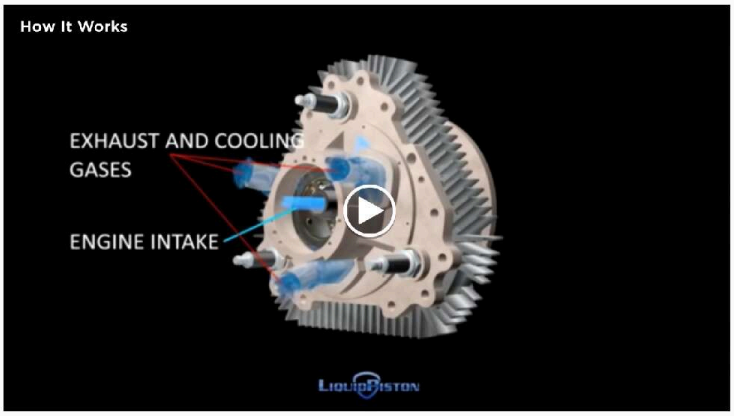
First wholly new combustion engine / cycle in 85+ years

Engines are dirty, and physics tells us we can do better! We've developed an optimized thermodynamic cycle and built a fundamentally new combustion engine that's cleaner, cheaper, quieter, and smaller. Compared to piston engines, our "X" rotary engine can be ~5-10x smaller and lighter than a Diesel, and up to 2x more efficient than a gasoline engine. An electric vehicle using LiquidPiston combined with a small battery pack could have a lower CO_2 footprint compared to plug-in electric vehicles.

Follow (1,122)

hardware technology automotive clean tech

Alexander Shkolnik
CEO
Entrepreneur, R&D technology developer/program manager, and technical specialist, with experience in applying his knowledge to living neuronal networks to robots to internal combustion engines.



Why you may want to invest

1. Raised $1.29M from 727 investors on Wefunder in 2017.
2. Since then, DARPA awarded a Phase 2 $2.5M development contract in October 2017, a follow-on to our 2 DoD contracts, totaling $5.5M in non-dilutive funding.
3. New engine architecture could improve fuel efficiency by up to 2x over a gasoline engine while reducing size and weight by up to 10x over a diesel engine.
4. 45 patents issued or pending in the U.S. and internationally.
5. Our 70cc "X mini" engine is a 3-5hp gasoline engine the size of a honeydew melon. Measured 50% increased efficiency over comparable per-cylinder displacement gasoline engine. The engine is being inserted into a 2kwe hybrid electric generator for Army applications.
6. Our 750cc "X-4" engine is a 40hp rotary Diesel X engine "Alpha" prototype, which ultimately may fit in an 11" box while weighing just 40 pounds. We are proving it's efficiency and power.
7. Completed $1M "seedling" program with DARPA in 2015.
8. $460 billion total addressable market; starting with military industry and handheld engine.

Our Ambition

We can't overstate how important our new thermodynamic cycle is - this is the first leap forward in combustion engine technology in 85 years. We've exceeded objectives in several multi-million dollar government contracts, and received follow-up funding to continue R&D. We have huge enterprise customers lining up for potential licensing deals. Initially, we will be 100% focused on military applications. We won't stop, however, until we overturn the entire $400 Billion combustion engine market.

LPI_PitchDeck.pdf

liquidpiston.com

Bloomfield, CT

8

Why I Like LiquidPiston

I like to invest in companies that have two key ingredients -- important new technology AND great people. I feel LiquidPiston has both. Their engine is a fundamentally new and important breakthrough, with broad commercial and military applications. And the entrepreneurial management team is truly impressive -- brilliant, high-energy, pragmatic, and totally committed. I'm thrilled to be able to play even a small part in making this company successful.

Bob Stearns

LIQUID PISTON INVESTOR. MANAGING DIRECTOR OF STERNHILL ASSOCIATES AND FORMER CTO OF COMPAQ - INVESTED IN LIQUIDPISTON

8

The big advantage of a pistonless rotary engine is its high power to weight ratio, reduced weight, and simplicity.

Wired

DARPA Project Manager Mark Gustafson, who has led high-profile projects for the military such as the $6 billion propulsion system for the F-35, sees great promise in the LiquidPiston technology.

Popular Mechanics

We developed what we call the X4 engine, which is like the old Wankel rotary engine, but flipped inside out. It solved a lot of the challenges the Wankel used to have while giving it this new thermodynamic cycle upgrade... Our engine has the potential to be very quiet. There's no piston slap, for instance, so the only real noise is from the gears and combustion. So, it's relatively quiet.

Alec Shkolnik

CEO of Liquid Piston

8

"Engines are dirty, and physics tells us we can do better! We've developed an optimized thermodynamic cycle and built a fundamentally new combustion engine that's cleaner, cheaper, quieter, and smaller. Compared to piston engines, our "X" rotary engine can be ~5-10x smaller and lighter than a Diesel, and up to 2x more efficient than a gasoline engine. An electric vehicle using LiquidPiston combined with a small battery pack could have a lower CO2 footprint compared to plug-in electric vehicles.

Alexander Shkolnik

CEO of Liquid Piston

DARPA believes that there is potential for a family of high-efficiency, compact, lightweight heavy-fuel engines. If fully successful, this project will provide proof of concept that our challenging objectives are achievable and pave the way for potential new capabilities in ground, air, and maritime applications.

Mark Gustafson

DARPA program manager

8

The company develops and licenses compact & efficient power solutions based on an optimized thermodynamic cycle and a new type of rotary engine architecture. The patented high-efficiency cycle is the biggest leap forward in combustion engine technology over the last 85 years, and holds great promise as the preferred future propulsion solution for both military and heavy commercial drones.

Randy Goers

Founder of The Drone Radio Show

We started with the mission statement of building an engine that would have much higher

efficiency, consume less fuel, be smaller, and quieter. We wanted to create an engine that is better than every other engine on any single parameter. We were very ambitious!

Nikolay Shkolnik

"The engine... has just two moving parts: a rotor and a shaft to transfer power from the engine. Minimal moving parts means the engine is smaller, lighter, more reliable and quieter than a conventional piston-fired engine. It's also smoother, which, if you've ever used a weed whacker or leaf blower, you'll consider a big plus.

Jordan Golson

Writer for WIRED

"With the X Mini's High Efficiency Hybrid Cycle (HEHC) design, the volume remains constant: no undulating piston exists to alter the operating environment inside the cylinder. By applying near maximum pressure into this consistent environment, the result is a more efficient combustion cycle. Fewer parts mean lower vibrations and fewer potential mechanical problems.

Michael Kanellos

Contributor to Forbes Magazine

"The nation would benefit greatly from the development of a high-power-density, energy-efficient engine that could operate on heavy hydrocarbon fuels. We are excited about the plans to develop and test key technologies that could help achieve that goal, and look forward to LiquidPiston's efforts to accelerate progress in this important field of work.

Mark Gustafson

DARPA Project Manager

"I like to invest in companies that have two key ingredients -- important new technology AND great people. I feel LiquidPiston has both. Their engine is a fundamentally new and important breakthrough, with broad commercial and military applications. And the entrepreneurial management team is truly impressive -- brilliant, high-energy, pragmatic, and totally committed. I'm thrilled to be able to play even a small part in making this company successful.

