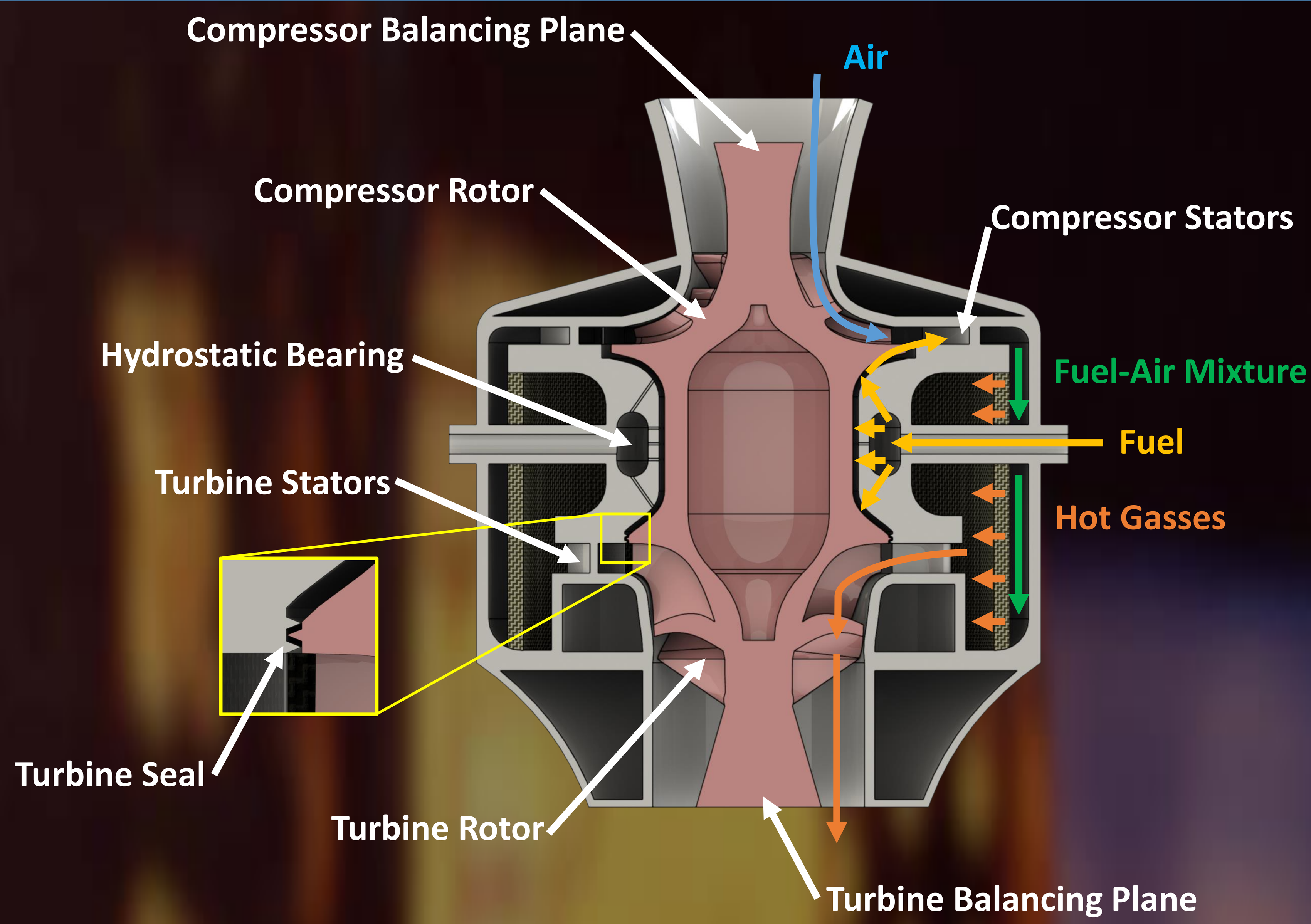
Additively Manufactured Incessantly Printed Engine

