

# **Turbo Charging Micro – Turbines**

**(Boosting 40 kW to 200 kW)**

**October 2012**

# **Applications**

- **Power Generation – CHP (Combined Heat and Power) for Decentralized Generation market**
- **Aerospace – UAVs**
- **Turbo-Pumps/compressors for various applications**

# The Rational

**Addition of Commercial Turbo-Charger to the basic TG-40 engine quadruples the output and reduces the installed cost by ~ 65-70%**

**(from 1700 \$/kW to 500-550 \$/KW)**

**Thus – the enhanced TG-200 is a potential competitor to IC (internal combustion) piston engines in the “Decentralized Generation” market, and other markets / Applications**

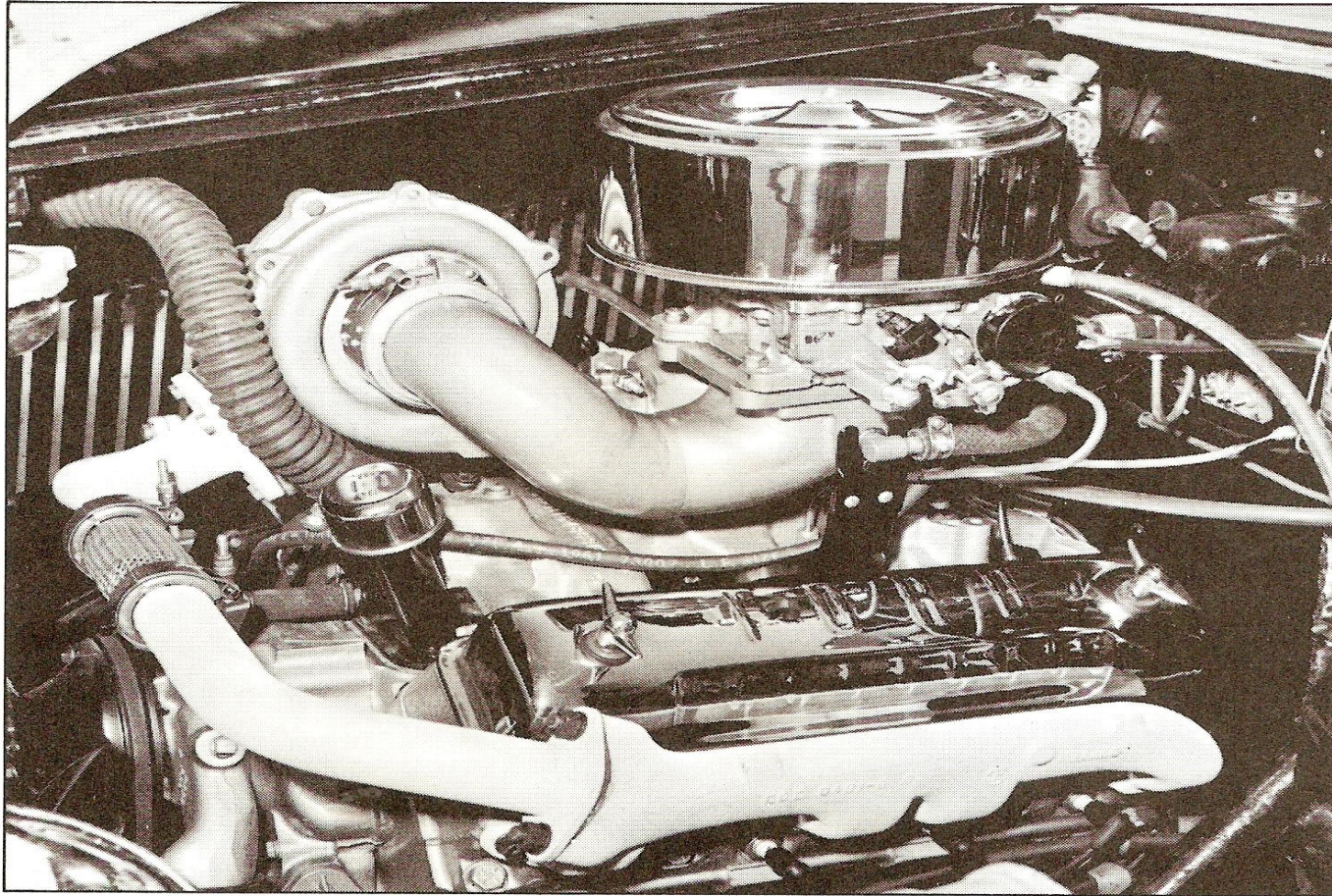
# Piston Engines Turbocharging

Turbocharger cycle:

- Serves mainly to boost air inlet pressure and mass flow;
- an intercooler is optionally placed between the compressor and engine inlet.

Automotive modern turbochargers attain high components efficiencies and use ball bearing technology lubricated by main engine oil system

# Piston Engine Turbocharger



Duke Hallock, former high-performance coordinator and test-lab supervisor for AiResearch, has driven the same '37 Ford pickup since it was new. Ford 292 with AirResearch T-7 turbo is one of many engines he has installed in the chassis over the years. A plate perforated with 1/4-inch holes is used at original manifold flange to create turbulent flow for good mixture distribution.