Bob Stearns

Former CTO of COMPAQ

NEW ATLAS

LiquidPiston unveils X Mini engine

Back in 2012, Gizmag looked at LiquidPiston's X2 rotary engine and now the company is back with the 70 cc X Mini engine, which LiquidPiston's President and Co-Founder, Dr Alexander Shkolnik unveiled on Wednesday at the SAE International/JSAE 2014

June 25, 2018 @ newatlas.com

SAE INTERNATIONAL

Preliminary Development of a 30 kW Heavy Fueled Compression Ignition Rotary 'X' Engine with Target 45% Brake Thermal Efficiency

This paper presents initial progress in the development of LiquidPiston's 'X4', a 30 kW heavy-fueled rotary compression ignition engine prototype. The X4 is the newest version of the unique rotary 'X' engine architecture. This development is partially

June 25, 2018 @ sae.org

MilitaryTimes

Quieter military drones that fly farther? The Pentagon thinks this engine could be the answer

Most people haven't heard of the engine created by Felix Wankel in the 1960s, but its derivatives may end up powering the military's future unmanned aerial vehicles. Despite a compact design that allows it to run at higher speeds and produce more

June 20, 2018 @ militarytimes.com

DRONE RADIO SHOW

The Next Generation UAV Engines: Alec Shkolnik, Liquid Piston - Drone Radio Show

What might the next generation UAV engines look like? For that question, we turn to Alec Schlonik, co-founder and CEO of LiquidPiston, a Connecticut based company that is revolutionizing next-generation engine development. The company develops

May 7, 2018 @ droneradioshow.com

MIT

MIT Corporate Relations and MIT Startup Exchange announce STEX25 additions

MIT Startup Exchange is pleased to announce the addition of seven companies to its roster of STEX25 startups. New additions to the program include: Asimov (programmable living cells), Feature Labs (data science automation), Form Energy

April 27, 2018 @ ilp.mit.edu

MOTOR TREND

13 Tech Trends Worth Watching, From the 2018 SAE World Congress - Motor Trend

The Society of Automotive Engineers' annual World Congress-WCX18 in abbrev-speak-aims to be the SXSW of the car-biz's nerd-illuminati. "Better mousetraps" for accomplishing nearly anything mechanical or electronic onboard a vehicle are

April 24, 2018 @ motortrend.com

COMMERCIAL UAV NEWS

LiquidPiston Enters the UAV Arena with a Revolutionary Rotary Engine - Commercial UAV News

On March 6th, LiquidPiston Inc., an advanced internal combustion engine technology company, announced its intention to enter the UAV market with a revolutionary rotary engine aimed at powering medium-sized drones. As part of the company's push into

April 2, 2018 @ expouav.com

X marks the spot

LiquidPiston Inc. has developed a new engine that can run on multiple fuels, including diesel, jet fuel, and gasoline. This platform uses an optimized thermodynamic cycle and a new rotary engine architecture and could increases flight endurance over
March 22, 2018 @ sae.org

LiquidPiston receives $3M Rapid Innovation Fund award from US Army for 2kW hybrid-electric genset

LiquidPiston, Inc. (LPI), a developer of advanced multi-fuel-capable rotary combustion engine technology, has been awarded a $3-million Rapid Innovation Fund (RIF) award from the US Army to develop an innovative ultra-portable 2kW diesel
June 28, 2017 @ greencarcongress.com

8

DARPA awards LiquidPiston $2.5M to advance further X4 rotary engine prototype

The US Defense Advanced Research Projects Agency (DARPA) has awarded LiquidPiston Inc. $2.5 million to continue development of a new, patented, high-efficiency, lighter-weight rotary engine. LiquidPiston, a developer of advanced
December 14, 2016 @ greencarcongress.com

Sikorsky names LiquidPiston winner of 7th Entrepreneurial Challenge

Sikorsky, a Lockheed Martin company, named LiquidPiston, developer of engines based on its High Efficiency Hybrid Cycle (HEHC) (earlier post), as the winner of the 7th Entrepreneurial Challenge. The Entrepreneurial Challenge, driven by Sikorsky
December 2, 2016 @ greencarcongress.com

LiquidPiston: Could This Be The Engine Start-Up That Makes It?

Nikolay Shkolnik says LiquidPiston's X Mini rotary engine can double fuel economy, eliminate noise and vibration and reduce the size of engines by 30% to 75%. Check out the video: a four pound X Mini replaces a 40 pound standard engine in this go
August 28, 2016 @ forbes.com

8

LiquidPiston's 4-lb Rotary Engine Shows What it Can Do - SolidSmack

LiquidPiston has invented a new rotary type engine that is piston-less, valve-less, and weighs only four pounds. They published a proof of concept video for the XMv3 engine, shown powering a small go-kart, that builds evidence that the High Efficiency
June 28, 2016 @ solidsmack.com

New lightweight LiquidPiston engine unveiled

US-based startup LiquidPiston last week unveiled a new lightweight engine delivering significant advantages over traditional designs. The new engine, called the X Mini is a new gasoline powered engine utilizing a unique new engine architecture. Based off
June 19, 2016 @ themanufacturer.com

Remodeled Mazda Rotary Engine For EVs, Drones Catches US Military Attention For Oil Problems, Engine Reliability

First Posted: Jun 16, 2016 04:10 AM EDT Electronic vehicles and drones having been using compact machineries similar to go-karts, but a new engine has been unveiled outside the laboratory for the first time. Alexander Shkolnik, co-founder and president
June 16, 2016 @ scienceworldreport.com

Startup Company Creates Rotary Engine That Weighs Four Pounds

Connecticut-based startup LiquidPiston announced today that it has built a compact engine powerful enough to drive a go-kart. The firm's X Mini engine weighs just four pounds and has just three moving parts, yet it can produce 3 horsepower, enough to
June 16, 2016 @ msn.com

Este motor de combustion ruso del tamano de un iPhone tiene 5 CV y puede impulsar un kart

Cada cierto tiempo alguien inventa un nuevo tipo de motor con la idea de revolucionar el mercado automovilistico. El ingeniero mecanico ruso Nikolai Shkolnik tenia otra idea en mente, y quiza por ello su motor de apenas dos kilos de peso ya
June 16, 2016 @ es.gizmodo.com

LIquidPiston's tiny but powerful rotary engine could usher in a new era for drones

Building the perfect engine for a drone is no easy task. They require small, high-powered engines with a high level of fuel efficiency and minimal vibrations - particularly if they're being used for filming or taking measurements. Those
June 15, 2016 @ digitaltrends.com

LIquidPiston's tiny but powerful rotary engine could usher in a new era for drones

"We started with the mission statement of building an engine that would have much higher efficiency, consume less fuel, be smaller, and quieter," says Nikolay Shkolnik. "We wanted to create an engine that is better than every other engine on any single
June 15, 2016 @ finance.yahoo.com

How a 4-Pound Engine Can Replace a 40-Pound Engine

Connecticut-based startup LiquidPiston announced today that they have built a small, compact engine that is powerful enough to drive a go-kart. Their X-mini engine weighs just 4 pounds and has three moving parts, and yet can produce 3 horsepower,
June 14, 2016 @ popularmechanics.com

A Powerful Yet Tiny Engine Inches Closer to Powering EVs and Drones

A go-kart isn't the most obvious place to find the engine that could change how cars, drones, and anything else with a motor gets around, but it makes sense when you

think about it. Karts are small, cheap, and crazy fun. "It's a thrilling ride," says
June 14, 2016 @ wired.com

LiquidPiston Signs $1M Agreement with DARPA to Develop Fuel-Efficient, Lightweight, Heavy-Fueled, Rotary Combustion Engine Technologies for the U.S. Military | Business Wire

LiquidPiston, Inc., a developer of advanced combustion engine technology, today announced that the company has signed a $1 million agreement with the
April 23, 2015 @ businesswire.com

