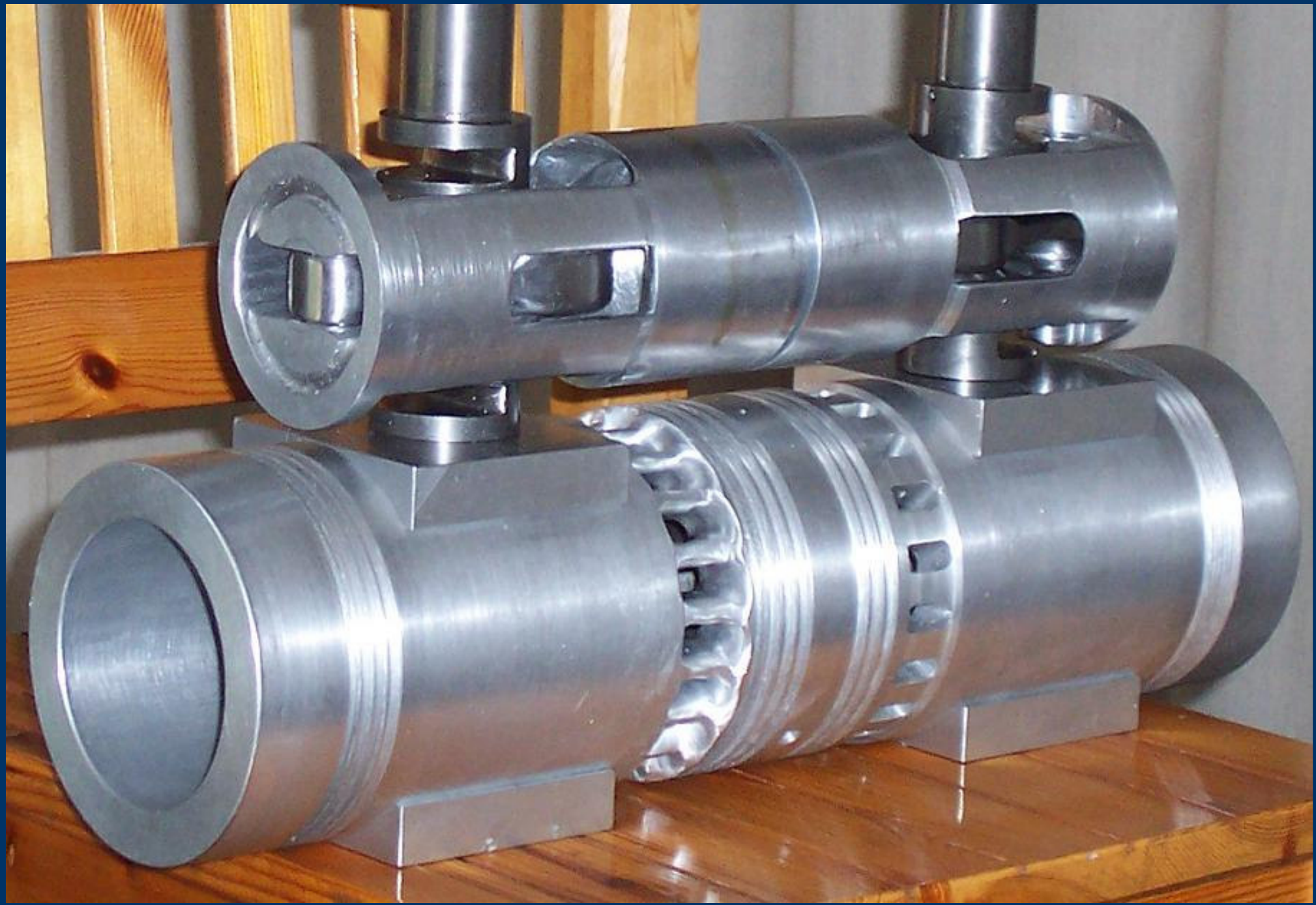
*optimal downsizing – another approach*

# *OPRE*

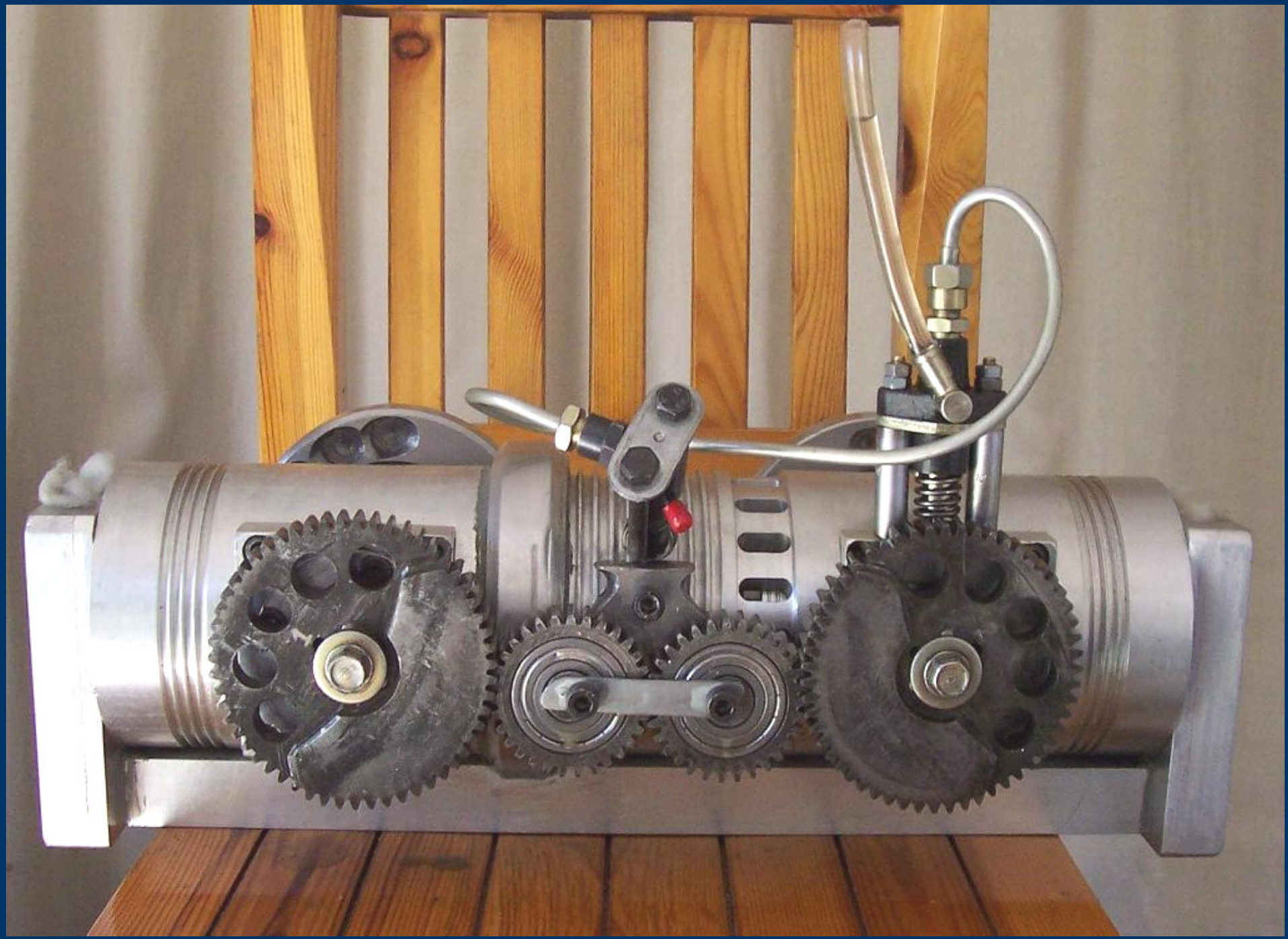
***O**pposed piston **P**ulling **R**od **E**ngine*


