Tour Engine, Inc.

Revolutionary Internal Combustion Engine

Efficient, Green, Simple

3rd Conference on Propulsion Technologies for Unmanned Aerial Vehicles

(30/1/2014, Technion, Israel)

Dr. Oded Tour

Company Milestones

Two successful prototypes

Demonstrating the mechanical and thermodynamic feasibility

Awarded three grants for the development of prototype II

Additional proposals will be submitted (one pending)

Six issued patents

US, China and South Korea. Additional patents pending worldwide (US, EU, Japan, China, India and Russia)

Selected to present at major conferences

ARPA-E Summit, NERL IGF, DOE DEER, and SAE World Congress

Discussions with leading OEM

Investing internal resources and considering joint development

TourEngine™ - Key Features

Efficient - Unparalleled Potential

20% - 50% increase in efficiency

From 33% BTE to above 50% BTE

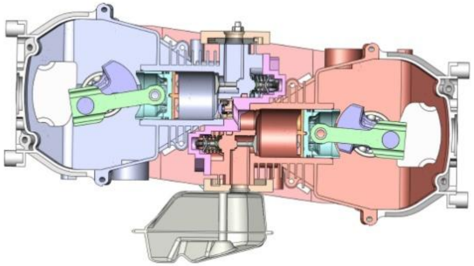
(Based on three independent computer models)

Green - Reduced Emissions

Proportional reduction in CO_2 emissions

(Potential reduction in other emissions: NOx, HC and CO)

Simple - standard components



Based on standard components – Easy to adopt

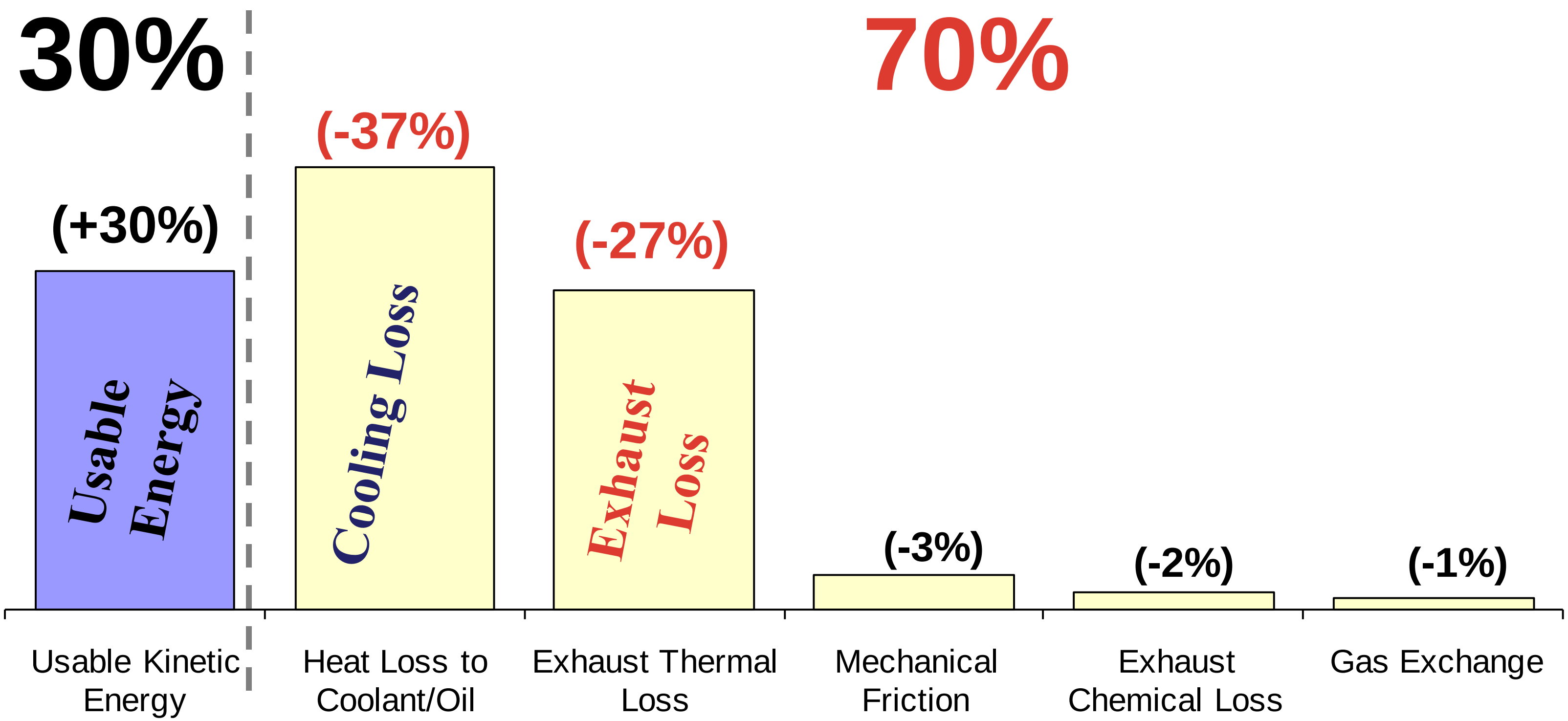
(Based on standard technology: Piston/cylinder)

The Problem of Conventional Engines

Significant Cooling and Exhaust Losses

Today's engines' energy distribution at full load

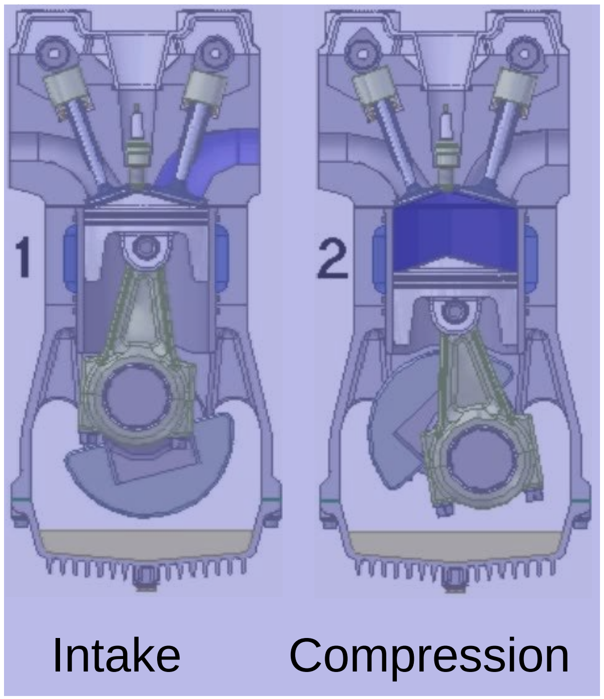
(Source, Ricardo Inc.)