New Rotary Engine Lands $1 Million DARPA Contract

We love when a tiny company does big things. LiquidPiston, Inc., of Bloomfield, CT, recently signed an agreement with the U.S. Defense Advanced Research Projects Agency, better known as DARPA, to use the hyper-efficient rotary engine technology
April 23, 2015 @ popularmechanics.com

Small engine packs a punch

Noise, excessive vibration, and relative inefficiency are drawbacks of the piston-based internal combustion engines (ICE) that power today's lawn and garden equipment, such as leaf blowers and lawn trimmers. But now MIT startup LiquidPiston has
December 5, 2014 @ news.mit.edu

LiquidPiston Unveils Very Small 5-horsepower, 70cc Rotary Engine - EngineLabs

A new 70cc rotary 4-stroke engine that's a little bigger than an iPhone yet could pump out five horsepower was unveiled by LiquidPiston at last week's SAE International/JSAE 2014 Small Engine Technology Conference in Italy. Called the X
November 24, 2014 @ enginelabs.com

Compact Rotary engine is a petite powerhouse

There's a new spin on the rotary engine. Liquid Piston, a Connecticut-based engineering firm, has turned the classic Wankel engine design inside out to create a more efficient, and cleaner-burning motor. The X Mini is a little powerhouse with a
November 24, 2014 @ foxnews.com

This Tiny Engine Could Make Leaf Blowers Sound Less Like Jets

Big engines like the 707-horsepower monster Dodge put in the Challenger Hellcat or Volvo's little four-cylinder that makes 425 ponies get all the attention these days. But there are millions of tiny engines doing tiny things (think garden trimmers, leaf
November 21, 2014 @ wired.com

LiquidPiston unveils X Mini engine

Back in 2012, Gizmag looked at LiquidPiston's X2 rotary engine and now the company is back with the 70 cc X Mini engine, which LiquidPiston's President and Co-Founder, Dr Alexander Shkolnik unveiled on Wednesday at the SAE International/JSAE 2014
November 20, 2014 @ gizmag.com

Green Car Congress: LiquidPiston unveils 70cc rotary gasoline engine prototype embodying HEHC; power dense, low-vibration

Print this post LiquidPiston X1 engine features three separate combustion chambers creating 3 power strokes per revolution for high power density. Source: LPI. Click to enlarge. LiquidPiston, Inc. (LPI) the developer of engines based on its High Efficiency
November 19, 2014 @ greencarcongress.com

Small Engine Fuels Big Ideas: Quieter, Lighter And More Efficient

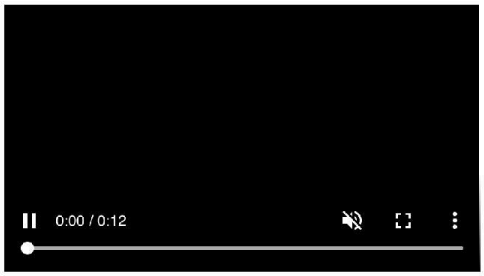
LiquidPiston Inc. has an iPhone-sized engine it says could lead to quieter power generators, lighter weed-whackers, and more efficient unmanned flying drones. At 4 pounds, the three-horsepower X Mini gasoline engine, which the Bloomfield company
November 19, 2014 @ courant.com

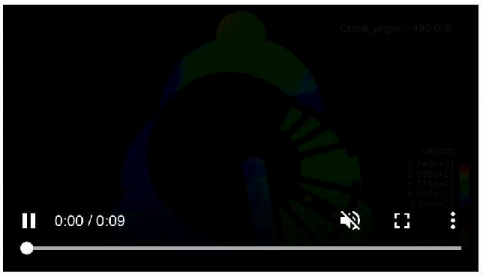
Super-efficient, unconventional ICEs take aim at Otto and Diesel

Today's combustion engines typically are only 20-30% efficient at part-load operating conditions, resulting in poor average fuel economy-and inspiring powertrain designers to reach further. Imagine new internal combustion engines (ICEs) that
April 24, 2012 @ articles.sae.org

Combustion Engines Haven't Been Updated in 100 Years

Over 120 years ago, the thermodynamic cycles for Otto (gasoline) and Diesel cycles for internal combustion engines were developed—and the piston engine design hasn't changed much since the days of Henry Ford. LiquidPiston has designed a totally new type of rotary internal combustion engine technology. The design is new. The thermodynamic cycle is new; the approach is rooted in physics and optimization. The engine is up to 2x more efficient than comparable powered gasoline engines in production today, and up to 10x smaller and lighter than comparable Diesel engines.





Multi-Fuel Capable

Much like a piston engine can be configured to run on different fuels, the LiquidPiston engine can do the same. We have demonstrated the engine on gasoline, Diesel, kerosene, and JP8 fuels. Our most advanced engine prototype, the 70cc Spark-Ignited XMv3 engine, has successfully run multiple types of fuel in a single configuration, including gasoline and kerosene. Our 300cc X4 concept is intended to run Compression Ignition on Diesel.

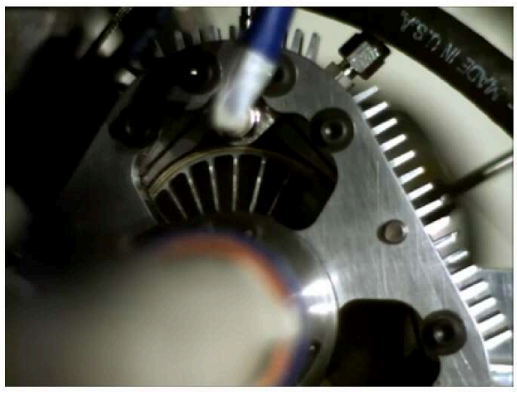
Piston Engine vs. LiquidPiston

Today's gasoline engines, in a typical automotive drive cycle, only convert about 20% of the available energy in the fuel into useful mechanical work, and 80% of the energy is then wasted as heat in the exhaust, or out the radiator.

Our approach fundamentally changes the thermodynamic cycle of the engine to make a much more efficient engine. As a result, our engine has the potential to be up to two times more efficient than a gasoline engine, while also being incredibly power dense – about 10 times smaller and lighter than any other diesel engine out there; it is also quieter, and has near zero vibration. In addition, the X Engine is incredibly simple – it has just two primary moving parts, and yet it achieves three combustion events per rotor revolution, resulting in tremendous power density.

Video: Old School Engine Inefficiency

The traditional combustion process is far from ideal. Today's engines rely on injecting, mixing, and burning the fuel while the piston is near "Top Dead Center", but it takes a long time. By the time the engine is actually burning the fuel, the piston is already expanding and the pressures are dropping due to expansion which fight the combustion, so the engine is not efficiently converting the heat from combustion into mechanical work.



Video: Liquid Piston Efficiency

The 'X' rotary engine allows for a longer period to burn all of the fuel at a nearly constant combustion chamber volume. The arc of the rotor matches the arc of the housing, which means that the rotor can continue turning at high speed while the combustion chamber volume remains approximately constant for a longer period. This gives the engine more time to burn the fuel resulting in a much more complete combustion process before it starts expanding the

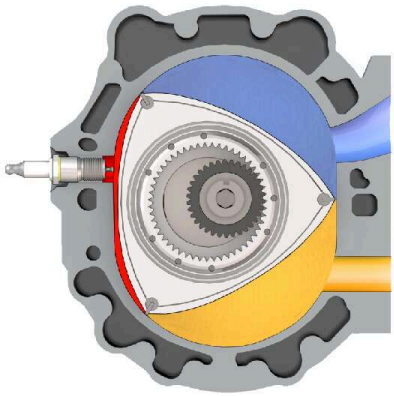
gases. Constant Volume combustion has been shown, thermodynamically, to improve efficiency by 50% over a Diesel engine.

