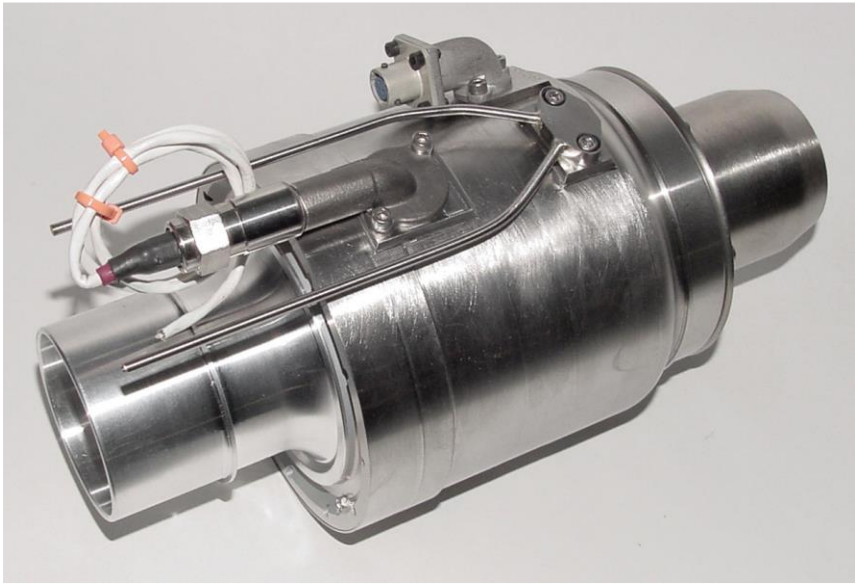
Concepts NREC
EXPERTS IN TURBOMACHINERY

Technical Directions Inc.

CASE STUDY

Breakthrough Development of Miniature, Low-Cost Turbojet Propulsion System

For over two decades, Technical Directions Inc. (TDI) of Ortonville, Michigan, has been developing low-cost, expendable turbojet propulsion systems for mini-cruise missiles and other military applications. The success of TDI's unique miniature engines – as small as 4.5 inches in diameter – can be directly attributed to the engineering breakthroughs achieved in the development of their base engine technology, much of which was funded by the U.S. Small Business Innovative Research (SBIR) program.



The low-cost TDI turbojet design incorporates a turbocharger impeller and eliminates the need for separate lubrication and cooling systems.

According to TDI chief engineer, Joseph Kovasity, "When TDI was approached by a major prime contractor wanting a low-cost, miniature munitions propulsion system, we believed our turbojet technology could achieve the stringent performance and configuration specifications required for a mini-cruise missile." In addition to having sufficient power and range to complete a search and destroy mission, the engine requirements included easy starting, plus operation without an oil lubrication system. In teaming with the contractor to develop such an engine, TDI also gained support from the U.S. Air Force through a series of SBIR awards.

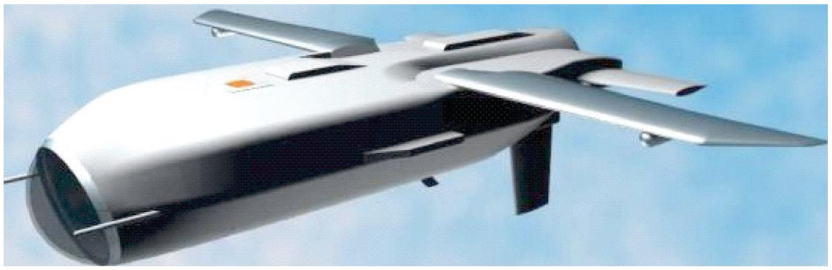
During SBIR Phase I and Phase II, TDI developed a low-cost turbojet engine (Model TDI-J45) utilizing the inexpensive rotating components of a turbocharger. The successful design met all Air Force requirements and created a unique propulsion-system configuration that could be scaled for a wide range of small expendable missiles.

Air Force program manager for the TDI-J45 project, Lt. John Mehrman commented, "Development of an engine that can 'windmill start' and not require a separate oil-lubrication system or oxygen assist for sustained operations is truly a significant technology breakthrough."

The patented TDI-J45 engine employs low-inertia, radial compressor, and turbine wheels, plus a low-speed ignition for easy starting – that also permits windmill cranking. The fuel metered to the engine both cools and lubricates internal components, thereby saving the space and weight of a separate oil-lubrication system. As a secondary benefit, the fuel flow is prewarmed for more rapid and complete combustion. The success of the TDI engine established new standards and methods for designing a miniature, low-cost single-mission weapon system. And throughout the development of this breakthrough technology, TDI requested various engineering and manufacturing services from Concepts NREC, including periodic design audits of the engine's turbomachinery components.

