Atec, Inc.

Advances in Ground-Based Testing of Directed-Thrust/High-Thrust Engines for Next-Generation Aircraft

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Vice President – Atec, Inc.

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Atec, Inc.

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Corporate Overview

- **Turbine Engine Support Business Since 1956**
  - **Headquartered in Stafford, TX. (Houston)**
  - **Serve Aerospace Market**
    - **Design**
    - **Manufacturing**
    - **Integration Services**
  - **Financial Strength**
  - **Worldwide Capability**
  - **AS9100 Quality System**
  - **ISO 9001:2000 Certified**

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Corporate Overview

- **Engine Test Equipment & Facilities for Over 35 Years**
  - **Whatever it takes to run jet engines off the wing!**
    - **Turboprop, Turboshaft, Turbofan, Turbojet**
  - **Turn-key Facilities to Cell Modifications/Upgrades**
  - **Engine Adapters, Thrust Stands, Dress Gear**
    - **Bellmouths, Screens, Probes, Cables**
  - **Data Acquisition/PLC Systems**
  - **Fuel/Air/Oil Systems**
  - **Inlet/Exhaust Systems**

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Corporate Overview

- **Military Engine Test Systems**
  - **Pratt & Whitney**
    - **F100-100,200,220,220E,229**
    - **F117, F119, F135, J52, TF30, J58**
  - **General Electric**
    - **J85, J79, F101, F110, F404, F414, F118, TF-34, T700, T64**
  - **Rolls Royce/Allison**
    - **T56 Air Force/Navy Versions**
    - **501D, 501C**
  - **Honeywell/ Allied Signal/ Textron Lycoming**
    - **T53, T55, F124**

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Corporate Overview

- **Commercial Engine Test Systems**
  - **Pratt & Whitney**
    - **JT8-15, 17, 200; JT9, PW2000, PW4000's**
  - **General Electric**
    - **CFM56-3, 5, 7; CF6, CF34, CJ610,CF700**
  - **Rolls Royce/Allison**
    - **501KB, 501KC**
  - **Honeywell/ Allied Signal/ Textron Lycoming**
    - **TPE331, TFE731**

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Directed Thrust Engine Development

- **Directed Thrust Aircraft / Engine Systems**
  - **V/STOL Harrier**
    - **Circa 1969 – Present Day**
    - **Passive Engine with Active Aircraft Ducting**
      - **Rolls Royce Pegasus F402**
      - **22K lbs. Thrust**
    - **Test cells use fixed slave nozzles to facilitate bifurcated ducting arrangement.**
  - **Foreign Military**
    - **Russian SU-37 Super Flanker**
      - **2 ea. AL-37FU Engines / 40K lbs. Thrust**
      - **2D Thrust Vectoring In Pitch Axis**
      - **Very Impressive Flight Display Farnborough (1996) Paris (1997)**
      - **Video Of Super Cobra Maneuver**

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Directed Thrust Engine Development

- **Directed Thrust Aircraft / Engine Systems**
  - **1988 – 2000's**
  - **F15 Active / F16 Vista**
    - **PYBBN F100-229 / F110-100**
      - **Active 3D Engine Nozzle**
      - **Flight Test Only**
      - **Test Cell**
      - **Full 3D Testing at OEM**
  - **YF-22, YF-23, F-22**
    - **YF119, YF120 2D Active Nozzle**
    - **F119 2D Active Nozzle**
      - **Flight Test - 2D Test OEM & Field**
      - **Production Test – Axial Only**
      - **Vectored Thrust Locked Out**

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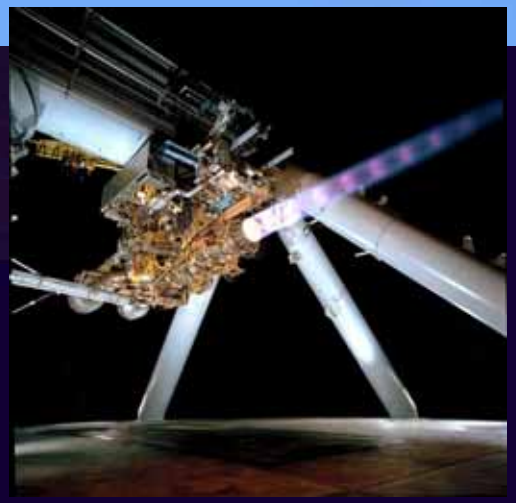
Directed Thrust Engine Development