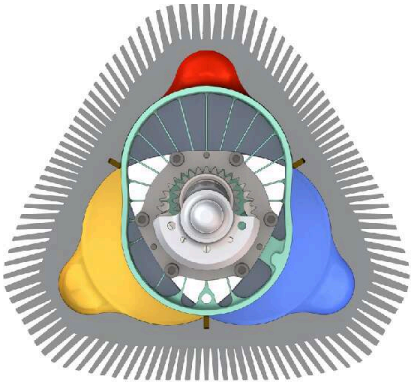
1x	4x	1
More efficient than other gas engines	Smaller and lighter than comparable diesel engines	Combustion events per rotor revolution

"Today, a 30kw diesel generator weighs 2750 pounds. Imagine the impact if we can reduce that to less than 200 pounds! Such an ultra-portable generator can be used in new applications, for example to charge the battery of an Electric Vehicle (REV), or enable hybrid electric drones."

Alexander Shkolnik
FOUNDER & CEO LIQUID PISTON

LiquidPiston vs. Wankel Rotary Engine





Old-Style Wankel Rotary Engine

- Otto cycle – gasoline only
- Efficiency less than 25%
- Sealing/lubrication issues
+ High power density

LPI X - Engine

+ HEHC cycle – diesel/gasoline/multi-fuel
+ Efficiency greater than 40% (depending on size)
+ Sealing/lubrication solved
+ High power density

See How It Works

The X engine is simple, having only 2 moving parts – a rotor and a shaft – making the engine incredible compact, up to 10x smaller and lighter than today's comparable power diesel engine. Yet it executes the optimized High Efficiency Hybrid Cycle, potentially doubling the fuel economy of the engine, while achieving 3 combustion events per revolution. The low part count and reduced raw material could make the engine significantly cheaper when volume production is reached.

How It Works

Built and Tested

LiquidPiston in Action

In June of 2016, the X-mini engine has been successfully installed into a vehicle demonstrator (e.g. a "Go-Kart"), marking a significant milestone in development. This milestone is the first time the engine was run outside the lab, and shows the engine powering something tangible that users can feel. Significant development was required to move the engine from the lab and into this application, especially in cooling the engine so it does not overheat, developing the controls and mapping the engine across its operating band, etc.

Go Kart Demo (Short)

Go Kart Demo (Long)

Immediate Use Cases

Over the past four years, LiquidPiston has developed the XMv3 "X-Mini" 70cc Spark Ignited engine, which is the Company's most advanced demonstrator to date. An engine of this size could power everyday items like handheld lawn equipment, including chainsaws or brush cutters, small generators, or small vehicles including mopeds, go-karts, etc. (as shown by our go-kart video above). This engine is demonstrated in and out of the lab, and is already showing excellent power density, low-vibration, good fuel economy, and ability to run on multiple fuels including gasoline or JP-8.

READ MORE

Military

Unmanned Flight

Electric Vehicles

Home Energy

Generators

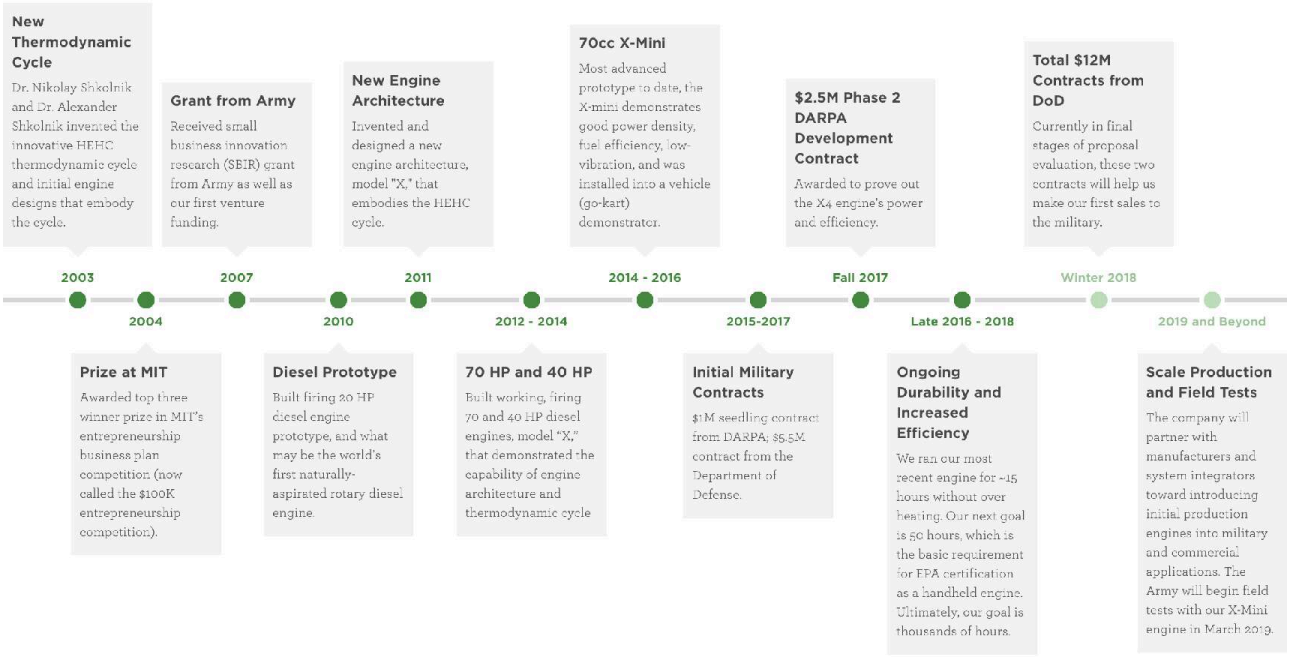
Household

Timeline

Our Accomplishments Since Our Last Raise

Since the close of our last raise, we began a multi-phase program funded by the Department of Defense. We exceeded all the reach goals set out by phase one, and were awarded a $2.5 million follow-on contract for phase two, which will run through October 2018, to prove out the engine's power and efficiency. This program is for our 30kW, 40hp X4 rotary engine for diesel and jet-fueled engines, which the military relies on. If we successfully complete phase two, we'll then transition the technology to large-scale production and sales, test the X4 in an application, and ramp up production.

Our X-mini engine, seen in the go-karts, is in the transition phase, nearly ready to be packaged into a generator application. We're halfway through a two-year $3 million contract from the Army's Rapid Innovation Fund which runs from March 2017 to March 2019 for the X-Mini engine. Field tests will start in March 2019.



Letter from Alexander Shkolnik (CEO) to Potential Investors

July 5, 2018

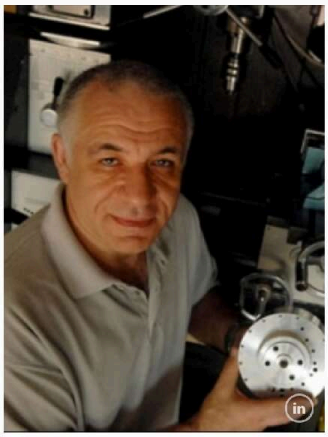
We are a father and son team: Nick, a physicist and accomplished inventor, and Alec, an MIT-trained computer scientist. We set out 14 years ago to fundamentally improve combustion engines in order to make an impact that will last for generations to come. The reality of today's engines is that ~80% of the energy in fuel is wasted as unutilized heat. That's unnecessary, and results in far too much CO2, CO, NOx and other emissions that negatively impact our environment. There have been many incremental improvements to engines over the last century – but few breakthroughs have had significant impact.