Take a pipe 120mm/90mm, 450mm long.
Make two holes for the bearings.
Make two pistons,
two connecting rods, two crankshafts.

# *OPRE is almost …*

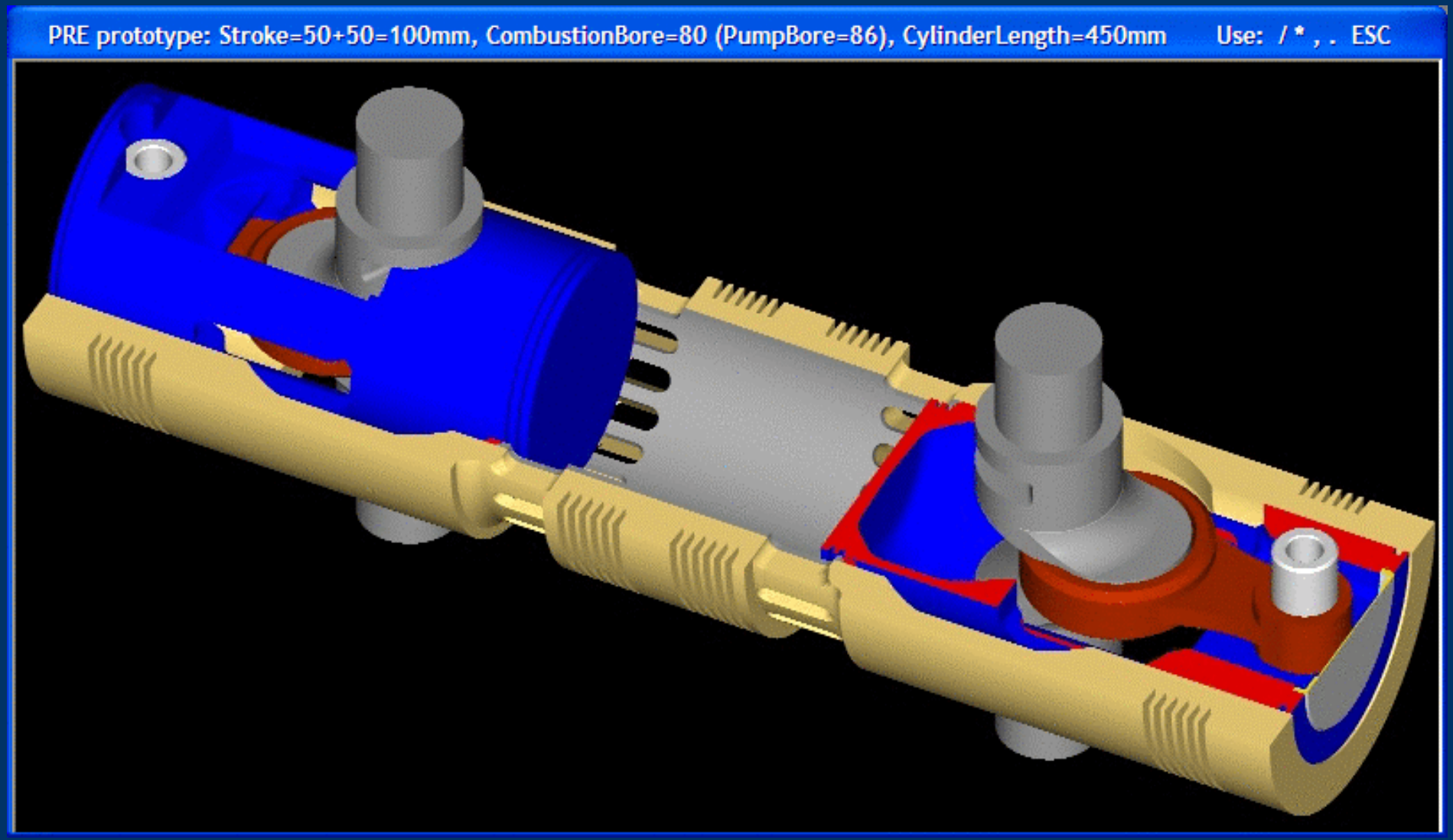


# *… ready to …*



# *… operate (video) …*

# … like (animation):



# *optimal downsizing*

*A two-stroke direct injection Diesel rid of the known two-stroke problems (oil consumption, scavenging etc) is a step for downsizing.*

*Another step for downsizing is the longer piston dwell at Combustion Dead Center (piston waits combustion to complete): it improves the thermal efficiency and extends the efficient rev range of direct injection Diesels even over 6000 rpm (high specific power).*

*Inherent perfect balance, is one more step.*

# *To the point*

*OPRE direct injection Diesel offers:*

*Better thermal efficiency than conventional diesel (additional constant volume portion for combustion),*

*Weight and bulk a few times smaller than conventional,*

*Peak power over 6000 rpm and volumetric breathing,*

*Simple mechanism close to conventional,*

*Perfect balance,*

*Common materials and manufacturing.*

# *More time at CDC for better thermal efficiency*

*As revs go high, Diesels' thermal efficiency drops quickly (peak power around only 4000 rpm compared to 6000 rpm of most spark ignition engines).*