High **cooling** and **exhaust** losses are inherent features of **<u>any</u>** engine that use the same cylinder for compression and combustion

Conflicting Optimization Requirements

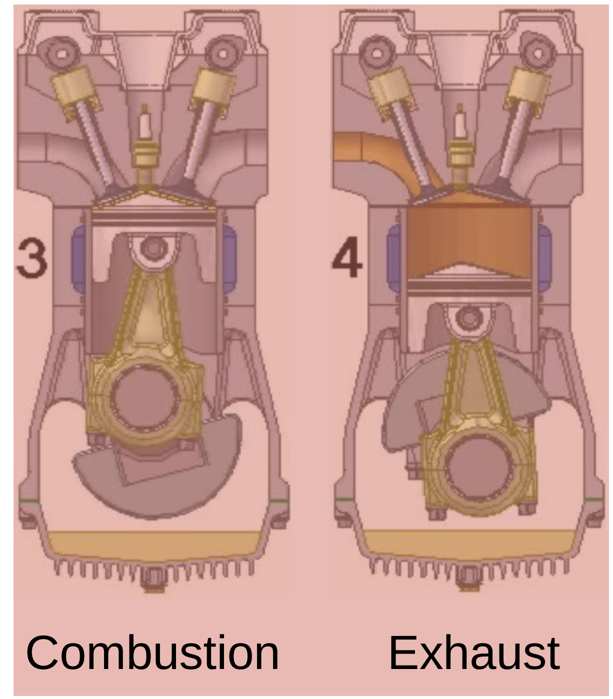
Two cold strokes



(-37%) Cooling loss

Radiator “steals” heat for efficient **Intake** and **Compression**

Two hot strokes



(-27%) Exhaust loss

Combustion energy only partly used - exhausted gas contains unutilized energy

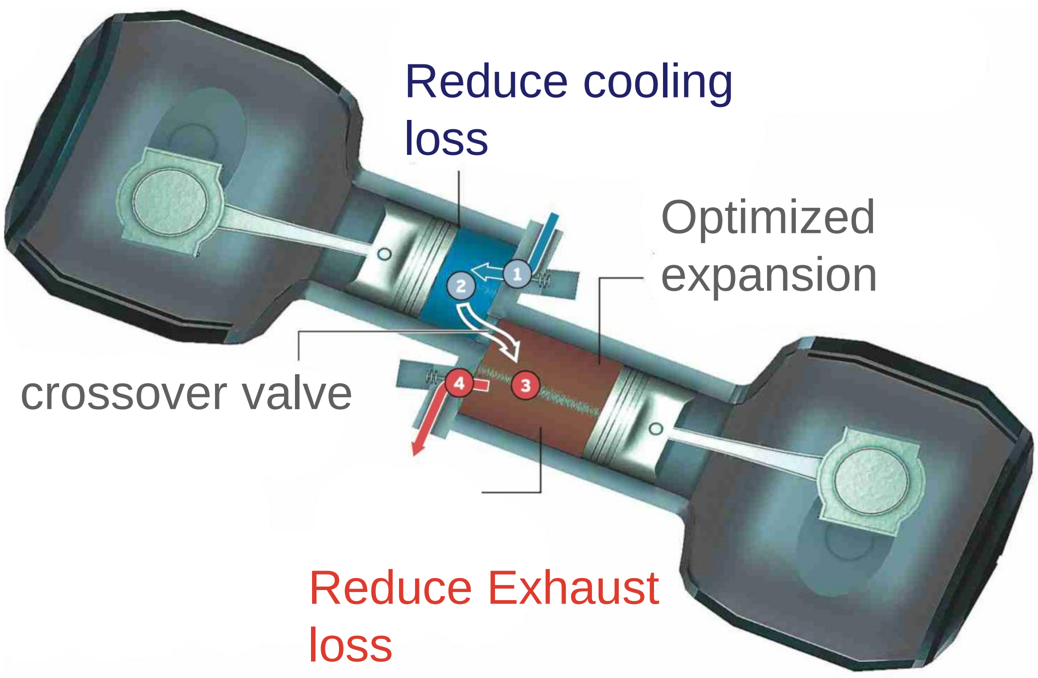
(+30%) Useful energy – for modern gasoline engines

Our Solution – Superior Thermal Management

Integral-Cycle Split Engine

Cold Cylinder

for **Intake** and **Compression**



Hot Cylinder

for **Combustion** and **Exhaust**

The engine architecture enables a higher level of *engineering freedom* to better optimize engine components to their specific task

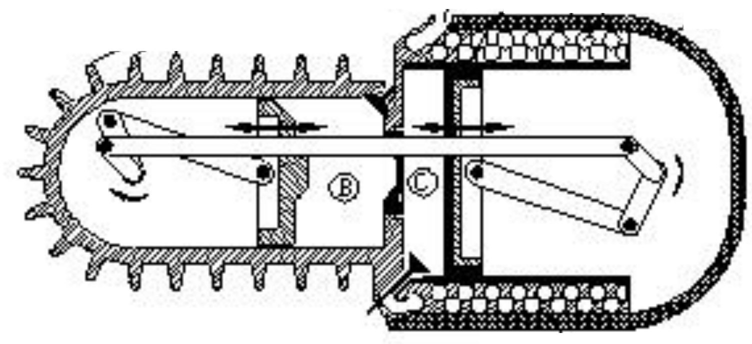
Our Solution – Higher Efficiency

Reducing the major losses of today's engines

Reducing Cooling Loss

- Intake and compression occur in a separate cylinder that is relatively cold, therefore less active cooling is needed.
- The power cylinder will be cooled by the extra expansion of the working fluid.