## **“Turbo-Charging” Gas Turbines**

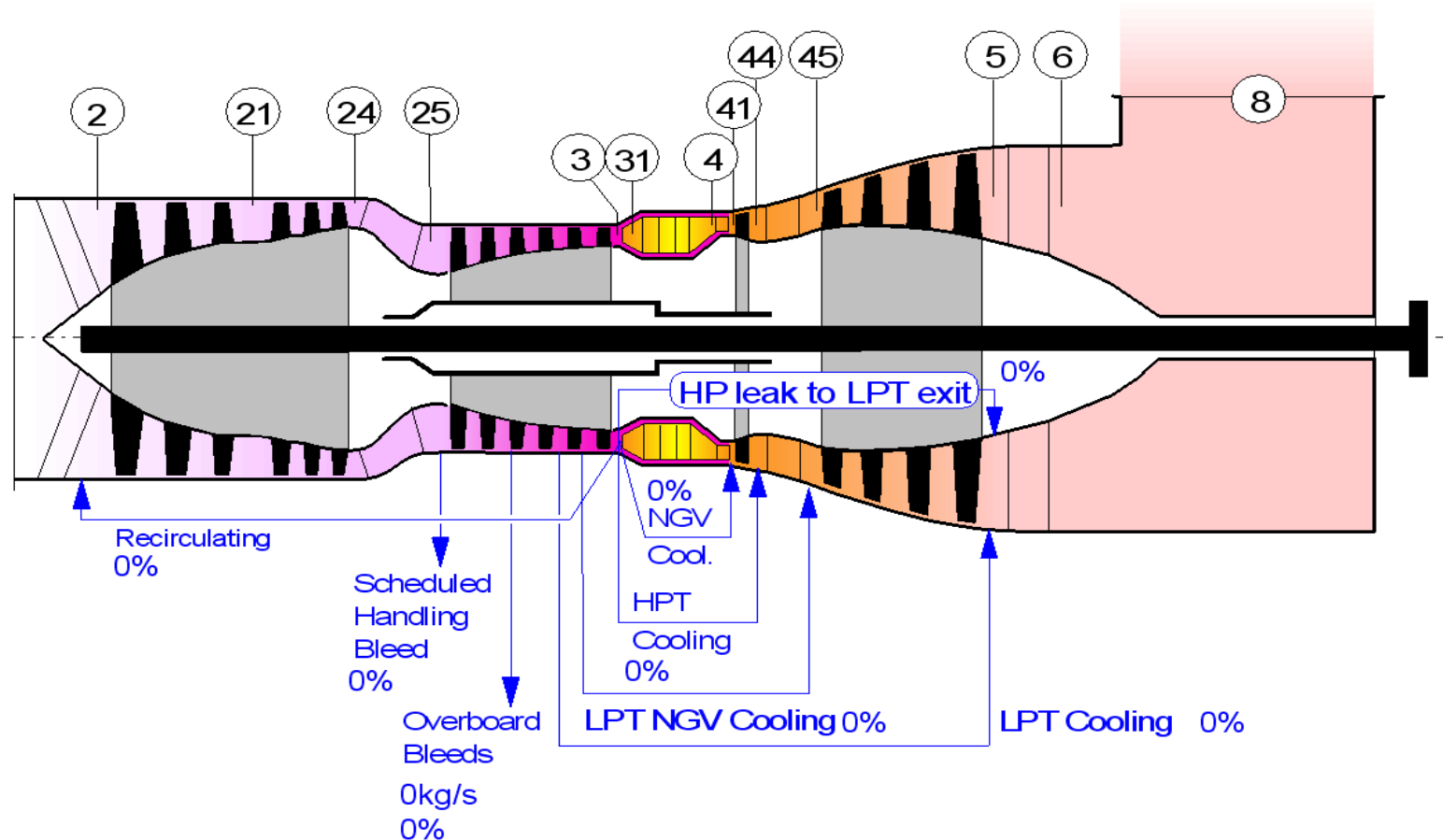
### **A. None/Intercooled- recuperated Cycle**

2 or 3 shaft gas turbine cycles - mainly used for aircraft engines.

An integral concentric design is required due to size weight/limits.

Not applicable to microturbines due to small shaft size.

## 2 Spool Turbo-Shaft

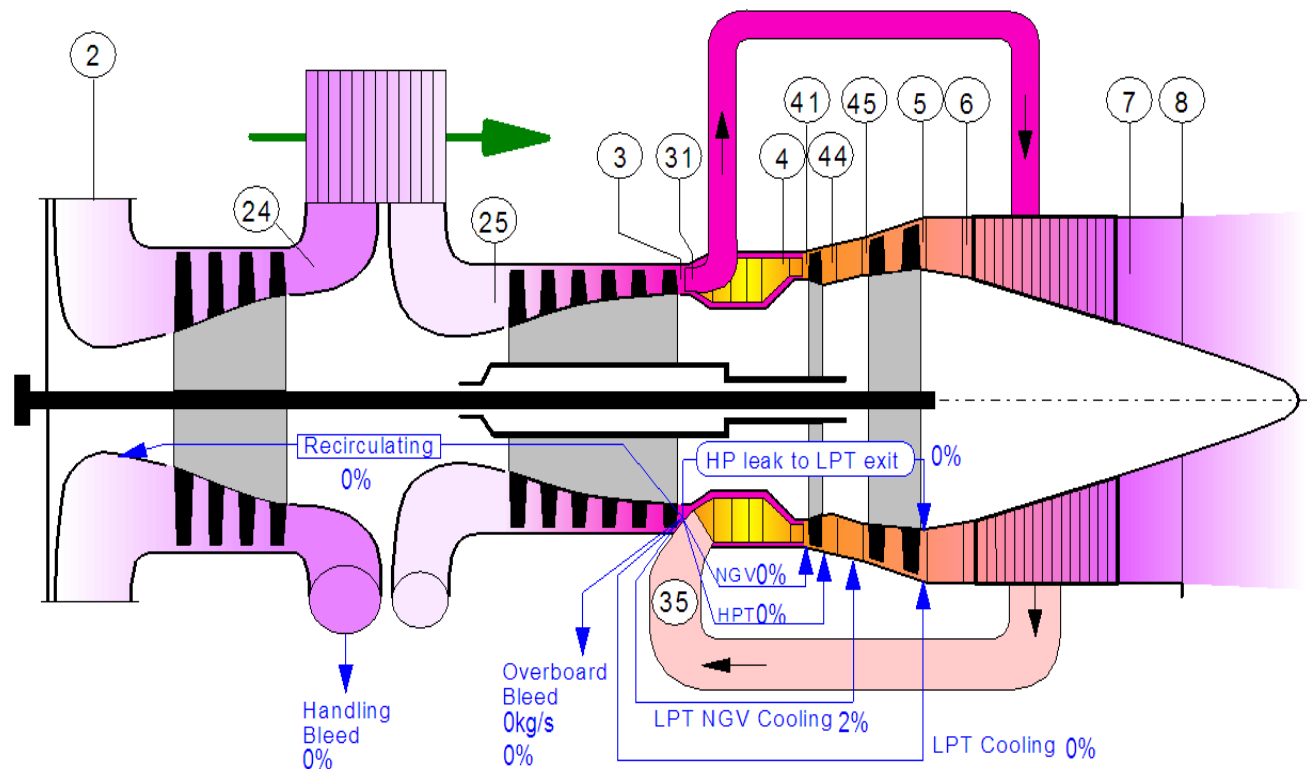


### **B. Recuperated / Intercooled Cycles**

Requires an “open” architecture in which the combustor and recuperator are accessible to minimize pressure losses.

Therefore-not used in aircraft engines but in large commercial gas turbines pre-designed for such architecture.