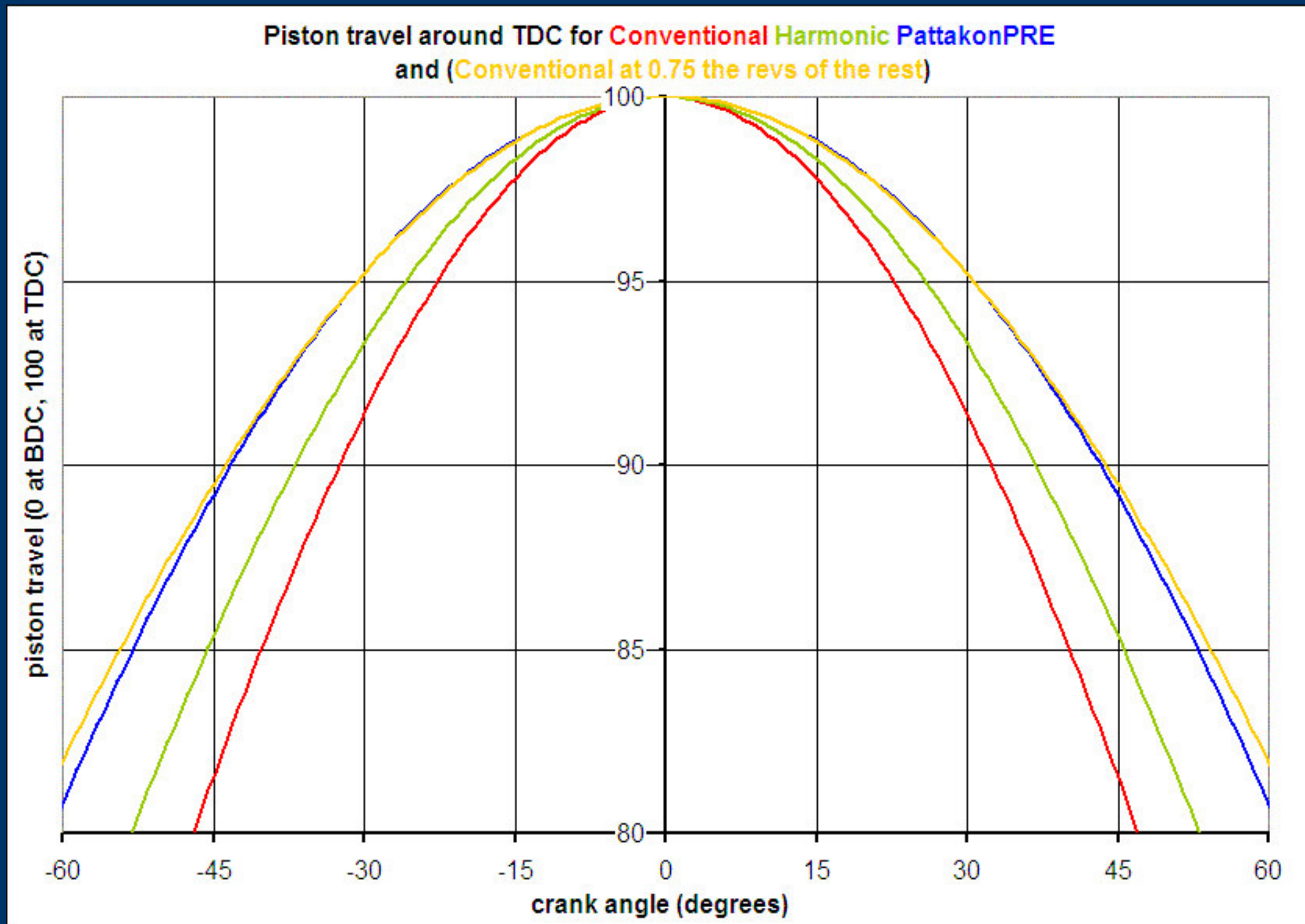
***OPRE** provides ungrudgingly additional time, at **C**ombustion **D**ead **C**enter, to prepare and burn the fuel in time.*

*For a compression ratio 21, to drop the **instant compression ratio** to 10.5 it takes some 22 crank*

*degrees in conventional and some 30 degrees in OPRE (while at the same 22 crank degrees OPRE's instant compression ratio is about 15).*

*What counts for the thermal efficiency is the instant compression ratio at which each fuel droplet or molecule burns.*

*In a diesel with 15:1 compression ratio, a molecule burned exactly at TDC provides, according the theoretical fuel air cycle, some 10% more mechanical energy than the same molecule burned at 20 deg ATDC (instant compression ratio about 10:1).*


Piston travel around TDC for Conventional Harmonic PattakonPRE
and (Conventional at 0.75 the revs of the rest)
piston travel (0 at BDC, 100 at TDC)
100
95
90
85
80
-60
-45
-30
-15
0
15
30
45
60
crank angle (degrees)

# *OPRE's additional dwell at CDC*

Ratio of crank angle in case of Opposed piston Pulling Rod Engine (OPRE) to crank angle in case of Conventional Engine

| Piston travel from TDC ( percentage of piston stroke ) | | | | | | | | | | Rod Length (% of stroke) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | **OPRE** | **Conv** |
| 1,60 | 1,56 | 1,52 | 1,48 | 1,45 | 1,42 | 1,39 | 1,36 | 1,34 | 1,31 | 100 | 140 |
| 1,57 | 1,53 | 1,49 | 1,46 | 1,42 | 1,39 | 1,37 | 1,34 | 1,31 | 1,29 | 100 | 160 |
| 1,55 | 1,51 | 1,47 | 1,44 | 1,41 | 1,38 | 1,35 | 1,32 | 1,30 | 1,27 | 100 | 180 |
| 1,53 | 1,49 | 1,46 | 1,42 | 1,39 | 1,36 | 1,33 | 1,31 | 1,28 | 1,26 | 100 | 200 |
| 1,49 | 1,46 | 1,44 | 1,41 | 1,39 | 1,37 | 1,34 | 1,32 | 1,30 | 1,28 | 120 | 140 |
| 1,47 | 1,44 | 1,41 | 1,39 | 1,36 | 1,34 | 1,32 | 1,30 | 1,28 | 1,26 | 120 | 160 |
| 1,45 | 1,42 | 1,39 | 1,37 | 1,35 | 1,32 | 1,30 | 1,28 | 1,26 | 1,24 | 120 | 180 |
| 1,43 | 1,41 | 1,38 | 1,36 | 1,33 | 1,31 | 1,29 | 1,27 | 1,25 | 1,23 | 120 | 200 |
| 1,43 | 1,41 | 1,39 | 1,37 | 1,35 | 1,33 | 1,31 | 1,29 | 1,28 | 1,26 | 140 | 140 |
| 1,41 | 1,38 | 1,36 | 1,34 | 1,33 | 1,31 | 1,29 | 1,27 | 1,25 | 1,24 | 140 | 160 |
| 1,39 | 1,37 | 1,35 | 1,33 | 1,31 | 1,29 | 1,27 | 1,26 | 1,24 | 1,22 | 140 | 180 |
| 1,37 | 1,35 | 1,33 | 1,31 | 1,29 | 1,28 | 1,26 | 1,24 | 1,23 | 1,21 | 140 | 200 |
| 1,39 | 1,37 | 1,35 | 1,34 | 1,32 | 1,30 | 1,29 | 1,27 | 1,26 | 1,24 | 160 | 140 |
| 1,36 | 1,35 | 1,33 | 1,31 | 1,30 | 1,28 | 1,27 | 1,25 | 1,24 | 1,22 | 160 | 160 |
| 1,35 | 1,33 | 1,31 | 1,30 | 1,28 | 1,27 | 1,25 | 1,24 | 1,22 | 1,21 | 160 | 180 |
| 1,33 | 1,31 | 1,30 | 1,28 | 1,27 | 1,25 | 1,24 | 1,22 | 1,21 | 1,20 | 160 | 200 |
| 1,36 | 1,34 | 1,33 | 1,31 | 1,30 | 1,28 | 1,27 | 1,26 | 1,24 | 1,23 | 180 | 140 |
| 1,33 | 1,32 | 1,30 | 1,29 | 1,28 | 1,26 | 1,25 | 1,24 | 1,22 | 1,21 | 180 | 160 |
| 1,32 | 1,30 | 1,29 | 1,27 | 1,26 | 1,25 | 1,23 | 1,22 | 1,21 | 1,19 | 180 | 180 |
| 1,30 | 1,29 | 1,27 | 1,26 | 1,25 | 1,23 | 1,22 | 1,21 | 1,20 | 1,18 | 180 | 200 |