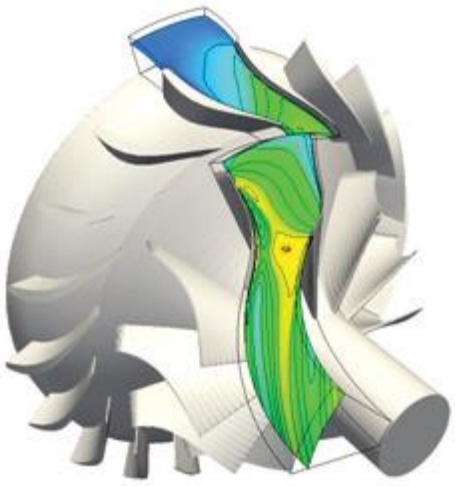
Advanced design exceeds higher efficiency goals

Following the initial success of the TDI-J45 engine, TDI conducted a follow-up program intended to improve overall engine efficiency by 8% and thereby further increase missile payload and range. Another objective of this U.S. Army/SBIR-funded development program was to achieve that performance improvement with minimal added cost.



The compact configuration of minimal engine components that comprises the TDI-J45 turbojet engine provides advantages in efficiency, size, and weight to increase maximum payload, flight duration, and range.

In an attempt to decrease fuel consumption by modifying the turbocharger-based engine components, TDI asked Concepts NREC to review the J45's compressor and diffuser and provide design modifications for reworking the parts. However, after making the recommended trim and profile modifications, engine



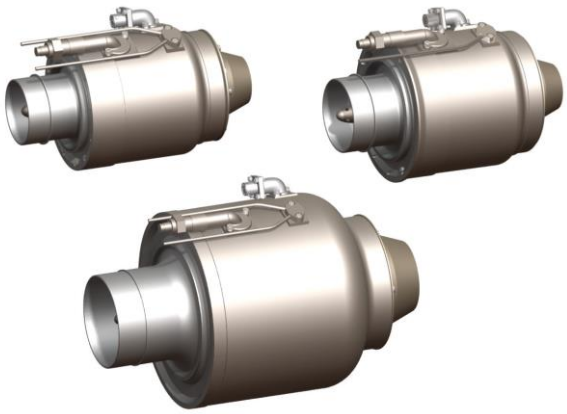
efficiency improved by only 5%. Achieving higher efficiencies for the TDI-J45 missile engine (with the potential to exceed initial goals) would require a new more advanced turbomachinery design.
A recent SBIR program conducted by TDI for the U.S. Air Force did focus on optimizing several of the engine's turbomachinery components for maximum efficiency. The original TDI-J45 compressor impeller was an inexpensive investment casting with limited machine finishing. *Concepts NREC*'s new impeller design featured very thin blades and was lighter, stronger, more efficient, and capable of achieving optimum performance with minimal flow losses.

The complex blade shapes and passages of the advanced compressor design required tolerances within .001" and blade thicknesses in the .010" range.

The manufacturing requirements of this advanced design called for replacing the investment casting with a fully machined compressor wheel. Therefore, concurrent with meeting performance requirements was assurance that the complex precise shapes of the proposed new design could be easily manufactured at a relatively low cost.

Specialized CAM achieves design fidelity and target cost

Realizing the extent of this formidable challenge to accurately and economically machine the new impeller design, TDI asked Concepts NREC to provide 5-axis machining toolpath instructions using their proprietary MAX-PAC™ CAM software for manufacturing turbomachinery components. As a result of the machine code generated by this specialized system, all machining issues were resolved, and all geometric features were held within their specified tolerances. Machining cycle time also met projections that helped achieve the target cost for a finished compressor wheel.



In tests of the TDI-J45 engine using the new compressor wheel and diffuser, gains in engine efficiency resulted in reduced specific fuel consumption by up to 28%, and additional efficiency gains are expected through further development. Recent wind-tunnel tests have also confirmed the self-starting capabilities of the engine system at all altitudes and vehicle speeds within the required flight envelope.

The TDI family of small turbojet engines currently includes the TDI-J45 (30 lb. thrust, 4.5 in. diameter), the TDI-J5 (55 lb. thrust, 5 in. diameter), and the TDIJ7 (100 lb. thrust, 7 in. diameter).

As a result of these impressive performance improvements for the TDI-J45 engine, Concepts NREC has designed new rotating components for several other TDI engines that include high-efficiency compressors, diffusers, turbines, and nozzles. Concepts NREC has also supplied the highly sophisticated machining toolpaths required to effectively manufacture their complex and precise shapes.

In addition to being used as an expendable turbojet propulsion system, TDI envisions numerous industrial and commercial applications that can also exploit the benefits of their low-cost turbojet engine technology –

including use as a power system in electrical generation. As these new applications are realized through innovative design, TDI can continue to count on the total turbomachinery resources of Concepts NREC.

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