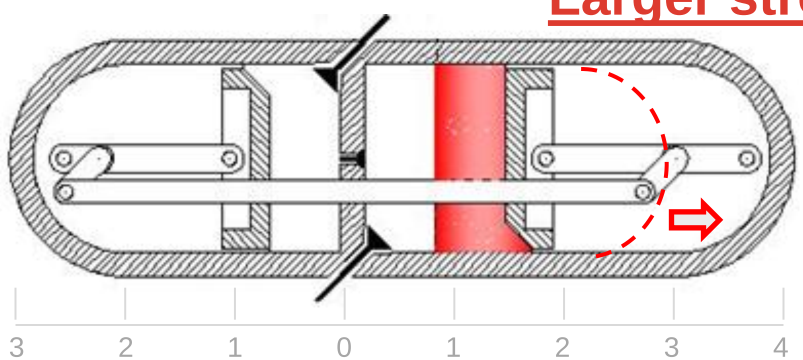
Larger bore



Reducing Exhaust Loss

- Enable the combusted gas to expand further and reject less heat is.

Larger stroke



(The combustion cylinder volume is bigger than the compression cylinder volume)

Reducing Dead Volume

- Design a split-cycle with high volumetric efficiency

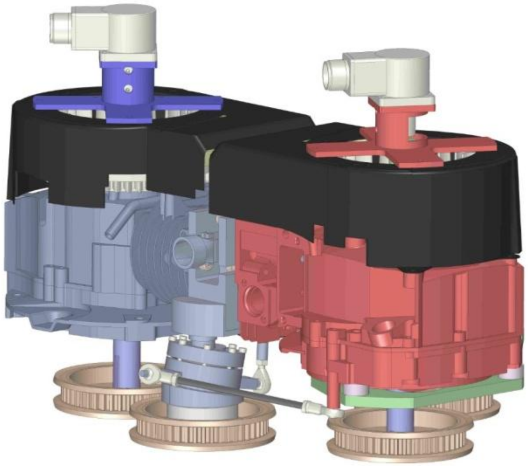
TourEngine™ Prototypes I and II

Successfully developed two operational engines

- **Demonstrating the mechanical feasibility**
  - Smooth operation
  - Dynamic response
  - Neglectable energy loss at charge transfer
- **Designed from two off-the-shelf engines**
  - 85% parts compatibility with common engines
  - Ease of manufacturing
- **Prototype II: Optimize crossover valve to enable technology**

Prototype I

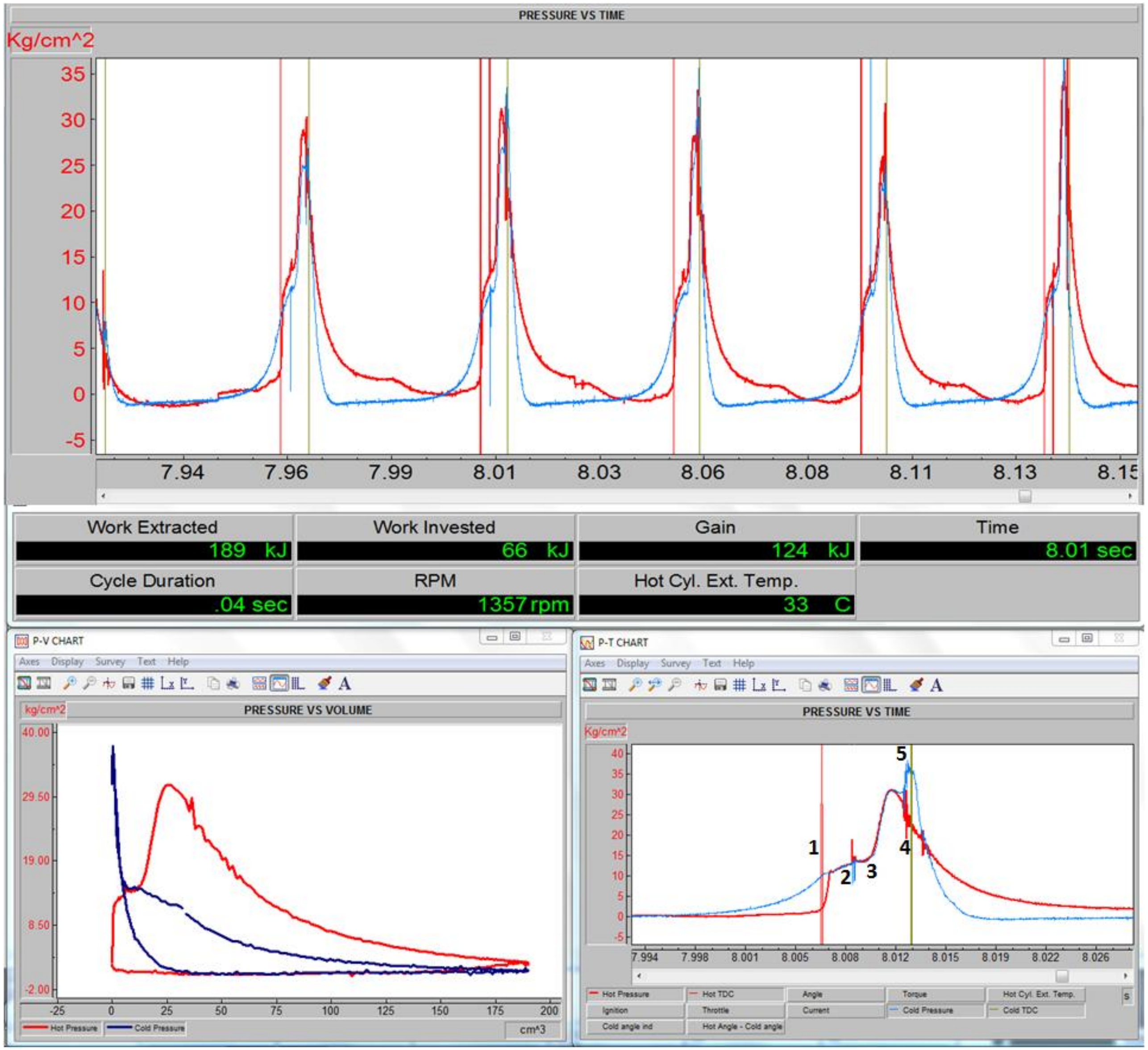
Prototype II



With the support of the Israeli Department of Energy and Water and California's EISG program