# *Perfect Balance*

*In case of divided load,*

*like in electric power plants with twin electric generators,*

*like in outboard boat engines with twin screws,*

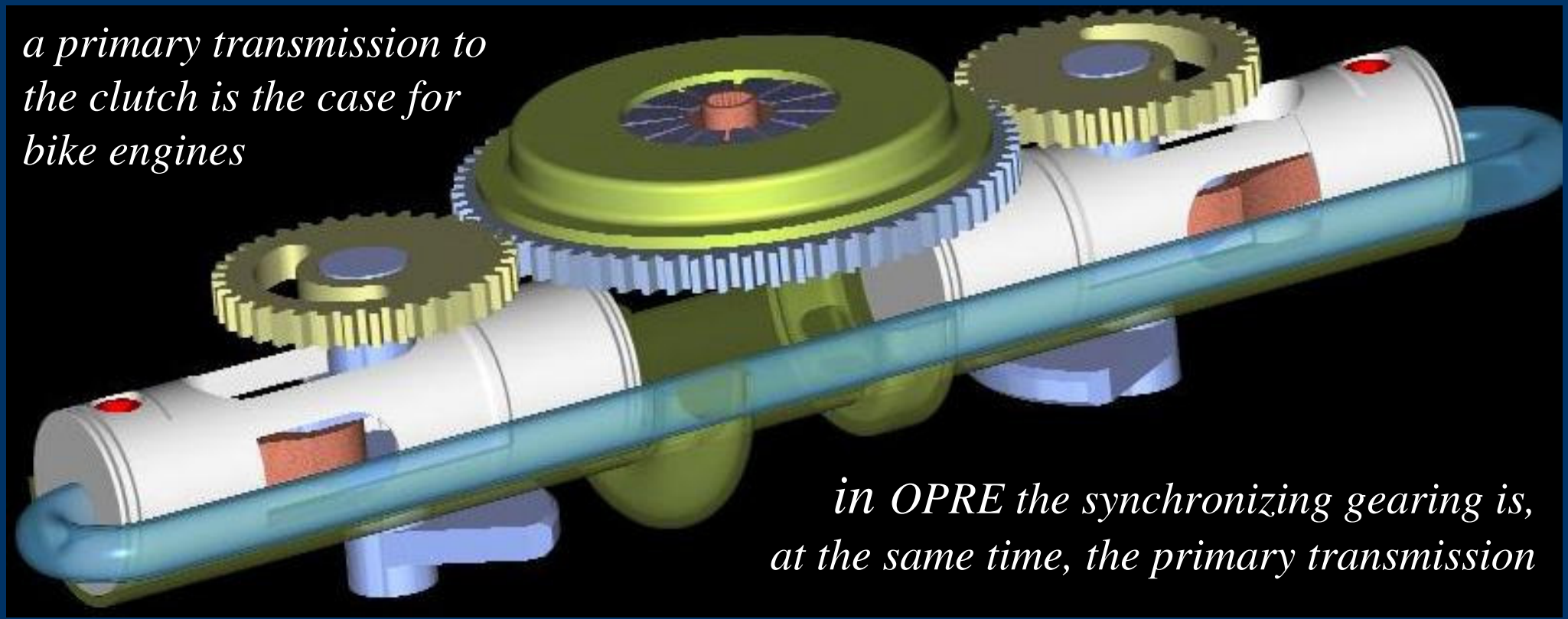
*like in portable-flyers / helicopters with twin counter-rotating rotors,*

*the basis of the single cylinder OPRE engine is rid not only of inertia vibrations of any order, but it is rid of combustion vibrations of any order too.*