SHOW MORE

Meet the Founders

The founders are a father and son team: Nikolay Shkolnik holds a PhD in Physics from UConn, and is a recognized expert in the field of TRIZ (Theory of Inventive Problem Solving) – an systematic approach to innovation. Alexander Shkolnik holds a PhD from MIT's CSAIL lab. The rest of the team consists of 7 employees with degrees or work experience in combustion engine development.

Alexander Shkolnik



Nikolay Shkolnik

CEO

Entrepreneur, R&D technology developer/program manager, and technical specialist, with experience in applying his knowledge to living neuronal networks to robots to internal combustion engines.

CTO

Ph.D., Physics, General Relativity. Winner of Motorola Award for Creativity. Former clean energy program manager and TRIZ specialist, at GEN3 Partners.

AND THE REST OF THE TEAM

Victoria DiBacco

Raised $3,935,836 from 1198+ Investors

$251,000	$1,230,000	$999,999	$299,150	$200,000
February 2016 CONVERTIBLE NOTE	September 2016 CONVERTIBLE NOTE	April 2017 CONVERTIBLE NOTE	September 2017 CONVERTIBLE NOTE	May 2018 CONVERTIBLE NOTE

$100,000	$855,687
March 2019 CONVERTIBLE NOTE	March 2019

Building on $20M Invested Previously Into The Technology Development

This is a seed round. Initial funders include Bob Stearns, former CTO of Compaq; Jim Marsh, Retired Director of Lockheed Martin;

Barnaby Zelman

Former career in international trade and specialty chemical exporting and licensing worldwide. Pilot, investor, collector, and family man.

Andrew Douglas VanderPloeg

Passionate about everything business. Finance Manager. Babson (Olin) 2017 MBA Graduate

Stanley Forwand

Semi-retired cardiologist doing locum tenens work up to four days a month. the rest of my time I'm playing tennis.

Wijnand D Langeraar

Freelance GIS and mapping consultant with 4 decades of international professional experience. Lives in Bali for the last 25 years.

Manish Chabria

Currently working in Finance. Looking to invest in startup business that aims to provide a great product / service.

Tom Dalton

Sales executive

MORE INVESTORS

Interview

WF: What does Liquid Piston do? ^

– COLLAPSE ALL

LP: We created a new type of internal combustion engine. Our mission is to develop a totally new type of rotary internal combustion engine technology, by innovating the fundamentals of how engines work – how the fuel is converted to work and how the physical engine platform is made and functions.

Our technology is really grounded in physics, and we're trying to fundamentally change the thermodynamics of the engine to make a much more efficient cycle.

It's been over 100 years since the current thermodynamic cycles for a combustion

engine – basically how all heat engines operate – were introduced to the market. We all know these cycles as the gasoline (Otto) and diesel cycles operating in virtually all engines around us. The cycle describes the underlying physics of the engine. Not only have we developed an optimized cycle, but we've built prototype engines to implement this new cycle.

We're also embodying that cycle in a new type of engine design that offers still more efficiency, while also being extremely compact and lightweight. Our engine will be up to 10 times smaller and lighter than any other diesel engine out there, is quieter, and has near zero vibration, while potentially doubling the fuel efficiency over a gasoline engine, depending on the application and usage pattern.

In 2016, when we did our first round of fundraising, we were working on a small seedling program with DARPA. They asked us to look at a few key technical risk areas, and we successfully accomplished those. They wanted to resolve some key questions before starting a completely new engine program. At the end of 2016, we kicked off a clean-sheet engine program. That new development program features a 40 horsepower (HP) engine, and the objective is to really advance the state-of-the-art for engine efficiency and power-to-weight, especially for heavy-fueled engines, diesel and jet-fueled engines, which the military relies on. That in itself was a multi-phased program. We successfully completed the first phase of that program in September of 2017.

WF: How is it better than the current internal combustion engine?

LP: We're changing the physics processes of how the engine operates to make them more efficient. Today's engines, in a typical automotive drive cycle, only convert about 20% of the available energy in the fuel into useful mechanical work, and 80% of the energy is wasted as heat through exhaust, friction, and cooling losses.

Consider the Diesel engine, which is known to be more efficient than a gasoline engine; in reality, the Diesel combustion process is far from ideal. Diesels rely on injecting, mixing, and burning of the fuel while the piston is near "Top Dead Center", but these processes actually take a long time. By the time the engine is actually burning the fuel, the piston is already moving due to the expansion of the combustion gases and the pressure begins to drop, so the engine is not converting all of the heat addition into useful work – it's literally wasting this heat in the exhaust. Ideally, the engine would try to bring the piston to a dead halt at the top dead center position, to allow the fuel time to mix and burn, but that's almost impossible to do with a conventional piston architecture.

Instead, we are using a rotary engine, which allows us a lot of flexibility in the geometry to enable a longer period to burn all the fuel. If you look at the operation of our engine, you will see the arc of the rotor matches the arc of the housing. This means that the rotor continues turning at high speed, but near Top Dead Center position, the volume remains approximately constant for a longer period. This gives the engine more time, and therefore a much more complete combustion process before it starts expanding the gases. Even just applying this one feature of Constant Volume Combustion, the engine can extract 50% more energy vs. a Diesel engine.

The thermodynamics are described by the High Efficiency Hybrid Cycle (HEHC) that we developed. It utilizes 1) a high compression ratio; 2) constant volume combustion; and 3) over-expansion of gas until approximately atmospheric pressure is attained. The result is a 74% thermodynamic efficiency, which is significantly improved over gasoline or Diesel piston engines in use today. For comparison, the Diesel cycle has a thermodynamic efficiency of 57%. Efficiency is important because it translates to lower cost (less fuel consumption) for users and longer range for mobile applications.

Typical engine development is incremental, and may change a single parameter, often at the expense of another. We're really trying to improve the engine in all parameters, so we can combine a potential 2x improvement in fuel economy with up to a 10x reduction in size and weight over a diesel engine. And because it's 10x less material, in volume production manufacturing costs are anticipated to be quite a bit lower than today's engines, in a package that has little to no vibration, is well balanced and responsive, and is relatively quiet.

State of the art automotive gasoline engines reach peak efficiencies around 38%-40% Brake Thermal Efficiency (BTE), however, their average efficiency over a typical drive cycle is only on the order of 20% because efficiency drops when the engine is not running in its sweet spot, which it almost never is.

WF: What are the initial use cases?

LP: We have two versions of the engine under development – the tiny 70cc Spark Ignited X-Mini v3 (XMv3), which is working in the lab now as a proven engine prototype; and a larger 300cc Compression Ignited (Diesel / JP8), "X4" engine concept. The X4 weighs a meager 30 pounds, and fits in a 10x8x8" box – while producing 40 HP of power. The X4 is a more optimized, refined, and longer term

producing 70 HP of power. The X1, a more optimized, refined, and longer term engine development program, which is just in initial stages of the design phase.

Ultimately, we see the engine potentially replacing any combustion engine in use today. But we're starting with the military as a first potential customer. We have a lot of traction with them already, as they have such an immediate, dire need for an improved engine. Right now, the military relies on JP-8 fuel, which is a heavy fuel - so they are forced to use Diesel engines, which are big and heavy. Furthermore, consider that it can take up to 99 gallons of fuel to deliver a single gallon to the frontline. It's not just expensive in terms of dollars; this oil must be protected on its journey, and we lose soldiers some times in protecting this fuel on its way to the frontline. With the military, costs can literally be measured in human lives, so efficiency is especially critical. They are a good customer for us, because they are willing to help pay for development, and in the long term, are willing to purchase large numbers of engines to power all of their equipment. In fact, a single generator contract (for one engine size) can be on the order of $200M, enough to build a viable business.