- **Directed Thrust Aircraft / Engine Systems**
  - **2000's - Beyond**
  - **F35 Joint Strike Fighter**
    - **F135/F136 Engine Variants**
      - **Active 2D Engine Nozzle**
      - **Active 1D Lift Fan**
      - **Active Roll Control Thrusters**
    - **Developmental Test – Full Thrust Vector at OEM**
    - **Flight Test – 1D Testing of Main Nozzle on Test Stand**



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Directed Thrust Test Experience

- **YF22/23 Program Support - 1989-1991**
  - **YF119 Engine Test Support for Both Lockheed and Northrop Aircraft**
    - **Outdoor Ground-Based Thrust Frame and Engine Adapter Kit**
    - **Thrust Vectoring +/- 22 degrees at Full Augmentation**
    - **Dual I-Beam Deadmen**
    - **New 4000 PSI Concrete Pad**
    - **Vectored thrust tie-rods directly coupled to concrete for maximum thrust restraint safety factor.**
    - **System delivered 2 months ahead of schedule to support competition fly-off.**

Lockheed-Boeing-General Dynamics YF-22
and Northrop-McDonnell Douglas YF-23
USAF Museum Photo Archives

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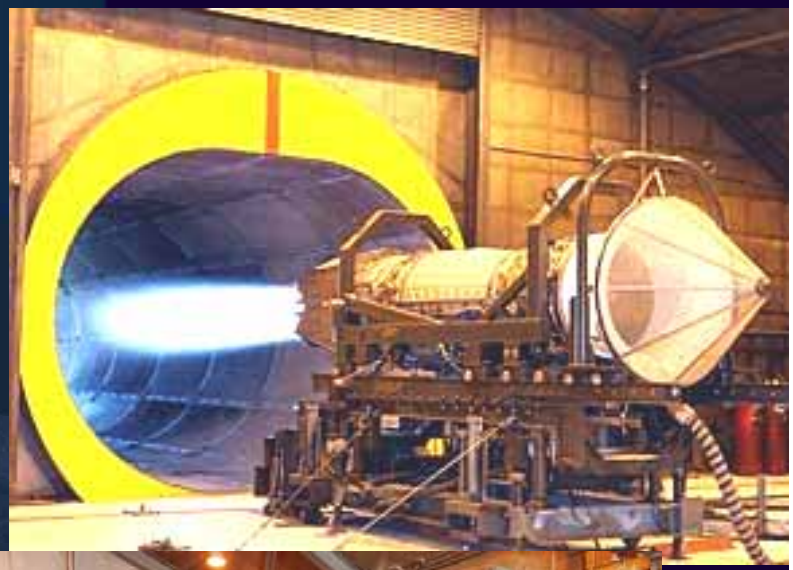
Directed Thrust Test Experience

- **F22/F119 EMD Engine Test Support – 1994-1997**
  - **Engine Test Adapter Kits for Both Flight Test Locations**
  - **New Thrust Frame for Vectored Thrust Support**
  - **Redesigned Engine Adapter to Match Revised Engine Configuration**
- **USAF M37X Thrust Stand Redesign for 50K Thrust Engines for T-10 Hush House Installations**



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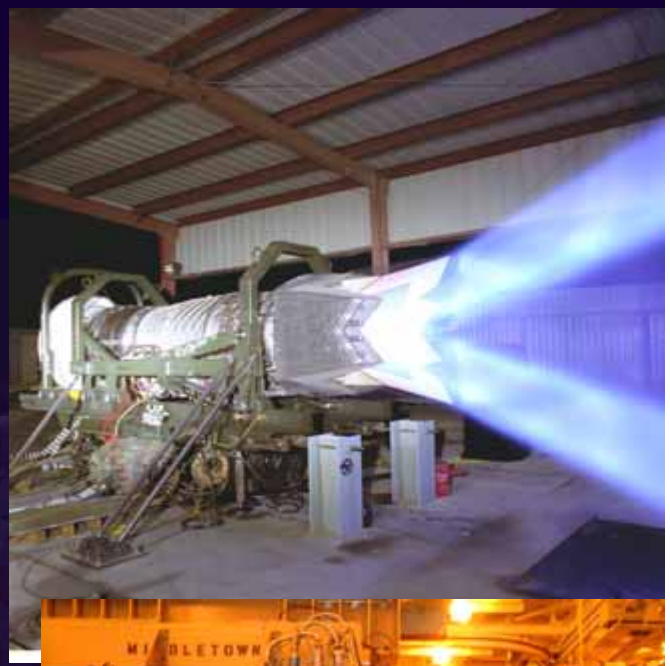
Directed Thrust Test Experience