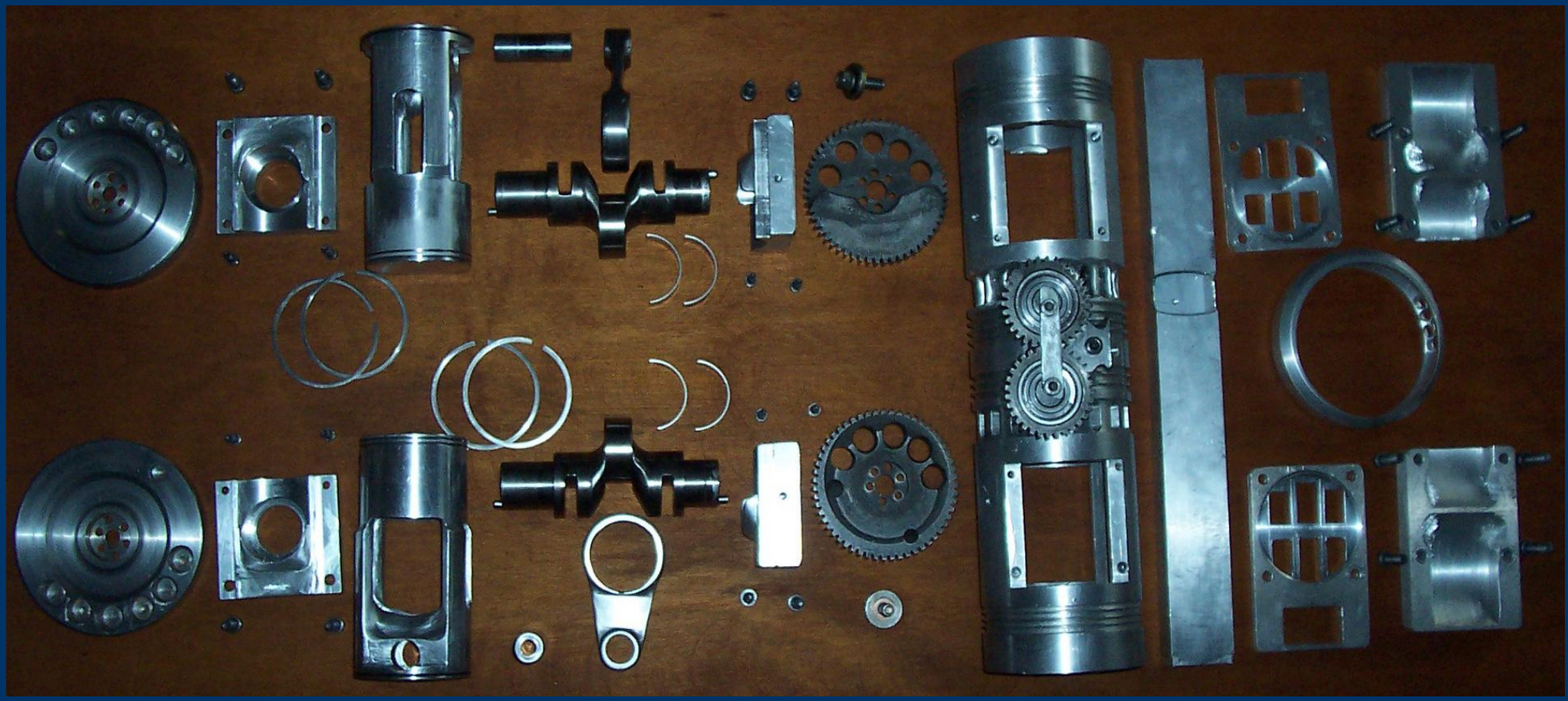
# *Perfect balance (video). Look at the cigarette.*

# *Excellent Balance*

*In case of single output shaft applications (for instance when OPRE replaces the engine of a vehicle), the only vibration on the engine basis is the inertia torque and the combustion power pulses torque.*



# *Simplicity/Reliability*



# *OPRE combines more*

*The built-in scavenging pumps (formed by the outmost sides of the two opposed pistons) have almost zero dead volume and add no extra cost or friction.*

*The "combustion bore" to the "scavenging pump bore" defines the scavenging ratio.*

*Through scavenging, wide port area and true volumetric scavenging force a specific quantity of air to pass through the cylinder per cycle, no matter what the load or the exhaust pressure are, providing wide band efficient aspiration (no need for tuned exhaust).*

# *OPRE combines more*

*EGR can be handled internally by controlling the exhaust flow resistance (after the combustion a part of the charge is trapped into the cylinder for the next cycle providing active radicals, reducing NOx etc).*

*The lubrication (and the oil consumption) is as in four stroke engines. The oil rings never pass over the ports, while flooding with oil is needed only at the compressor side of the piston (the cool side) where the thrust loads are taken.*

# *OPRE combines more*

*The piston skirt (OPRE, combustion side) will never touch the hot combustion cylinder wall. The piston crown and piston skirt (combustion side) are easily cooled by the oil of the crankcase (neither piston pin, nor bosses, nor connecting rod obstruct the oil).*

*On the contrary the piston skirt of the conventional engine thrusts against the hot cylinder wall, making necessary an oil film between the cylinder wall and the piston skirt, while con-rod, piston pin and bosses hide the piston's ceiling from the cooling oil.*

# *OPRE combines more*

*Through scavenging and tangentially cut ports provide, for free, swirl and turbulence (HC cracking, NOx control).*

*The different architecture of the kinematic mechanism allows better control of the piston (piston to cylinder clearance, piston tilting, piston friction, piston lubrication, piston and piston rings durability, noise from piston etc).*

# *OPRE III prototype: the moving parts*

# *OPRE combines more*

*The two short stroke pistons form a long combustion cylinder and a compact combustion chamber. The shorter the piston stroke, the less the mean piston speed and the friction.*

*Roughly speaking, 40% longer piston dwell at CDC allows the engine operate - at the same efficiency to conventional di Diesel - at 40% higher revs. For the same revs, the longer piston dwell at CDC of the OPRE improves its thermal efficiency.*

# *OPRE combines more*

*To synchronize OPRE's two crankshafts is easier and more compact than to synchronize crankshaft and camshafts of the conventional 4-stroke. In case of symmetrical-divided load, the synchronizing gearing of OPRE is practically unloaded.*

*The 20 Kp heavy, 500cc, OPRE-II prototype can provide some 8 Kp*m torque, which at 6000 rpm makes some 50 KW (0.4 Kp/KW) at direct injection Diesel efficiency.*

# *OPRE combines more*

*OPRE is gasket-free (simplicity-reliability).*

*OPRE is compact: for 100mm* ***cylinder-stroke*** *the height of the OPRE-II is only 505 mm.*

*The low friction, the lightweight and the compactness justify, in most applications, the use of higher capacity OPRE operating at lighter load to optimize efficiency and emissions. Normal Diesels cannot.*

# *OPRE combines more*

*OPRE can easily turn to a Continuously Variable Compression Ratio engine (VCR) by changing, for instance, the distance of the crankshafts' bearings, or simply by phasing the two crankshafts (e.g. by a VVT mechanism).*

*The total force on the combustion cylinder is negligible. It could easily perform a short stroke reciprocation per cycle, providing variable / controllable unsymmetrical timing.*

# *OPRE combines more*

*The question is, always, whether the additional complication (for VCR, for unsymmetrical timing etc) is justified.*

*Doubling all dimensions of the OPRE-II prototype, a 4 liter 2-stroke di Diesel results (bore 160mm, stroke 100+100=200mm) weighing around 100 Kp, having at 6000 rpm only 20m/sec mean piston speed and enough time for the efficient combustion of the fuel.*

# *OPRE combines more*

*Supposing a torque of only 12Kp*m/lit (too pessimistic value), this naturally aspirated 4 lit engine can make more than 300 KW.*

*OPRE can easily be combined to a turbo-super-charger (driven by exhaust gas).*

*Diesel OPRE pressure loads are significantly heavier than the inertia loads (the rev limit is set by the combustion and is reasonably lower than 6500 rpm).*