## A. 2 Spool Intercooled Recuperated Gas Turbine



## Small Recuperated Micro Turbines

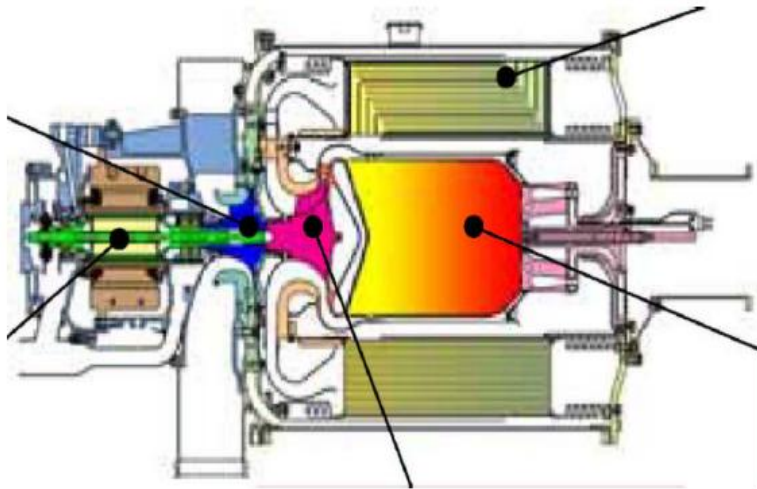
May be turbocharged if combustor is accessible -  
If not - major modifications are required.

Capstone - 30-60kW - not accessible

Honda - 20-30 kW - not accessible

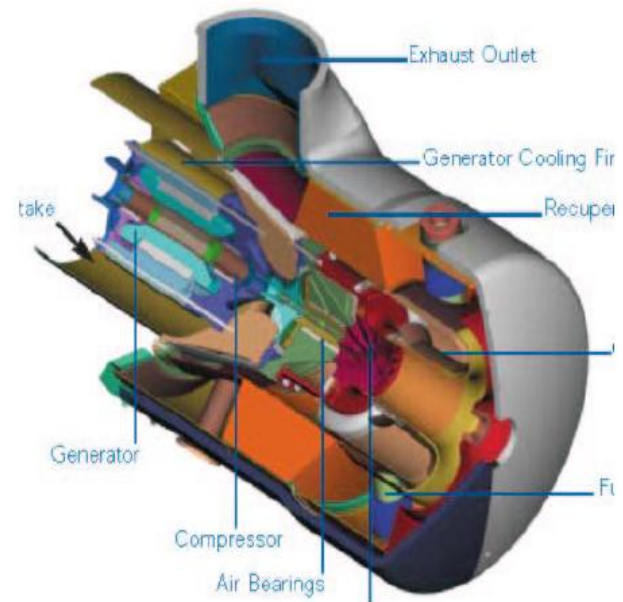
**TG-40/200 - Accessible**

## Recuperators - Annular design



Honda Microturbine

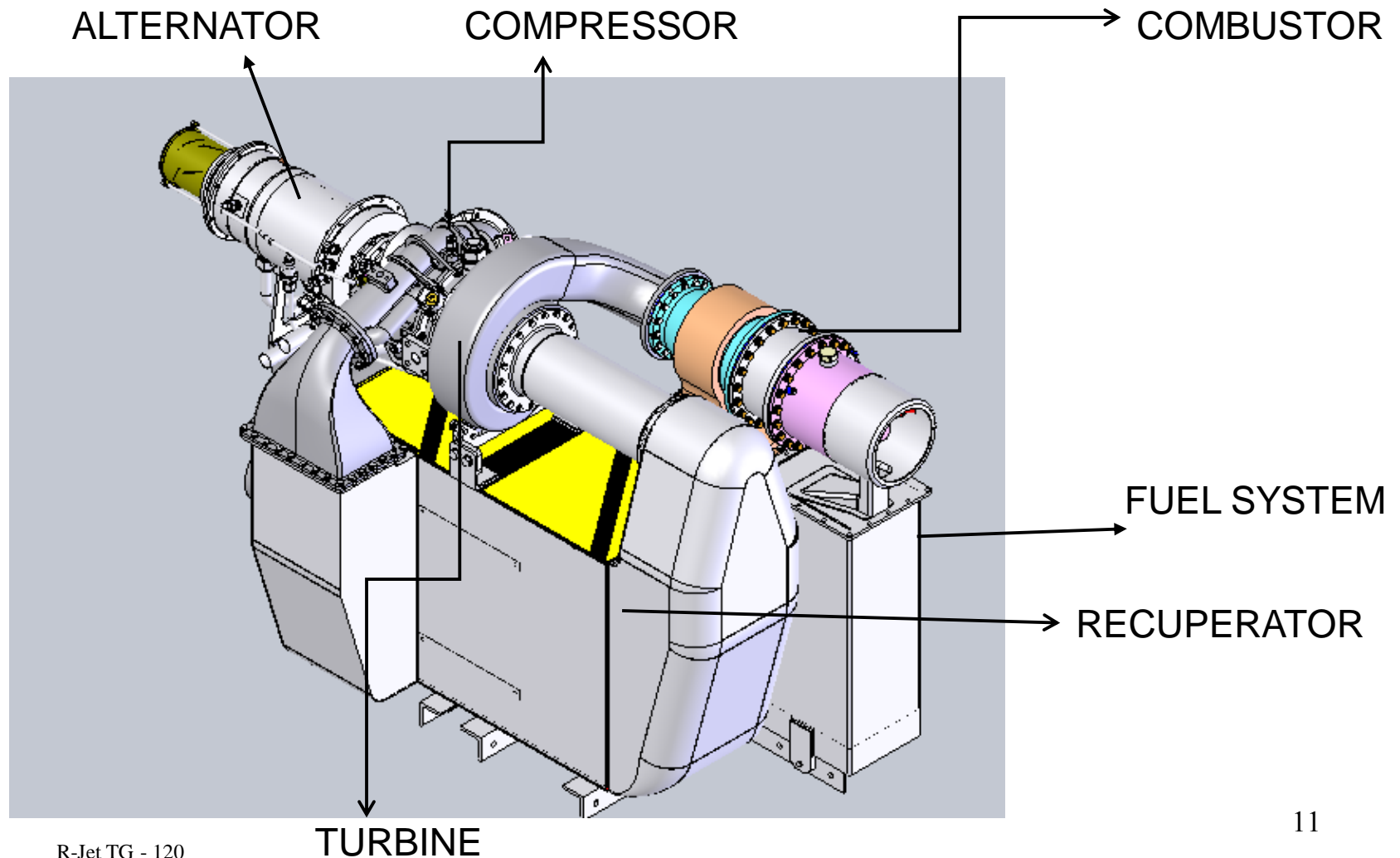
Ref.: Koichi Shinmura Presentation at the IGTI  
Turbo Expo, June 18 2003, Atlanta, USA



