level understanding of technologies required for evaluation and measurement of new technologies
- Embracing the “Designer” approach to innovation is instrumental to making inventions happen

# R&D Needs

## Leakage control

- Leakage accounts for ~25% of parasitic losses in gas turbine engines
- Turbo machines are inherently leaky
  - Comprised of many parts having gaps and clearances
  - Static-to-static parts
  - Static-to-rotating parts
  - Rotating-to-rotating parts
- Pressure difference maintained across these orifices to control environment