TourEngine™ prototype II

Data gathered during engine operation and testing



Top: Five cycles showing in-cylinder pressure as a function of time.

Middle: A set of parameters relating to a specific cycle.

Bottom Right: Zooming on a specific cycle (p-t).

Bottom left: Pressure as a function of volume for the same specific cycle (p-V).

Crossover Mechanism Design - Key Requirements

1) Minimal resistance: **Demonstrated**

During the transfer of the charge from the compression to the expansion cylinder.

2) Durable: **New IP**

Current crossover valves open and close within ~ 45^{o} crankshaft :

Open → Accelerate → decelerate → change direction → Accelerate → Decelerate → Close

This is 4 faster than a typical valve (Attempt to avoids extremely rapid actuation).

3) Minimal dead volume: **New IP**

In the compression cylinder, within the crossover valve and in the expansion cylinder

New IP: Undisclosed

Advantages

Slower crossover valves - **inertia reduced to 25%** relative to previous Tour crossover valve. Comparable to common engine systems.
Eliminate the dead volume within the crossover valve
Minimal dead volume in the two cylinders
Conventional sealing methodology in all design aspect

Prototype first run in Q2 2014

GT-Power* Modeling

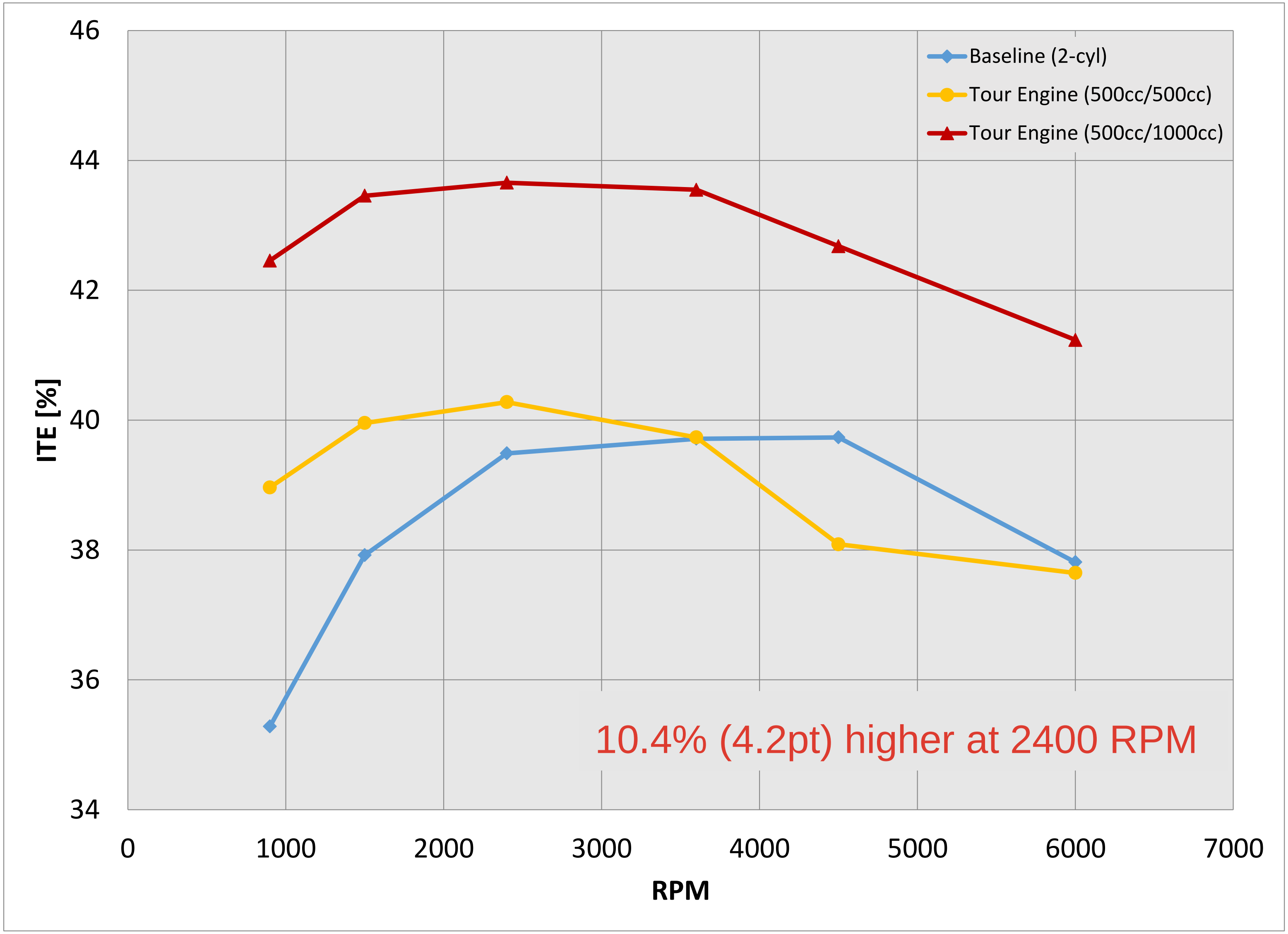
Dr. Michael Wahl

Modeling 3 Engines:

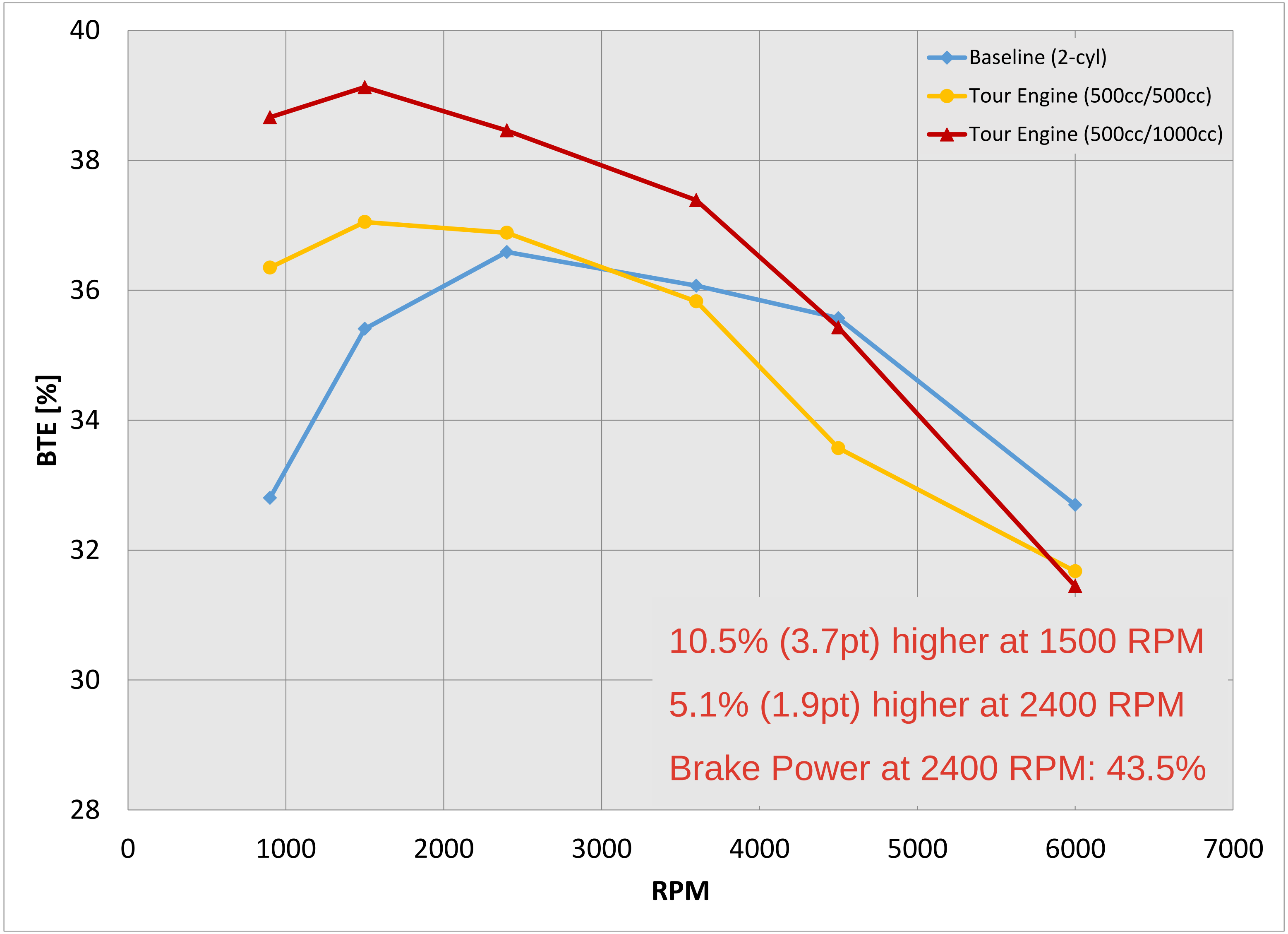
- **Baseline Engine:** Two cylinders (500 cc each)
- **Tour Engine:**
  - 500 cc/500 cc (Compression / Expansion)
  - 500 cc/1000 cc (Compression / Expansion)

*GT-Power software is widely used in the engine industry for 1-D transient engine performance simulations.