Within the military, there are a number of applications that our engine can serve, with similar immediate and painful needs for better power systems. For example, consider the standard 30kW Diesel generators that power mobile command centers today - they weigh 2700 pounds, and we could reduce this to < 200 pounds. A few people could lift and move this, rather than a whole truck, so it's a really game changing technology.

We're also looking at other applications, for example drones, power for other land, sea, and air vehicles, robotics systems, etc. there's just so many applications even within that one target customer. Of course, the military is just a starting point - there are similar applications on the commercial side that we can move into when ready.

WF: In the long term, what kind of products will use your engine?

LP: The first product/application pathway is a prototype engine which we have been working on and which is running in the lab right now, called the "X mini". This engine could be used to power, for example, various types of lawn equipment, like chainsaws or leaf blowers. The X-mini is a Spark-Ignited engine that displaces 70cc, has 3 firing chambers (despite of having just two moving parts), is about the size of a grapefruit and weighs about 4 pounds. Even though it's so tiny, it's produces 3hp right now, and it's on its way to producing up to 5 hp when fully developed. Still, even at 3hp, it's already far better than anything out there today. You'd get a lot more power, lower the weight, and because there's no vibration, you can use handheld equipment for longer without feeling like your hand will fall off. We can also see applications in small vehicles, like mopeds, and drones, which could also benefit from their light weight and lessened vibration.

We are also in discussions with the DoD to develop a slightly larger engine. This is a 300cc displacement engine that is expected to produce about 40 hp. This engine will fit in a 10x8x8" box, and weigh less than 30 pounds. While the military applications (e.g. drones and generators) are obvious, consider that cars are widely predicted to move more toward autonomous driving, and electrification of the drivetrain, and we want to incorporate our engines into future vehicles in a way that takes advantage of these changes.

There are electric cars with a 200-300 mile range, but this range comes at the cost of having large, heavy and expensive battery packs, and and charging outside the home is a hassle. We envision a car that has a small battery pack that can cover 95% of your daily driving needs, and if you need longer range, our generator would kick in. It'd be lightweight and you could even have it as an "attachment" sitting in a little box in your trunk. You could use that to charge up your batteries and then, every couple hundred miles, you could refuel the generator itself at any standard gas station, rather than having to find a special charging station. We therefore make EVs affordable for everyone, while allowing consumers the ability to rapidly refuel and the range they are accustomed to. However, perhaps even more important - as our engine is so efficient, you'd actually have a lower CO_2 footprint if you charge your battery with our engine, rather than plugging into the US power grid. This is because the power grid relies on significant sources of fossil fuel, and generation, transmission, distribution, and charging networks turn out to be less efficient than a small generator based on our engine.

WF: How long have you been working on this?

LP: Nick's been working on the physics of the engine for something like 20 years. As a physicist, the inefficiency of present-day engines always bothered him, and he saw this opportunity to make a much more efficient engine. In the late 1990s, while he was a clean energy program manager working at an innovation think tank, he did an analysis of what would be the most probable path of development for power conversion devices (evaluating fuel cells, supercapacitors, batteries, etc.), and concluded that, basically, engines are here to stay. This conclusion has been affirmed by a number of studies, and that's when he decided to really make a push to invent a better engine that wasn't so inefficient, large, and polluting.

We [Nick and Alec] teamed up in 2004 and applied physics and optimization to improve the efficiency and fundamental operation of the combustion engine. We think there's a lot of room for improvement, and that engines can be pushed to convert at least half of the fuel energy to actual work, as opposed to the current 20%. That's a two to three time improvement in efficiency, which can have a very big impact.

We were always targeting this ultra high efficiency, and we've been actively working on this for about a decade. When we first started out in 2004, we thought we were going to do an auxiliary power unit for long-haul trucks. It wasn't until last year that we found out about this incredible need within the military, and last year we entered into a contract with DARPA (Defense Advanced Research Projects Agency), which is basically the research arm of the military. So far, close to $18 million has been invested in the technology, through venture capital and $1M through DARPA. We are now on our fourth completely new generation of the engine architecture. This is the final configuration, and embodies the same thermodynamic cycle as the original "LiquidPiston" engine, but each iteration got simpler, easier to seal, and you just can't get any simpler than the 'X' engine that we have right now.

WF: How technically challenging is what you've built?

LP: The 'X' rotary engine is an incredibly simple device that has just two moving parts: the rotor and the shaft. Still, it implements all of the attributes of our optimized thermodynamic cycle. That was the first thing we had to work out: how to capture our cycle with a new kind of engine. If you look at the Wankel engine, it has a peanut-shaped housing and a triangular rotor. Our engine has the opposite - a peanut rotor inside a three-lobed housing. Because of this inversion, we can achieve a higher compression ratio, constant volume combustion, and over expansion (the processes that characterize our improved high efficiency cycle).

Second was the most critical aspect of any kind of rotary engine -- the sealing, which prevents gas from leaving your high-pressure chamber. When trying to achieve high efficiency, it's really important to keep the gas in the chamber. Unlike the Wankel engine, our apex seals are stationary, so they don't have the dynamics challenges that the old Wankel engine did. In addition, we're able to supply lubricant directly to these areas, so the engine can be really durable. We can reduce oil consumption by a full order of magnitude by directly lubricating the seals, as opposed to consuming oil in the combustion chamber which is what the Wankel does. We can therefore solve the fuel consumption, lubrication, emissions and durability challenges experienced by the old Wankel, while sharing the inherent simplicity and compact operation of the rotary engine.

So, it's been quite the process, first in selecting the most appropriate architecture to embody our cycle, and then getting all of the implementation details right. In fact, most of the focus of our work with DARPA this past year was focused around sealing. Once we figured that out, we automatically have a much better combustion system.

WF: Will you manufacture the engines yourself or outsource it?

LP: We're not planning to take our engines into high-volume production directly. We are opting for a capital-efficient business model that leverages our intellectual property position. We will establish partnerships in the industry and in the defense base, and work with manufacturers and Original Equipment Manufacturers (OEMs) to bring our products to market. Ultimately, we're going to be designing custom engines and providing engineering and testing services as a subcontractor for the manufacturer. This is pretty standard in the industry, for example GM will usually subcontract their engine development as well to one of a handful of engine design houses (like FEV, AVL, Ricardo, or IAV). We will ask them to fund our development for each program. In addition – and in the long term, this would become the largest income stream for the business, we will also charge royalties and upfront license fees for engines produced by partners.

For us, it's incredibly important to find a first partner that will adopt and embrace the technology and take it to market, and that is what we are working to achieve with highest priority.

WF: How many patents do you have and what stage are they in?

LP: The company has 27 patents that are issued or pending, which cover the technology. We are working with a great IP attorney, Bruce Sunstein, out of Boston, who is famous for patenting the Segway. Our portfolio is deep - at the top, we have issued patents that cover the entire thermodynamic cycle. One layer down from the cycle, we have issued patents that cover the 'X' engine architecture. The next layer covers implementation details - for example the strategies for cooling, lubricating and controlling the engine.

WF: Do you have customers right now?

LP: Right now, we have two potential contracts with the DoD that are in final stages of proposal evaluation. These contracts could total up to over 12 million dollars, and those could come through later this year. These contracts don't pay for everything, but if we can get some of these military contracts with non-dilutive funding in place, it'll really help us and investors along.