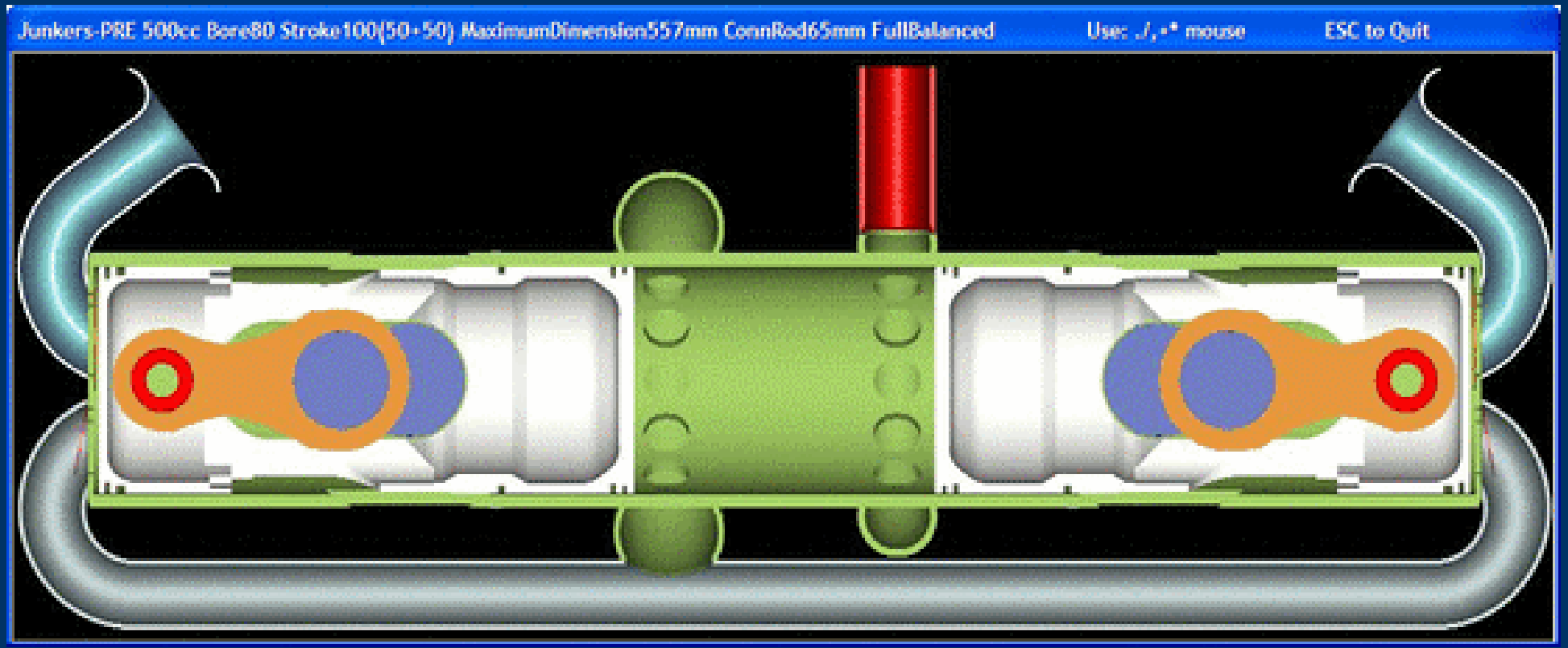
# *OPRE combines more*

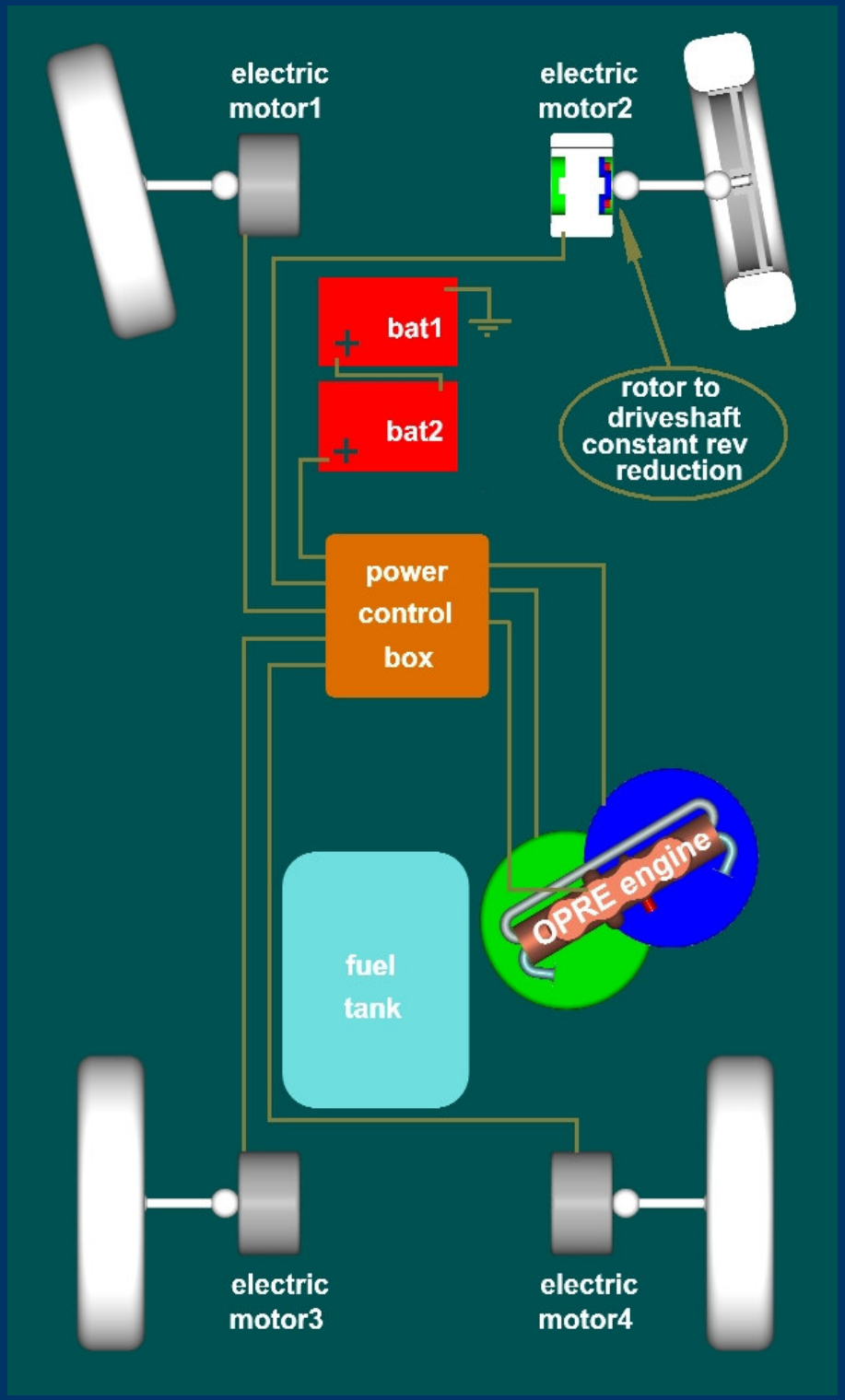
*OPRE's architecture is not restricted to compression ignition (Diesel) engines, neither to single cylinder.*