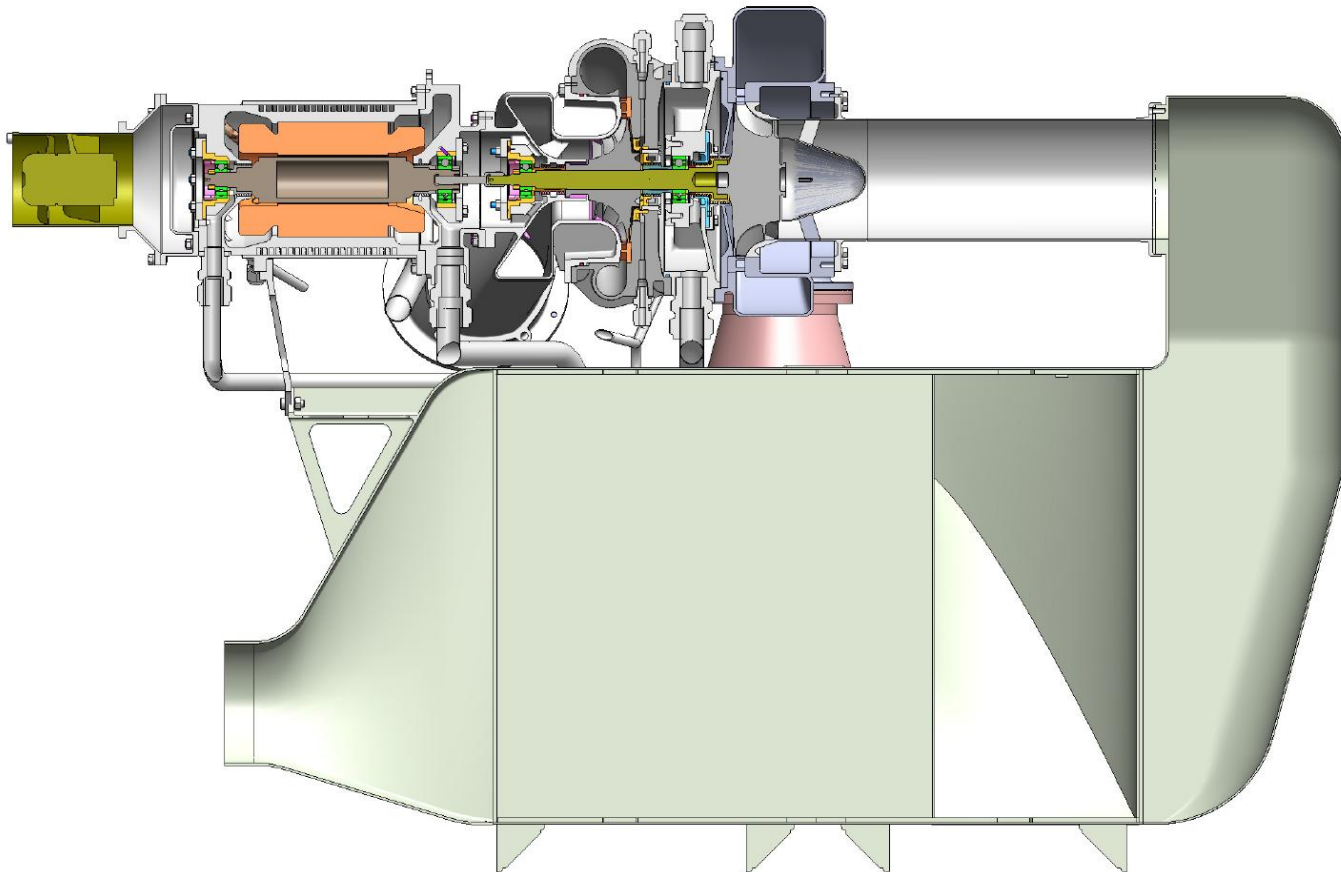
Capstone Microturbine

Ref.: Capstone Product Datasheet

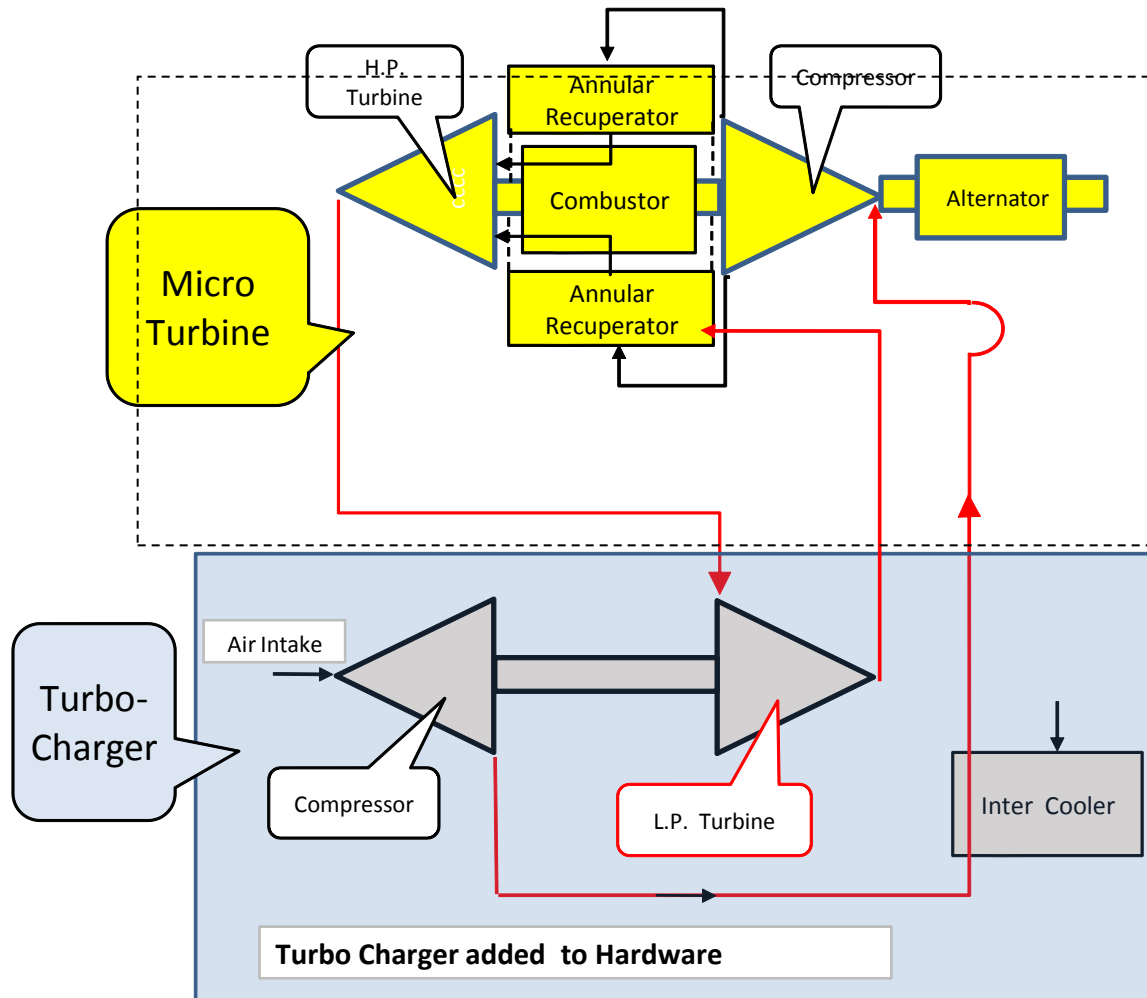
## R-Jet TG 40 Turbo-Generator 40 KW



## **Recuperated R-Jet TG - 40 Axial Section**

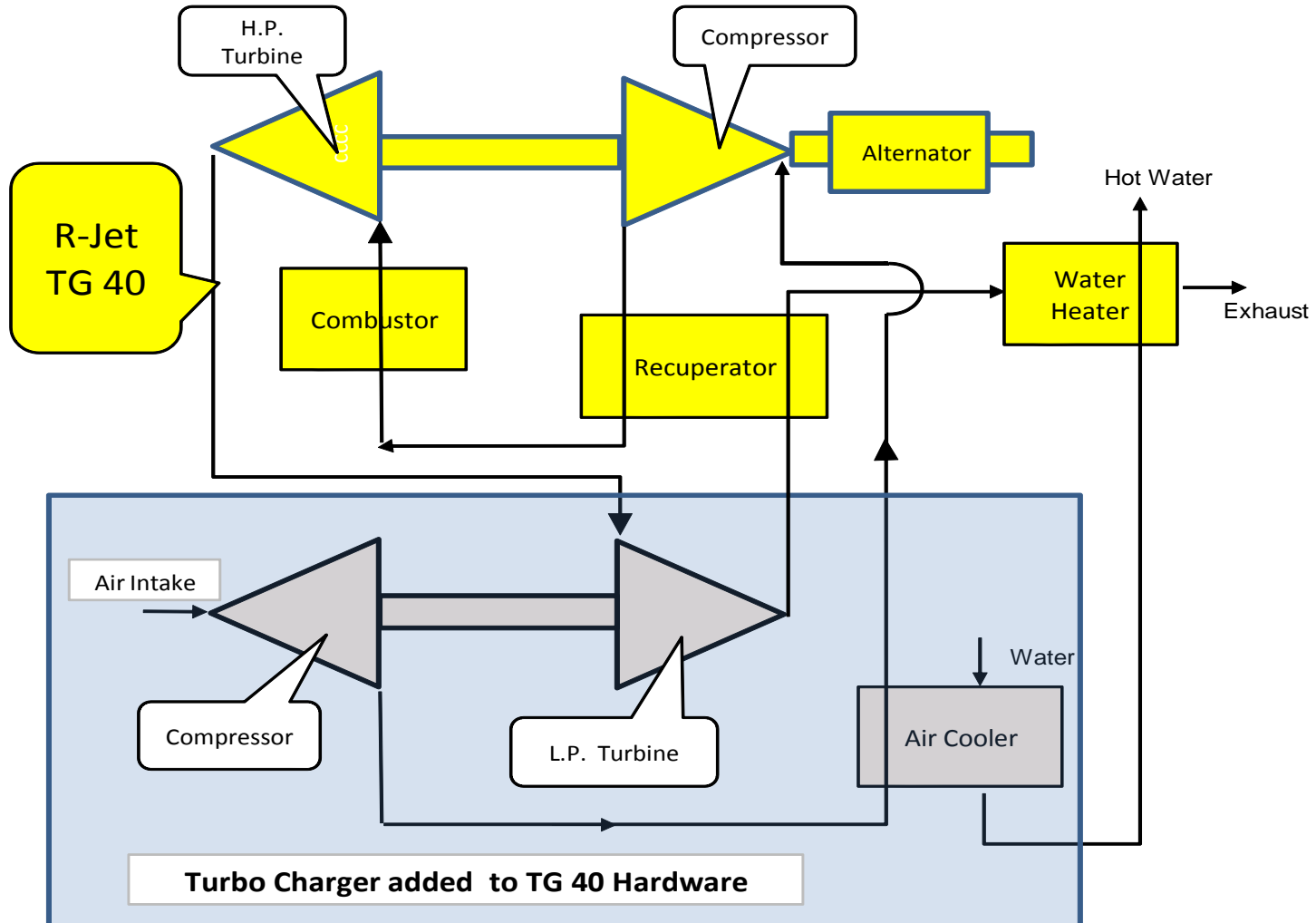


## INTERNAL RECUPERATED GAS TURBINE- ADAPTATION OF TUEBOCHARGER



1. LARGER RECUPERATOR REQUIRED - NO AVAILABLE VOLUME WITHIN CASING
2. DUCTING TO AND FROM ANNULAR RECUPERATOR TO TURBOCHARGER - A CHALLENGE

## Scheme of TG-40 - Integration with Turbocharger



# TG-200 kW Technical Concept

The TG-200 is a turbocharged version of the single shaft TG-40. It Includes the following –