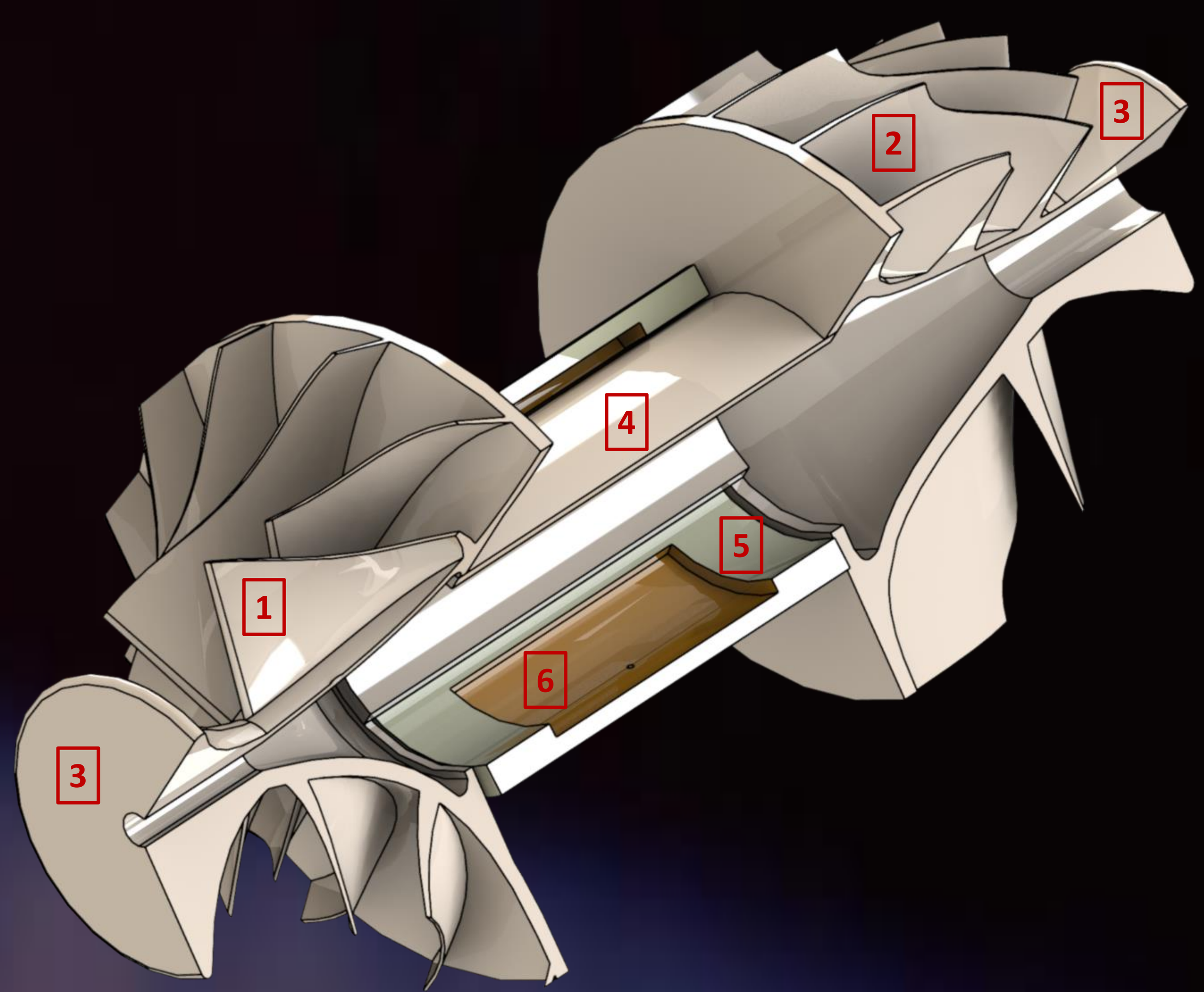
Turbomachinery and Heat Transfer Laboratory
Michael Palman, Assoc. Prof. Beni Cukurel

MOTIVATION

Unmanned aerial vehicles (UAV) capture ever-increasing part of our daily operations. This is especially true for small scale UAVs, which are commonly powered by micro-gas turbines. These micro jet engines have thrust ratings below 1 kN and have disproportionate cost that varies between 30,000 to 150,000 USD. For both disposable and reusable platforms, this inflates the system cost dramatically. Moreover, in multi-mission platforms, significant efforts are invested towards prolonging service life of these small yet expensive engines, and maintenance becomes important subject, which involves long chain of suppliers and overall work expenditures that can even surpass the base engine price.

Goal: Current project aims to remove costly and long production lines by providing cheap on-demand manufacturing solution for small-scale airborne propulsion systems.





APE spool layout:

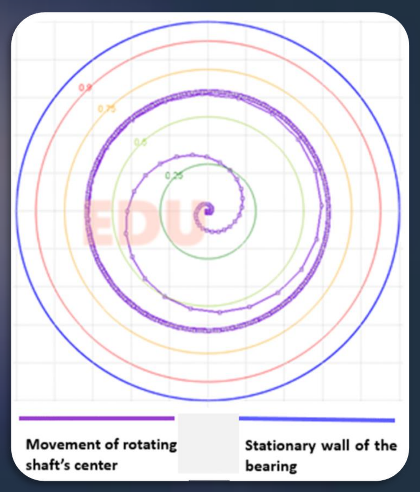
(1) Compressor,
(2) Turbine,
(3) Balancing Masses,
(4) Bearing / Shaft,
(5) Stationary Bearing Component,
(6) Pressurized Supporting Pocket