One of these funding sources takes technologies that are demonstrated but not quite to the point where they are ready to be embraced, and they try to cross them over into that tipping point where they can be adopted. That's a $3 million program that we submitted, in partnership with two major defense contractors - one of which is very well-known for making drones, and the other is a leader in providing military generator sets. This is really great for us, because not only does it fund our development of the product, but we'll also have a partnership with a manufacturer with the sales distribution and manufacturing channels to sell the product to the military. At the end of this 24 month program and $3 million effort, we'll have a working, running diesel generator that builds on our existing technology, will be field-tested by the Army, will be environmentally tested by our development partners, and we will be lined up perfectly with a potential future strategic partner.

WF: Why is the military an ideal first customer for you?

LP: A single generator contract in the military can be on the order of about $200 million. That's for a single contract for about a five year period. And they'll issue a new contract for every different engine size. We can build a lucrative business just in this DoD genset application. We view it as a stepping stone to an ultimate vision, but you can see how we can build a very nice and sustainable business here.

And they have relatively low barriers to entry. In order to produce a new type of engine, a company must meet emission standards, warranty suitable durability for the customer's application and a reasonable price to enter the market. The military has clear performance needs and, depending on the application, durability and emissions standards that are generally more lax than the general consumer market, making this early hurdle of production easier to get over. It saves time and money at this stage to not have to worry about such stringent qualifications. In the long term we are confident that the engine can meet today's emissions and durability expectations, but its beneficial to have a first customer that can relax these requirements.

WF: What technical challenges do you still need to solve?

LP: In the development process we have at least two phases: research, which is inventive, and development, which is more focused on engineering and productization. For the XMv3 line (where efficiency is less optimized), our research is mostly done, and we're entering into the development stage where most of the problems become engineering tasks. It's a standard engineering development focused on durability and emission that will require time and resources but the major inventive processes have already been accomplished.

Our next major phase will focus on increasing and providing durability. All our efforts to-date have been improving the performance and efficiency of our engine. We have the engine running in steady-state, so that it won't overheat when you run it for a long period of time. On our most recent engine, we were able to run it for about 15 hours. Our next goal is 50 hours, which is the basic requirement for EPA certification as a handheld engine. Our ultimate goal is to have it run for hundreds or thousands of hours, but that will require additional development.

For DARPA, we also have another program under way, which is really pushing the limits of efficiency and the power density and tightly integrating the entire engine into a neat package. So far, we've been very focused on the engine core, and have yet to focus on the package, but the DARPA program may cover that.

WF: Who are your competitors?

LP: There are a couple other startups doing combustion engines. Most of them focus on relatively large engines because they're going after the automotive and trucking industry, which is worth hundreds of billions of dollars. But even a very good, proven technology can take about 20 years to be adopted into the general automotive space, which is why we've moved away from that.

We're focused on much smaller engines, where there's much less development. But even though, right now, this is a step away from the auto industry, we see a lot of room for growth even within that industry as more and more cars become self-driving vehicles. Then, you'll really be looking for lighter vehicles and smaller engines, and we'll be well-positioned for that.

WF: How big is the market?

LP: The market is $400 billion for combustion engines. About 75% of that is cars and trucks, but that still leaves over $100 billion for other applications. That non-

automotive market is where we'll initially enter. Still, though, that's a huge market, and you can carve out really niche applications that are still sizeable enough to build a business. As an example, the handheld equipment engine market is itself a $7 billion market.

Longer-term, as we noted earlier, LiquidPiston plans to be in the range-extender engine market as the automotive industry increasingly becomes hybrid electric. Our power density and high-efficiency will make our engine an ideal fit for that application.

WF: How much will your engine cost?

LP: In single quantity our 3-5 HP engine would cost about $30,000, and in fact we are planning on making limited quantities of "development kits" available to select strategic partners. In a quantity of 500,000, the manufacturing cost of the engine core drops to a much lower number, that's competitive with piston engines, except that we're going to have a lot more power coming out of the package.

WF: Why are you guys the right team?

LP: We have a really solid partnership and team, with really complementary backgrounds. I'm [Nick] a mechanical engineer and physicist with a PhD in physics from the University of Connecticut. All my life, I have been interested in energy conversion devices and, specifically, engines.

My [Alec's] background is primarily technical. I studied at Emory University in computer science, mathematics, neuroscience, and behavioral biology, and did my Masters jointly at Georgia Tech. Then, I got my PhD at MIT in computer science with a focus on robotics, funded by DARPA. I see all these things as being similar: neurons and robots and engines. They're all technical systems with complicated dynamics. I just like solving tough technical challenges and playing with models. That's what motivates me.

We founded the company while Alec was doing his PhD at MIT. While there, we competed in the 50K Competition, and took second place, beating over 100 teams. Our advisor in the competition became our first venture capital investor a few years later, which really helped form the company.

From our background, you can clearly see that we, the founders, are outsiders of the engine industry. We believe this to be a great asset for the company as it is very difficult for people within the engine industry to overcome the psychological inertia that is inherent to all engineers and, more generally, to humans. Sometimes it takes an outsiders to see the world in a different light and to come up with understanding of problems and, correspondingly, with solutions, which are "hidden" to insiders. TRIZ – (Russian acronym that stands for Theory of Inventive Problem Solving) – helped us a lot in this process. Having said this, we also recognize the fact that being outsiders (read "amateurs") could be a great detriment to the company. This is why, from day one of our company existence, we have surrounded ourselves with true experts in engine technology. Together, we formed a winning combination of inventiveness, rigorous analysis and methodical engineering, which allowed us to solve myriads of technical challenges and, finally, to build a fully functional, operating engine.

We have a few other people on the management team: Per Suneby, who got an MBA from Harvard Business School, and worked for GE and Motorola doing program management. About 20 years ago, he jumped into startups and since then, he's been an entrepreneur working with various startups including LiquidPiston, as well as spending some time as a Venture Partner with a leading venture capital firm.

The other person to highlight is Dr. Tony Tether, the former director of DARPA. He was the longest serving director in DARPA's history, and managed over $25 billion in various technology development programs during his tenure. We are honored to welcome Tony to our board of directors and, being really connected in the industry, he can help connect us with potential military contractor partners.

WF: What results show the improved efficiency?

State of the art automotive gasoline engines reach peak efficiencies around 38% Brake Thermal Efficiency (BTE), however their average efficiency over a typical drive cycle is only on the order of 20% because efficiency drops when the engine is not running in its sweet spot, which it almost never is.

Our XMv3 engine is a tiny engine – with an effective compression displacement of only 19cc per chamber (the entire engine displaces 70cc, but each individual chamber compresses only 19cc). We have measured 18% BTE on gasoline, and extrapolated result of 21% BTE on diesel (based on firing one chamber). For reference, a competitive 23cc handheld gasoline engine, documented in Gordan Blair's textbook on engines, achieves only 12% BTE – so the XMv3 shows a 50% improvement already. The XMv3, however, was designed for low cost lawn and

garden applications – it was not designed for optimal efficiency. Supported by various thermodynamic modeling tools, extrapolating our engine to a larger size in the model, when the X engine is scaled up to automotive size and operating on diesel fuel in Compression Ignition mode, the engine can reach a peak efficiency of 47-57% and, most importantly, the average efficiency on the order of 40-50%. The fuel consumption of the vehicle is directly proportional to this average efficiency.