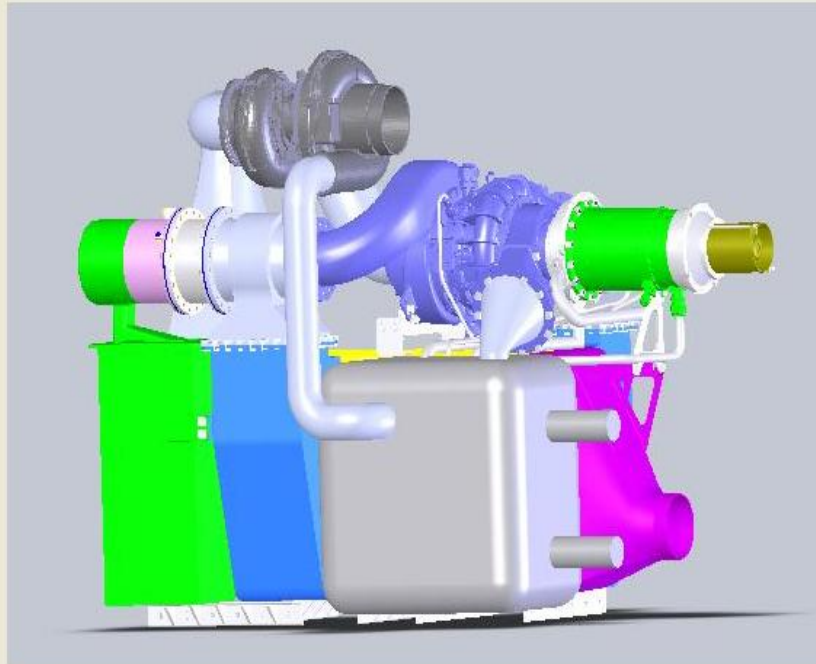
1. The basic TG-40 intercooled and recuperated turbo-shaft driving a 200kW alternator.
2. Turbocharger driving a booster compressing air into the TG-40 original compressor inlet through a inter cooler.
3. 200kW power converting unit.—alternatively a speed reducer to 1500 rpm and a conventional generator.

The design point performance is:

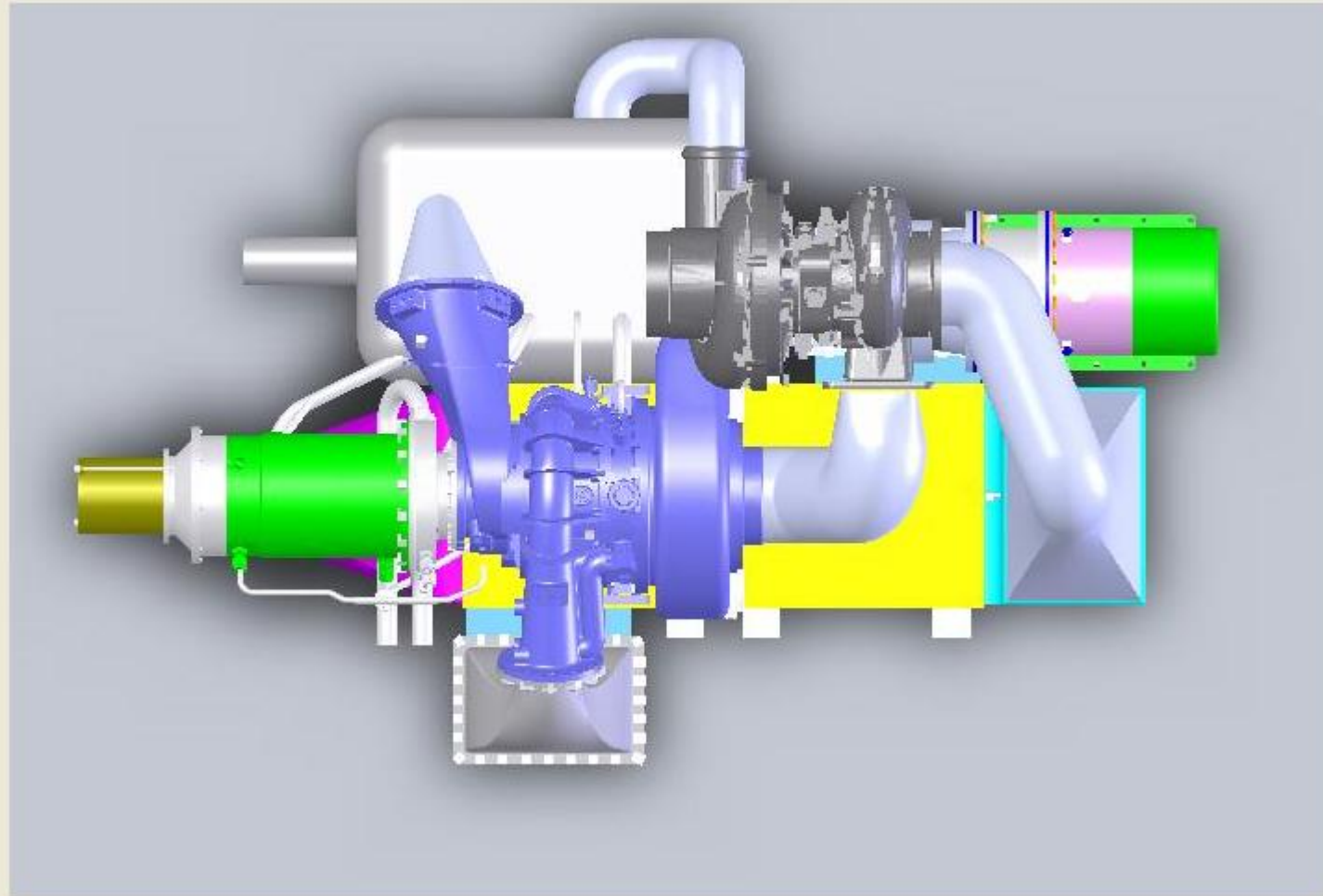
Thermal power - 225kW

Thermal efficiency - 36%

## TG-200 CHP Design.



### TG-200 - Top View



## **TG 200 - Mechanical Assembly Design**

Same foot-print as TG-40 ~0.6 Sqm

Frontal area- ~ 0.8 Sqm

Weight – 420 Kg (full CHP unit)

Optional features-

- natural gas booster

- solar adapter.

# **TG-200 kW with an automotive turbocharger Technical Concept**

The TG-200 is a variant of the basic TG-40 gas turbine.