Indicated Thermal Efficiency (ITE) as a function of RPM



Brake Thermal Efficiency (BTE) as a function of RPM

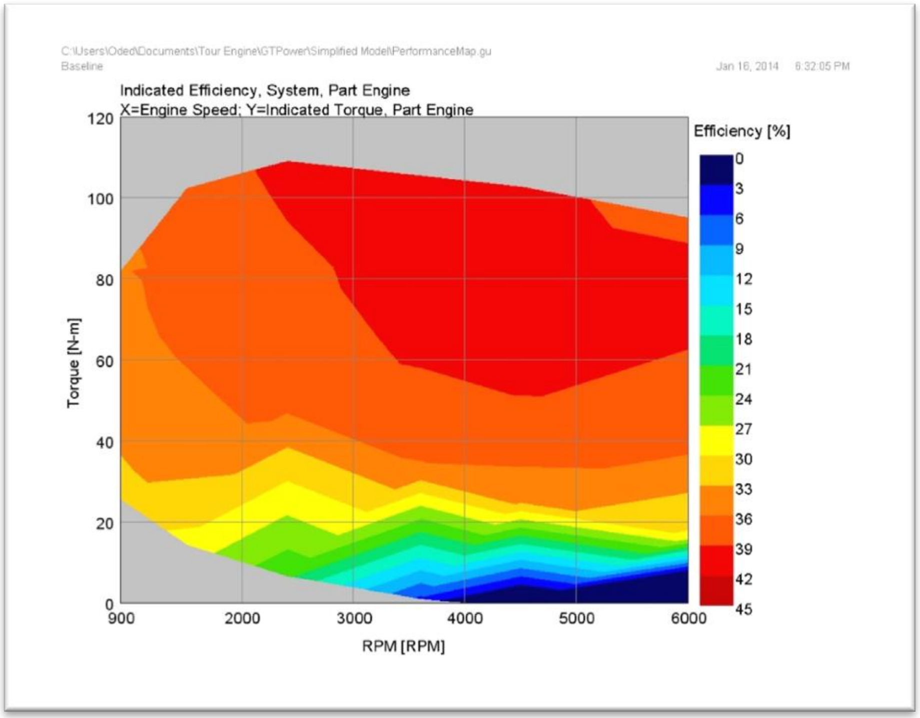


Performance Map

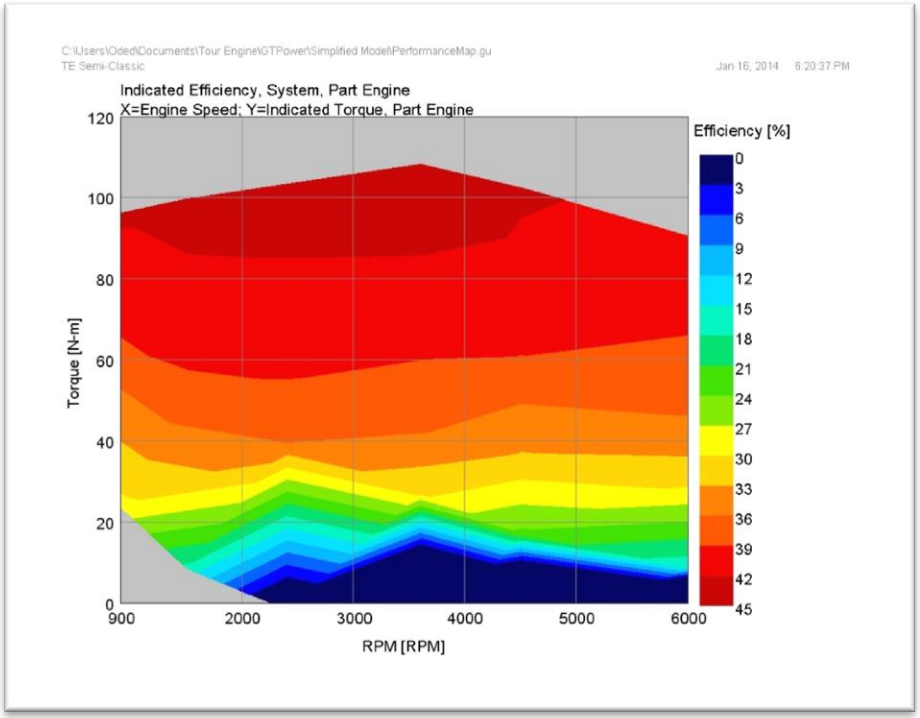
- **X-Axis: RPM**
- **Y-Axis: Brake or Indicated torque**
- **Contour: ITE or BTE**
- **Modeled engine type: Gasoline SI engine, naturally aspirated**
- **Torque modulated by throttle, target Air/Fuel Ratio: 14.5**
- **Baseline: 2-cyl. 500cc each**
- **Tour Engine: 500cc/1000cc (Comp/Exp) for best BTE**

Performance Map - Indicated Thermal Efficiency (ITE)

Baseline



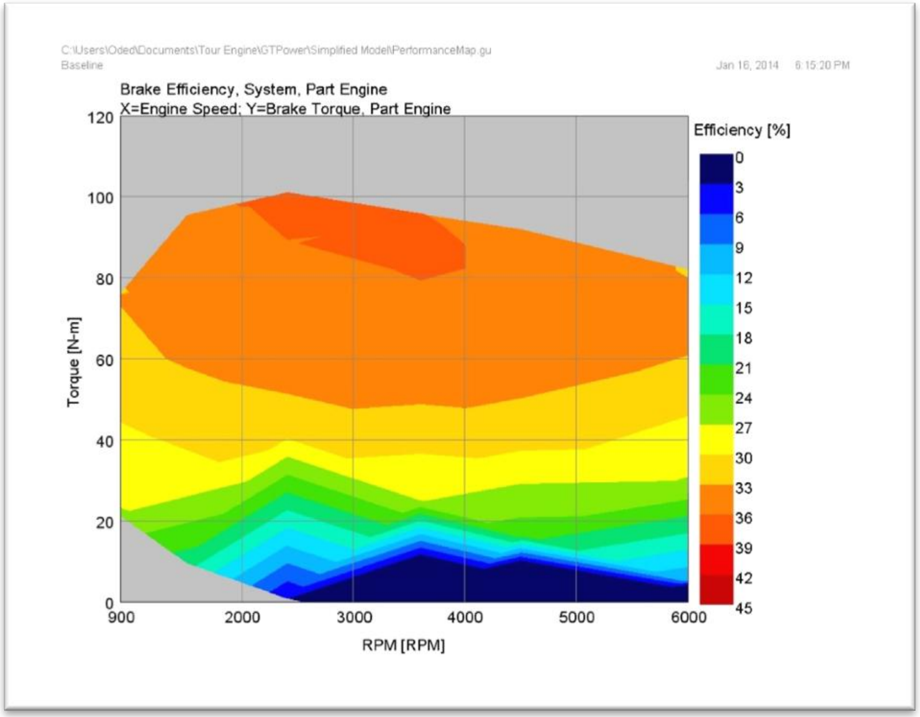
Tour Engine (500cc/1000cc Expansion)