*If desirable, OPRE can operate as a direct injection spark ignition engine with very high rev limit. In this case it is reasonable to use composite pistons: the outmost side from light and strong materials (carbon fiber), the combustion side from aluminum alloy.*

# *OPRE combines more*

*The small in length connecting rods (because of the two short stroke pistons that form a long combustion cylinder) are heavily loaded only in tension.*



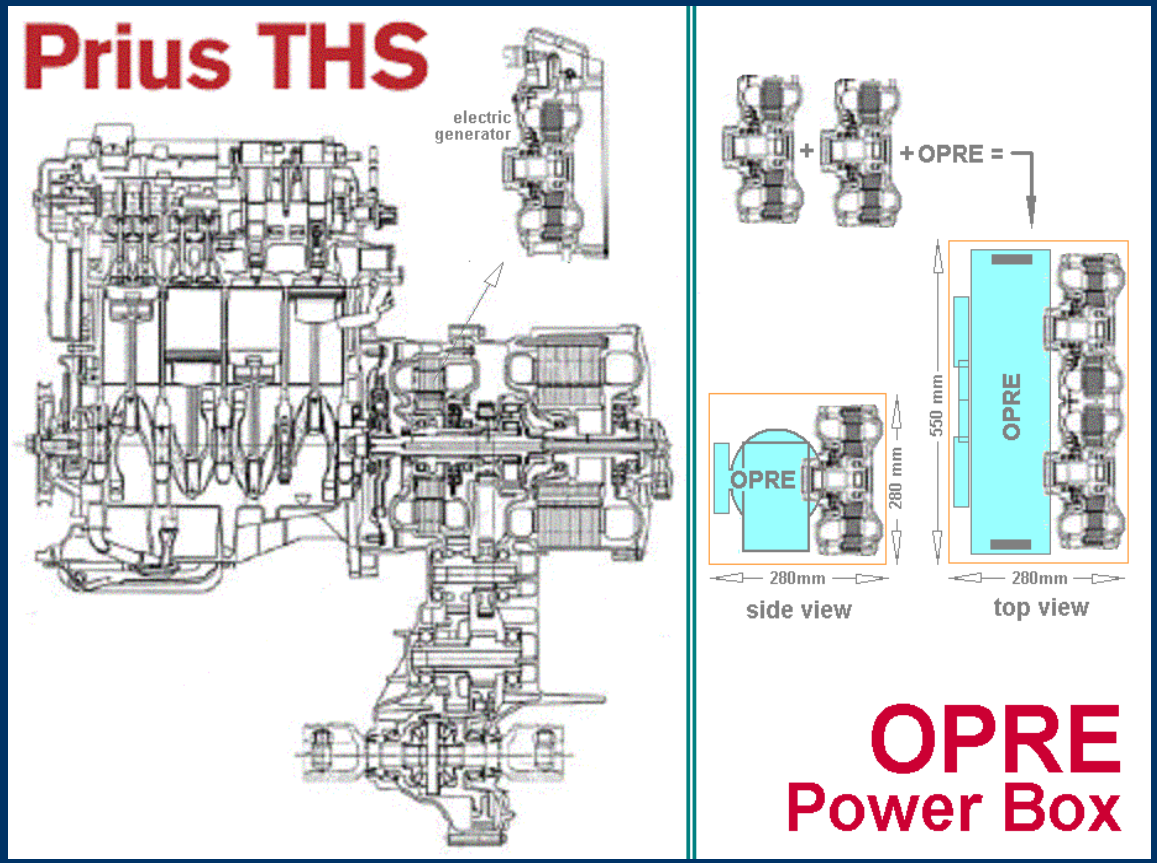



# *OPRE Hybrid*

***Components**: An electric motor per wheel, a constant transmission (~3:1) from electric motor to wheel, a battery, an OPRE Power Box and a power control unit.*

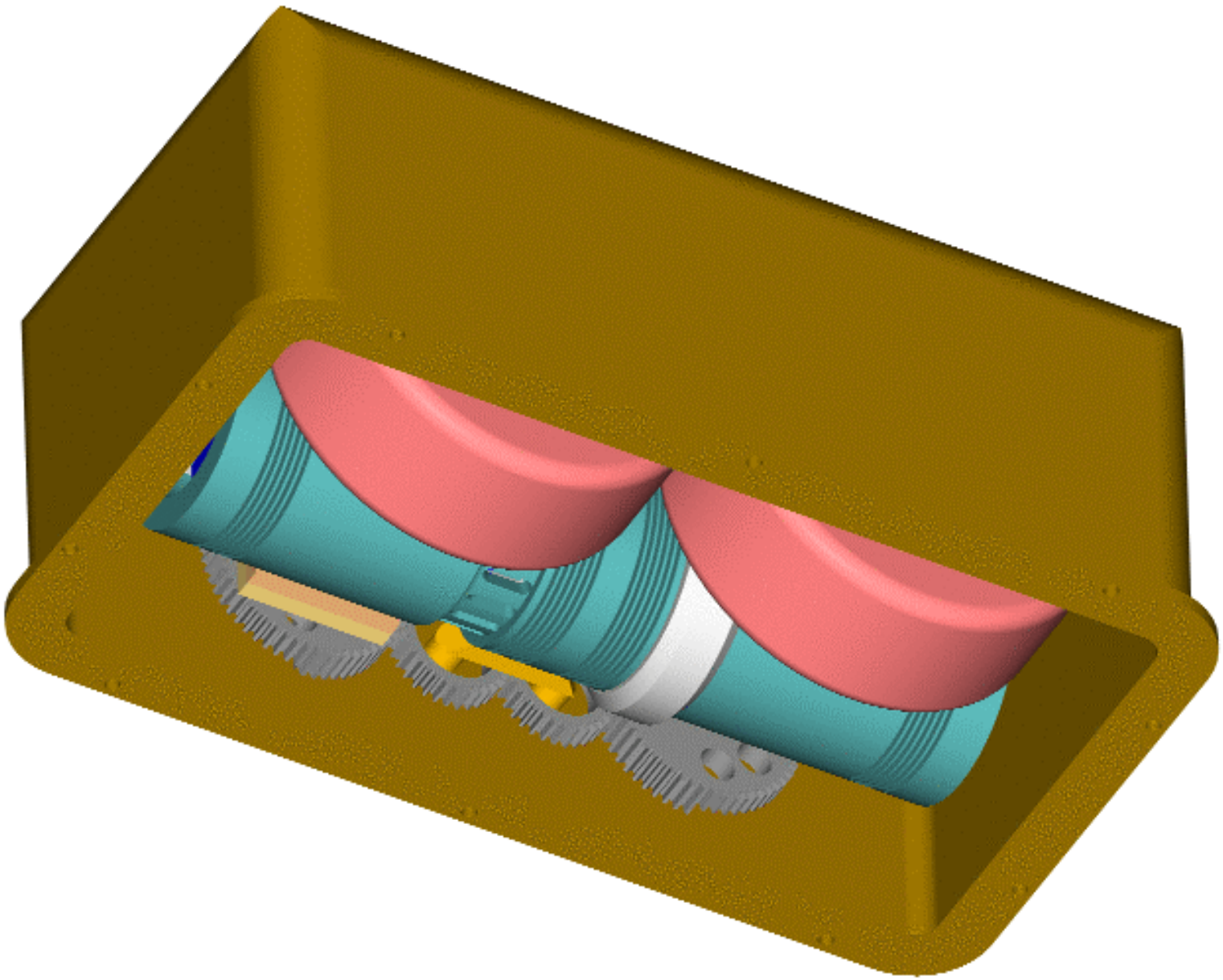
***Advantages**: Vibration free, rid of gearbox and differential(s), power plant anywhere in the vehicle, true AWD (4x4), least overall bulk, top overall efficiency.*