The turbocharger is – Garret model T5533R

Cycle pressure ratio-9.5

T.C compressor pressure ratio-3.5 eff.-75%

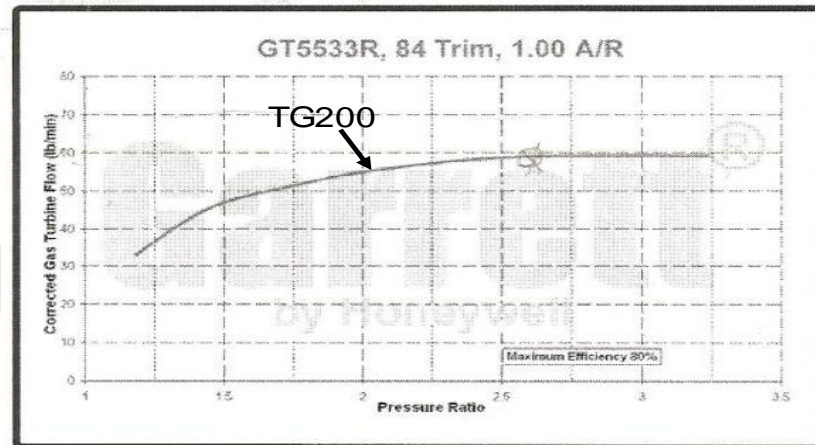
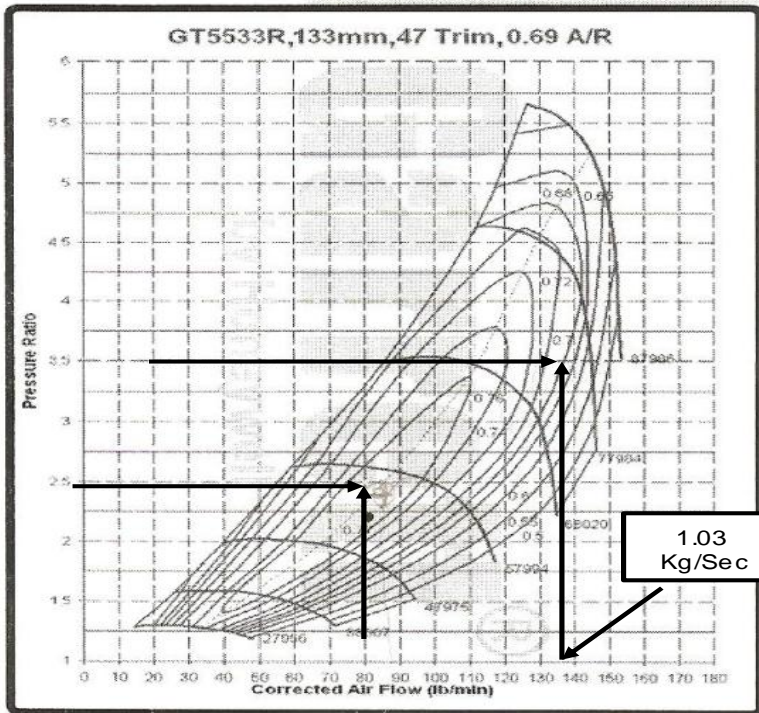
T.C turbine pressure ratio 2.19 eff.-80%

The thermal efficiency is-33%

The matching is shown in the following turbocharger map.

## Turbocharger Matching with TG-40

GT5533R		COMPRESSOR				TURBINE		
Turbo PN	CHRA PN	Ind Whl Dia	Exd Whl Dia	Trim	A/R	Whl Dia	Trim	A/R
769115-2	769210-3	91.2mm	133.3mm	47	0.69	111.5mm	84	1.00



### TG-200 Cycle—new turbocharger-Load on Turbocharger Shaft

Cycle pressure ratio-9.5

Air flow-1.03 kg/sec

H.P.T inlet temperature-1275k

Thermal efficiency-36.8%

T.C turbine pressure ratio-5.14 (2 stages)-eff.—86.5%

T.C compressor pressure ratio-3.5-- eff.-80%

Recuperator effectiveness-85%

Recuperator inlet temperature-830k

### TG-200 Performance - 225kW on Gas Generator Shaft

Cycle pressure ratio- 8.47

Air flow-1.03 kg/sec

H.PT inlet temperature-1275k

Thermal efficiency-35%

T.C turbine pressure ratio-2.09 , efficiency-86.5%

T.C compressor pressure ratio-3.6,efficiency-76%

Recuperator effectiveness-85%

Recuperator inlet temperature-853k

### **TG-200 - Modifications Program (of TG-40)**

Assure mechanical strength of rotating and stationary components to higher internal pressures.

Increase recuperator width.

Increase power electronic unit to 200 kW.

Design new alternator coupling.

Design and build air/water inter cooler.

Design and modify the TG-40 control system.

**TG-150**

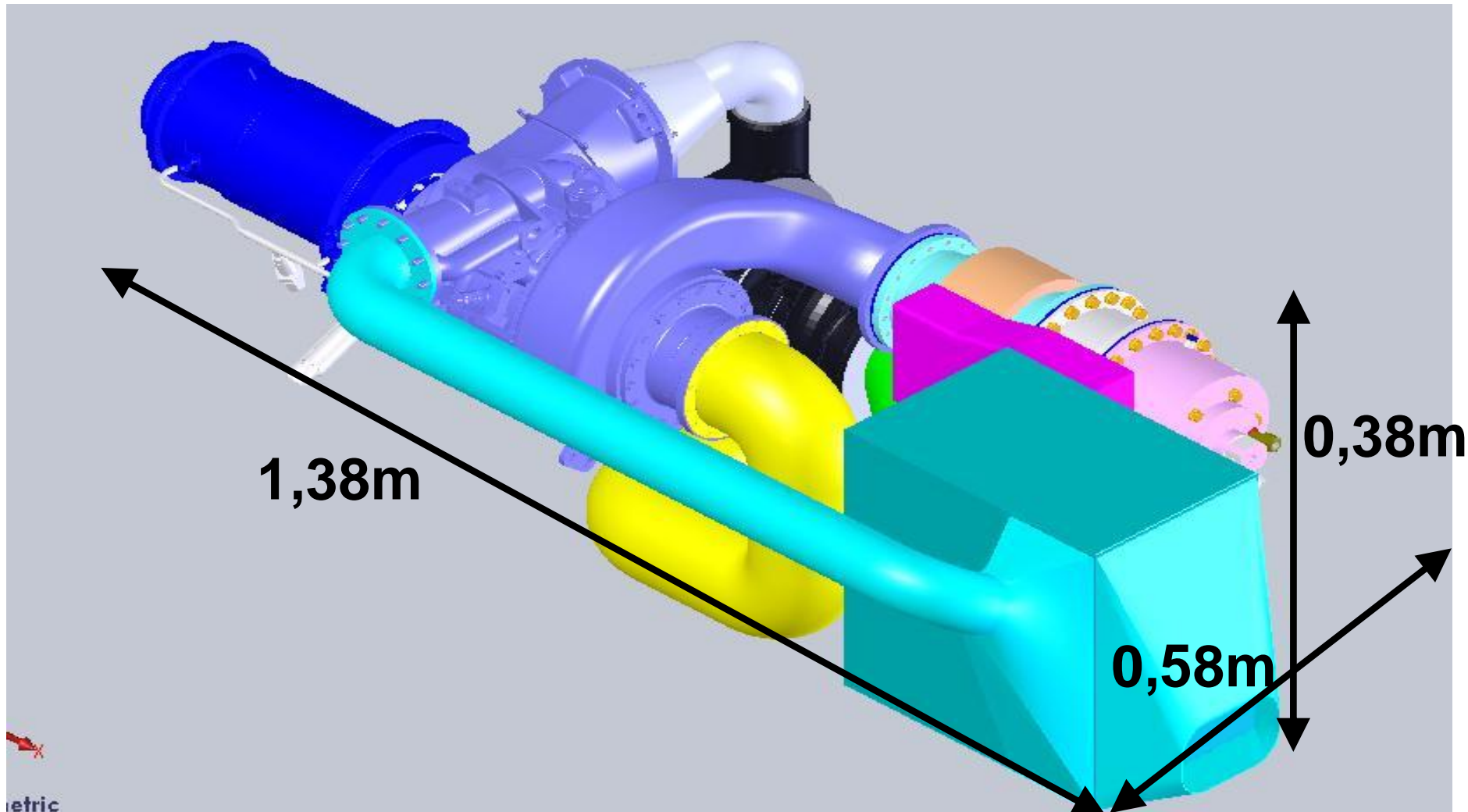
**Turbocharged Aerospace  
Performance**