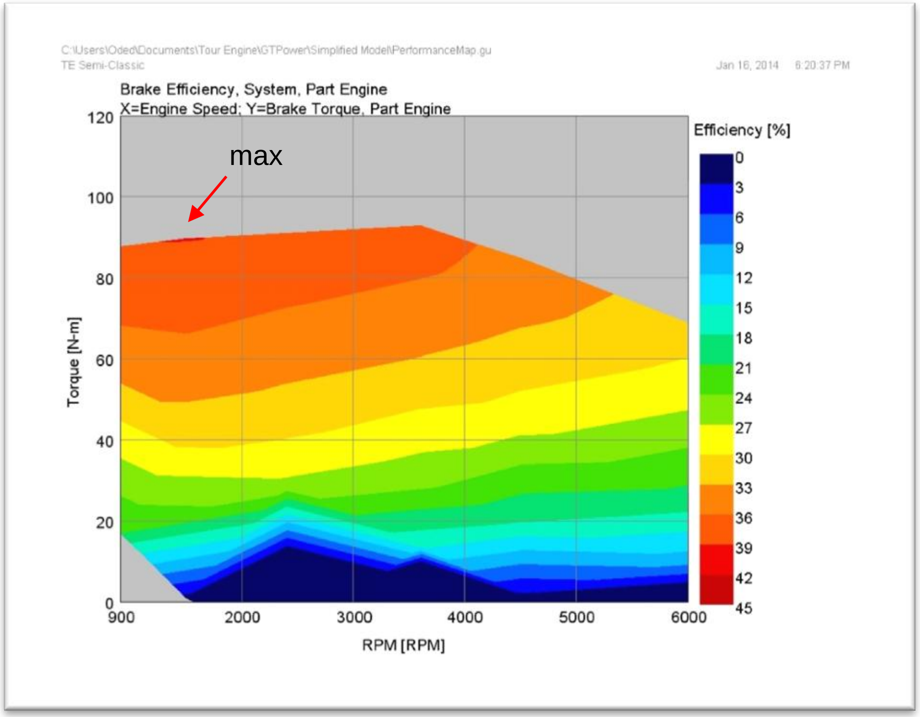
The Tour engine has a broader area of increased ITE compared to Baseline engine at comparable torque levels, particularly at lower loads

Performance Map - BTE

Baseline



Tour Engine (500cc/1000cc Expansion)



The Tour engine has large areas of increased BTE compared to Baseline at engine speeds below 4000 rpm. Accuracy of friction model very important.

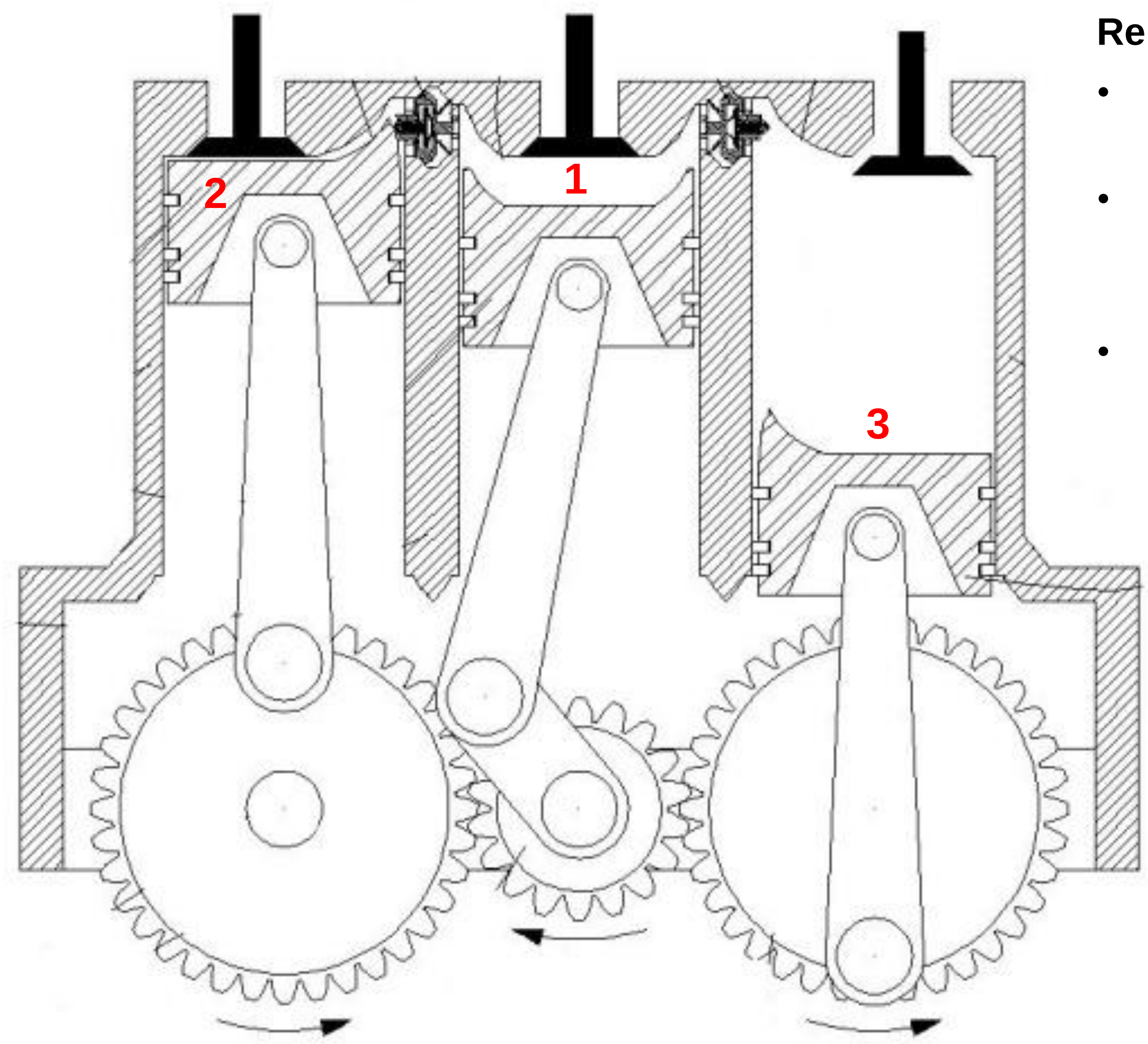
Tour engine with a good power/weight ratio

A higher level of engineering flexibility enables to optimize design to specific applications

In-line Tour engine with high power density

In-line Tour engine with high power density

A single compressor (1) is used to supply two combustors (2 and 3) in a consecutive manner