Ask a Question

Type your question here... ASK QUESTION

John Goodin Aug 2

Alex,

By your answer I can see why your having trouble raising money for your fantastic engine. Gearheads/knuckleheads go into their garage and power Go Karts with unusual engines. Even Henry Ford's first car (Ford Quadricycle) was a garage build, and until he (Ford) won the 1909 New York to Seattle cross country race (under stress), Ford was just another tinker/inventor (there were hundreds of would be car manufacturers). You may have gotten noticed for your Go Kart, but not in the way you think or needed.

Leaving the military and their motivations out of this .. "Certification for emissions" is doublespeak (especially to investors anxious for you to get to the meat of your intent) and of little consequence to an African village or any third world application. They (African village) need what you are promising .. efficient (fuel), small, powerful, long-running (MTBO), cheap to maintain (few moving parts) .. this is the gauntlet (stress) that will prove the worth of what your invention is supposed to provide (you only need one or two and should be an offshoot/civilian version of your product with DARPA). That will get you the serious notice you want and need

As for aerospace development (again doublespeak), while seeming a perfect application for your engine, the regulatory hurdles (FAA and EASA) is a huge black hole to pour money into (ask Mistral Engines (www.mistral-engines.com) about their slog/multi-year aviation rotary engine efforts .. also ask them about how you/Liquid Piston and Mazda have screwed up their investment/future, after spending tens of millions from 2001 to present).

Your best effort for a segment use of your tech (for direct drive) is a marine version of your diesel engine .. no regulatory hurdles, engine size will be a miracle/godsend for the replacement market (and welcome by marine engineers/architects for new designs), rotary inertia for the abstract inertia forces of the sea (a right angle configuration of two engines might give a secondary gyro stabilization effect), high fuel efficiency sensitivity, MTBO and few moving parts (a real game changer)

.

Timing is everything (the 4th dimension is a killer to ambition) and your engine would have been great for the small engine market, however the tide of electric engines is a force you can't compete with, the best will be ancillary APU and the market is ill-defined at present (with exception of Train engines/locomotives, but that is a mature large engine APU market).

As for our dependence on oil resources, the paradigm shift to electric propulsion and the myriad of tech that will spin a generator to power those electric motors is the reality to deal with .. I could care less about saving fossil fuel resources (but it will be nice/efficient). Your tech (and its job) will end the reign of the primitive (100+ yo), complicated, thrashing piston internal combustion engine, redeeming all the promises of rotary engines made over the decades, bringing real value to billions of lives all over the world.

When the Wankel engine was promoted/invested in .. visions of millions of car engines were the bonanza/market .. time has moved on (4th dimension), and the car market is headed in another direction (ask Mazda about their Wankel efforts in the face of coming electric cars). Your amazing tech has real-world application and merit. You need to get serious (i'm sure your military sponsors are deadly serious) .. You need to S#%TCAN the Go Kart and find a real application to demo the assets/advantages of your engine.

As reference/parallel, a crowdfunding/Indiegogo campaign for a new tech was initiated (and fulfilled/oversubscribed) bringing real results to a potential billion+ people all over the world killing their dependence/poverty cycle on fossil fuels and

people all over the world killing their dependence/poverty cycle on fossil fuels and they PR'd it in an African village to shine the (spot)light (pun intended) of their tech to the investment world

https://www.youtube.com/watch?v=qwEmgwrVUag

If you noodle around on YouTube you will find many garage tinkers with crude gravity lights .. Riddiford and Reeves stepped up and defined its parameters and its need/benefit turning a novelty into a real product/movement to benefit mankind. Much like Ford, "putting it on the line" separates the great men from the boys whining about "certifications for emissions" or "it's a long, extensive process".

Don't defend your mistake (Go Kart) .. don't let the perfect be the enemy of the good .. Greatness is at your feet and the 4th dimension haunts you!

ANSWER IGNORE

Anuj Sethi INVESTOR Apr 2
Hi, "Field tests will start in March 2019." Any feedback on these tests yet? Thanks.
ANSWER IGNORE

Daryl Diamond INVESTOR Mar 26
Can this engine work effectively as a miniature hobby aircraft engine? E.g. 1 cc diesel?
ANSWER IGNORE

Michael Gately Mar 13
Any chance you would be willing to consider lowering the min investment to 500 for the last couple of days to try and gain a few more investors? I've invested in 6 different wefunder startups but never more than 500 at a time
ANSWER IGNORE

Steve Gara INVESTOR Feb 24 2018
Hello, I wanted to find out what your plan is to eventually distribute shares of equity to your investors?
ANSWER IGNORE

Alan Jacobson Oct 28 2017
Hi, I hope things are going well. Will you be providing an update? And when do you think perks will go out? Thanks
ANSWER IGNORE

Olivier Willot Apr 5 2017
Following up on the answer of 3 Apr regarding the burn rate, it seems to me that the burn rate is pretty high for a very small company focused mostly on the creation and commercialization of IP. Can you please provide a more precise breakdown? How many employees do you have in total including the two founders, and how many are working on engineering / design / science? What is the range of employee salaries in the firm (min, max, average)? What salaries are the two founders taking? How much of the $3M+ burn is allocated to salaries?
ANSWER IGNORE

Jonathan Madden INVESTOR Apr 25
Hi Alex,
Do you foresee a 3rd round of CFing for LP?(understanding it would be down the road),Thank you.

ANSWER IGNORE

Dwaine Umberger Apr 6
How do you keep the engine cool?
ANSWER IGNORE

Daryl Diamond INVESTOR Mar 26
Is it possible to create an engine without individual counterbalances per rotor? For instance, by ganging together multiple cylinders? For instance, 2 units 180 degrees apart, or 4 units with 2 inner units 180 degrees apart from the 2 outer units?
ANSWER IGNORE

Rex Plumlee Mar 25
On March 11th you replied to a question that a lengthy update to the DARPA contract would be posted in the next day or so, did I miss it?
ANSWER IGNORE

Paul Collins Mar 22
How is this arrangement lubricated?

How is this arrangement fabricated?

ANSWER IGNORE

M Jellad Mar 20

Dear One,

What is your pre-Money valuation as present !? I have commited $1000, how many shares I will get? On a personal level, what would be your aspired return multiple you realistically believe you can aim for and which year would that exit be !? (and understand delays could occurred , I am just trying to your aim and I am not asking your to promise me anything whatsoever or given me any sorts of guarantees!!

Thanks in advance

ANSWER IGNORE

Daryl Diamond Mar 17

Would you please extrapolate the engine concept to 10K HP? How would it compare to a Wartsila-Sulzer RTA96-C? Would it be more efficient than 50%? Would it run at around 100 RPM?

ANSWER IGNORE

Michael Kelley Mar 13

Looking forward to getting a t-shirt. This will help get advertised in the North West.

ANSWER IGNORE

Jerry Foster Mar 12

I would endeavour to have us connect. jfoster@windular.com (www.windular.com)

ANSWER IGNORE

Jay Riordan Mar 9

You're asking for an investment; I don't see how investors are compensated or a break down once the company becomes profitable.

ANSWER IGNORE

Douglas Greenwood Feb 22

What is the altitude ceiling for your engine? I assume turbocharging will be necessary? Are there any cooling challenges at the ceiling? What is the % weight and volume increase to add the turbocharger (and heat sinks)?

ANSWER IGNORE

Venkatraman Swaminathan Feb 14

Have you started production or are you still working on development? If the latter is true, what's holding you up from production? Yes, I read you'll not directly produce the engines but license them. And if so, when will you start earning production revenues from selling to lawnmower companies, defense requirements etc?

ANSWER IGNORE

Javier Villacis Jan 3

Does the X engine can be fueled with gaseous fuels?

ANSWER IGNORE

MORE QUESTIONS