*Good for multi-axle trucks, too.*




*Securing two electric generators (like those in PRIUS) directly to the crankshafts of a 500cc OPRE, a compact "Power Box" results. Leaving the bottom side of the box open (to provide air for breathing and cooling, to allow exhaust pipe exit) and covering the other 5 sides by heat/noise insulator material, the Power Box becomes some 300x300x600 mm and can be placed anywhere in the vehicle (for instance under a seat).*

*OPRE power box (animation).*
*It fits even under the seat of a passenger.*



# *In a nutshell*

*The improved thermal efficiency, the perfect balance, the conventional technology it is based on, the four stroke lubrication, the transfer of the thrust loads, the built-in scavenging pumps, the through scavenging, the large port area, the swirl and the turbulence, the simplicity, the reliability, the compactness, the light weight, the low piston speed and friction, the low cost, the ability for higher "efficient" revs and peak power, make this engine a true alternative for many, if not all, applications.*

# *OPRE*

## *Opposed piston Pulling Rod Engine*

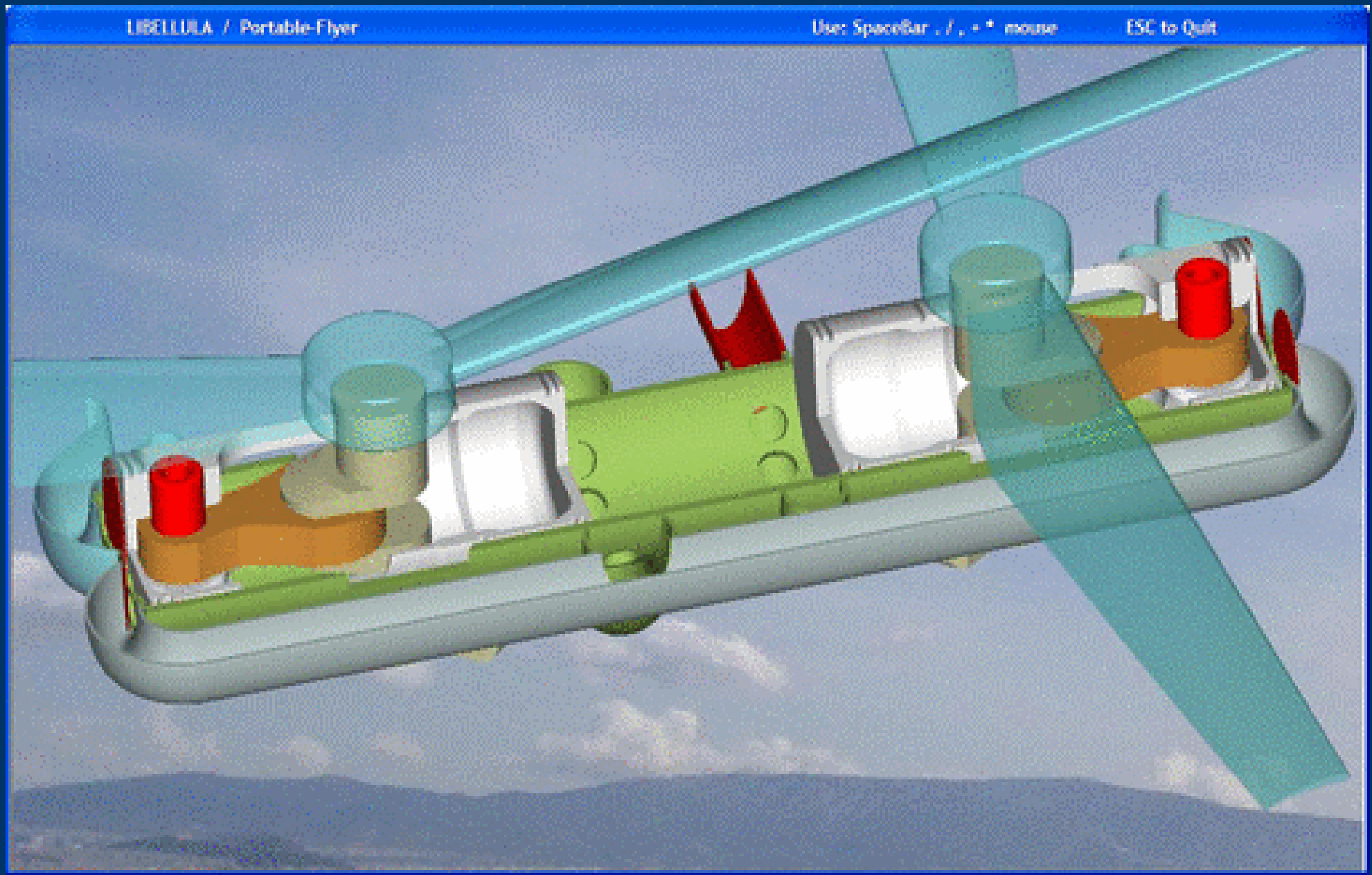
*A simple and reliable,*
*compact and lightweight,*
*true high speed, perfectly balanced,*
*improved thermal efficiency direct injection diesel.*

*OPRE III prototype (vertical crankshafts)*

*OPRE II prototype (horizontal crankshafts)*

# *Looking the flames through the exhaust ports*

*It is extreme. It is unconventional, too. But, just for a moment, think of the difference it can make…*



# *thank you*

*for more details:*
*www.pattakon.com*