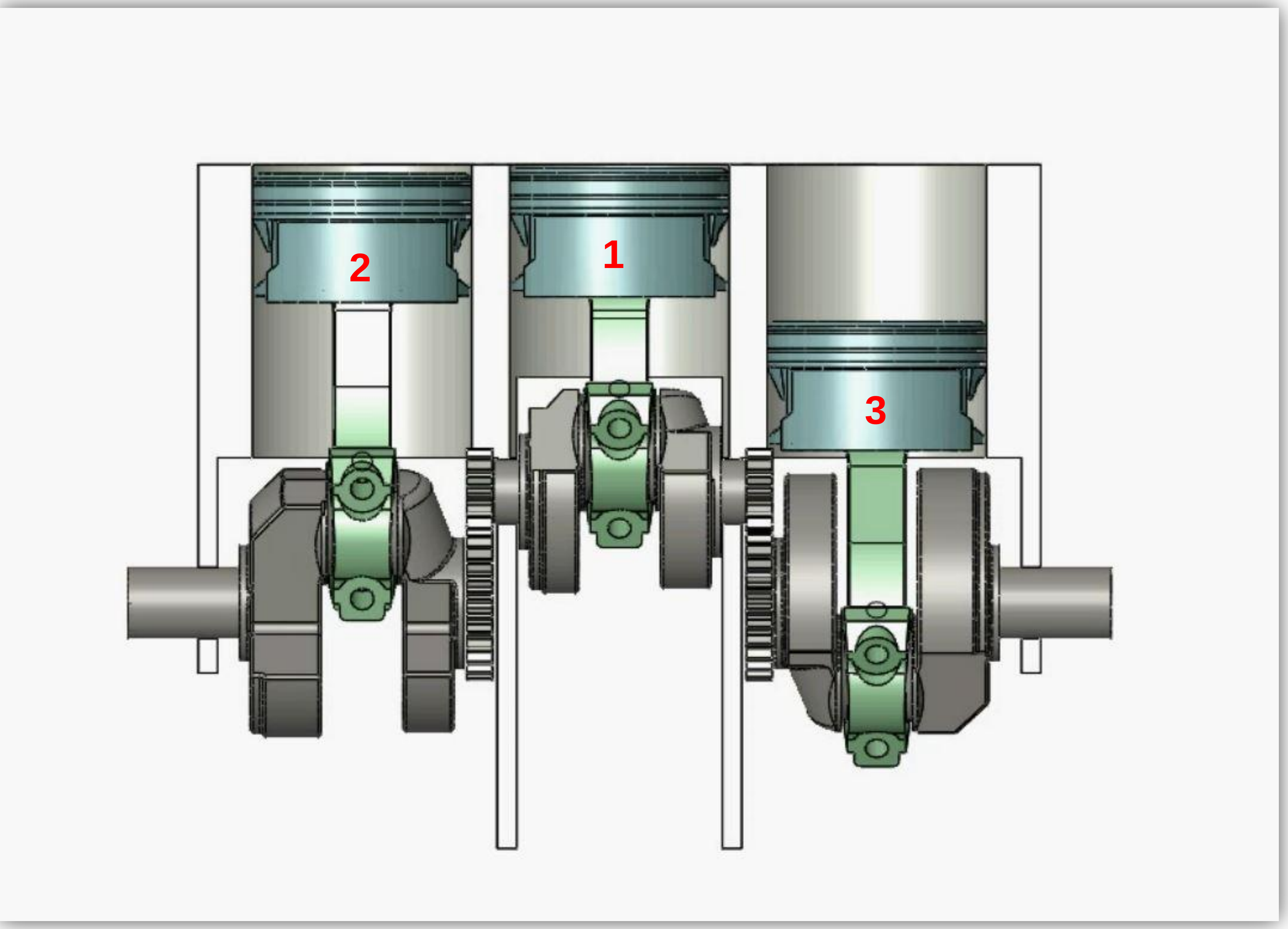


Remarks:

- The compressor runs twice as fast as the two combustors.
- The combustors are 180 degrees phased relative to each other
- Unique mechanical valves could be actuated twice while moving in a single direction by having two distinct close positions.

Achieving with V2.5 the power strokes of V4

The single compressor (1) has half the stroke and twice the RPM resulting with similar liner velocity to the two combustors (2 and 3) manner



Summary – OEMs are Our Costumers

Commercialization Plan (bottom up)

Establish business relationships with multiple OEMs. Following the first stage of fundamental development, each OEM will be offered the following 3 stage deal:

1. **Fundamental development** of the technology by Tour Engine core team
2. **Initial product development** of the technology to an OEM specific applications
3. **Product development** for/with a specific OEM

Our Mission

To develop and bring to market a family of superior engines

Create value trough IP and leadership

Company Founders

Lt. Colonel Hugo Tour, CTO, Co-founder

- The inventor of the TourEngine™ design
- Over 20 years experience developing novel IC engines
- Previously in command of all technical stuff at the largest Israeli Air Force (IAF) base
- The IAF's "out-of-the-box" mechanical troubleshooter and problem solver

Dr. Oded Tour, CEO, Co-founder

- Oversees operations, including interactions with OEMs, investors, IP development, academia and government
- PhD in neurobiology from HUJI. 20 years experience conducting pioneering research
- Associate researcher at UCSD, worked under 2008 Nobel laureate in chemistry, Roger Tsien

Advisory Board

Dr. Chris Atkinson (Adv. Board)

Former director of the Center for Alternative Fuels, Engines and Emissions at West Virginia University

Mr. Rick Sander (Adv. Board)

A former CEO & President of ISE Corp (2007-2011). ISE was a leading manufacturer of electric hybrid systems

Dr. William Sirignano (Adv. Board)

Leads the Combustion and Fluid Dynamics Group at the University of California Irvine

Dr. Michael Wahl (Adv. Board)

Former chief engineer of Achates Power and long-term consultant to Tour Engine