- **F22/F119 LRIP Engine Test Support – 2000-Present Day**
  - **Engine Test Adapter Kit for Flight Test Location**
    - **2D Vector Capable**
  - **Engine Test Adapter Kits for Operational Squadrons**
    - **1D Axial Thrust Limited**
  - **Redesigned Engine Adapter to Match Revised Engine Configuration**
  - **Engine Test Controller for FADEC Test Operation**
    - **Vectored Thrust Locked in System**
  - **Redesigned OEM Engine Adapters**
    - **Reduced Engine Prep Time by Order of Magnitude**
    - **Full 2D Thrust Vector Capable**



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Directed Thrust Test Experience

- **F35/F135 & F136 Engine Test Support – 2005-Beyond**
  - **Engine Test Adapter Kits for USAF and USN Flight Test Locations**
    - **1D Axial Thrust Limited**
  - **Redesigned Thrust Frame for Higher Thrust Capacity**
    - **Mobile Stand for Portability**
    - **Efficient Deadman System Eliminates Need for Costly Concrete Modifications**
  - **Vertical Engine Build Platform**
    - **Above-Ground Installation**
    - **Gravity-Assisted Engine Assembly**

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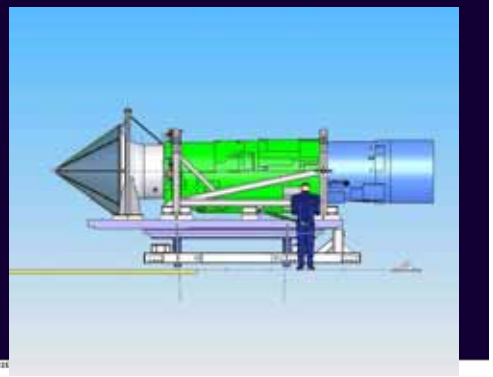
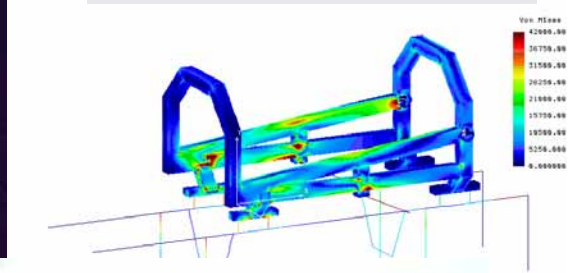
Test Technology Advances

- **Application of State-of-the-Art Design Tools/Methods to Support Equipment**
  - **Full 3D Solid Modeling**
    - **Improved Design Reviews**
    - **Fewer 1st Article Misfits**
    - **Inputs Directly Into FEA**
  - **Complete FEA of System**
    - **Static/Dynamic/Harmonic/Vibratory**
  - **Static Load Testing to 2X Rated Load**
  - **Full Post-Test NDI of Structure/Welds**





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Test Technology Advances

- **Engine Test Systems**
  - **Pre-Assembled Thrust Frames**
    - **Reduced Integration Time**
  - **Efficient Deadman Design**
    - **Eliminates Costly Facility Modifications to Foundation**
    - **Load distribution provides maximum thrust restraint capability for higher thrust/directed thrust applications.**
  - **Linear-bearing approach allows for thrust measurement without flexure plates.**
    - **Enhanced Strength for Vectored Thrust Load Transfer**
    - **Rotational and Overturning Moment Load Sensitivity Reduced**

Lessons Learned

- **Key Areas To Consider**
  - **Personnel Safety**
    - **FEA Review of Total System**
    - **FMECA of Total System**
    - **Intercom System**
    - **External Cameras**
  - **Concrete**
    - **Thrust Restraint During Vector**
    - **Vertical Load Tie-Rods**
    - **Deadman Arrangement**
    - **Blast Zone Protection**
  - **Ancillary Systems Protection**
    - **Vibration Isolation**
    - **Acoustic Exposure**
  - **Airflow**
  - **Vertical Thrust Test Lockout**

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Presentation Summary

- ***Key Areas to Consider***
  - *Personnel Safety*
  - *Concrete*
  - *Ancillary Systems protection*
  - *Airflow*
  - *Vertical Thrust Test Lockout*
- ***Atec = 16 Years of Directed-Thrust Engine Test Support***
  - *Mechanical & Electronic Systems*
- ***Atec = Over 35 Years of Experience in Engine Test Support***
- ***Atec = Whatever it takes to run your engine off-wing !!***

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Questions

Come See Us in Booth # 2011