### TG-150 Aerospace Main Features

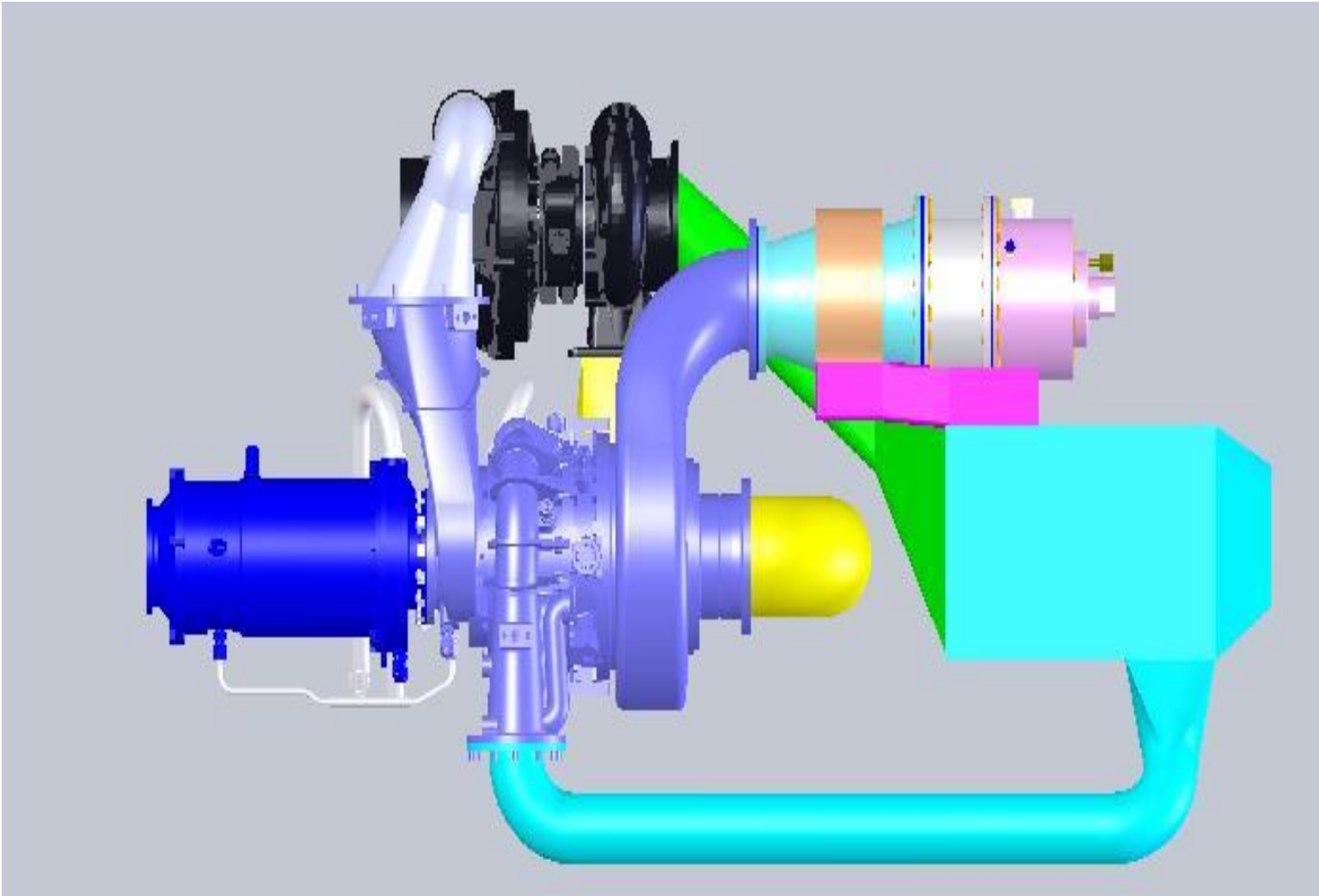
- Dimensions (mm)      length=1380    width=580    height=380
  - Weight- 145Kg      (including 20Kg transmission weight)
  - Thermal power -      150kW; Net power-145kW
  - Power/Weight ratio -    1
  - Recuperator-compact - stainless steel plate and fin construction
- Its effectiveness increases from 75% at SLS to > 90% at 10000m altitude., due to decrease of mass airflow and thermal load.

Performance	T.C. Loaded		T.G. Loaded	
	Power KW	Efficiency %	Power KW	Efficiency %
SLS	150	30.0	146	28.4
3000m-Mach=0.3	123	32.6	122	31.4
6000m-Mach=0.35	109	36.0	96	31.0
10000m-Mach=0.4	70	38.2	61.5	36.0

## TG Aerospace 150kW



## TG Aerospace 150kW - Top View



# Summary

- Turbo-charging a commercial micro gas turbine is presented as a cost effective method to boost its power 4-5 times while keeping a high thermal efficiency.
- Using automotive turbochargers as add-on modules simplifies the system design and reduces cost.
- Thus- a green competitive solution is available in the 40-200kW power range.