PROPOSED SOLUTION

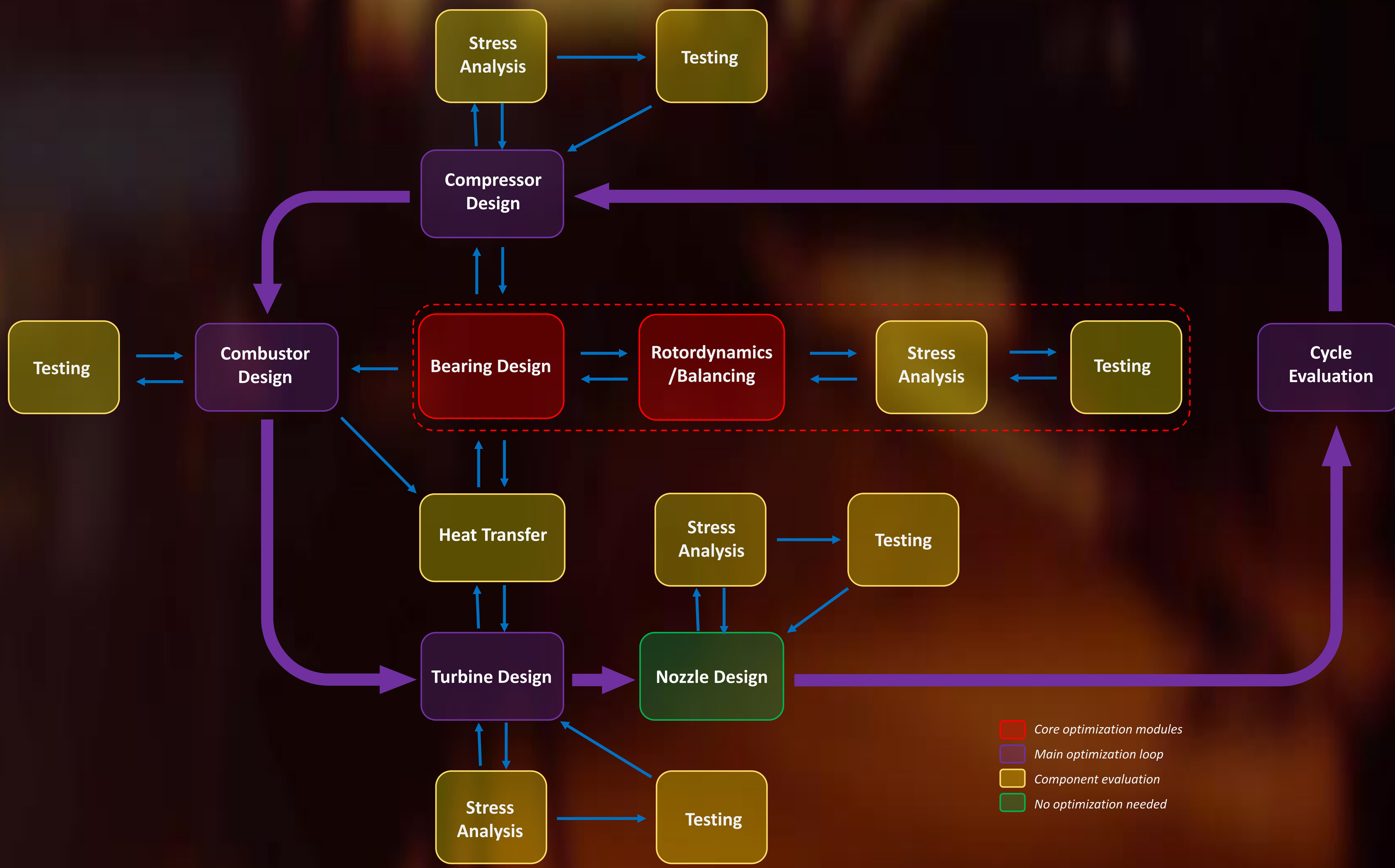
Proposed project aim to reduce number of engine parts to only two major components - static casing with embedded combustion chamber and rotating shell structure. Furthermore, the engine will be incessantly printed in its pre-assembled state. A single rotating part will include both the compressor and the turbine. Using fuel as bearing fluid will allow for further reduction of system complexity. Beyond lubrication, fuel will provide additional shaft cooling by evacuating heat generated by the combustor and the bearing. Addition of fuel preheating will further increase system efficiency by re-introducing the otherwise lost thermal energy into the thermodynamic cycle. Simplified model can be used to estimate potential performance of such additively manufactured engine.

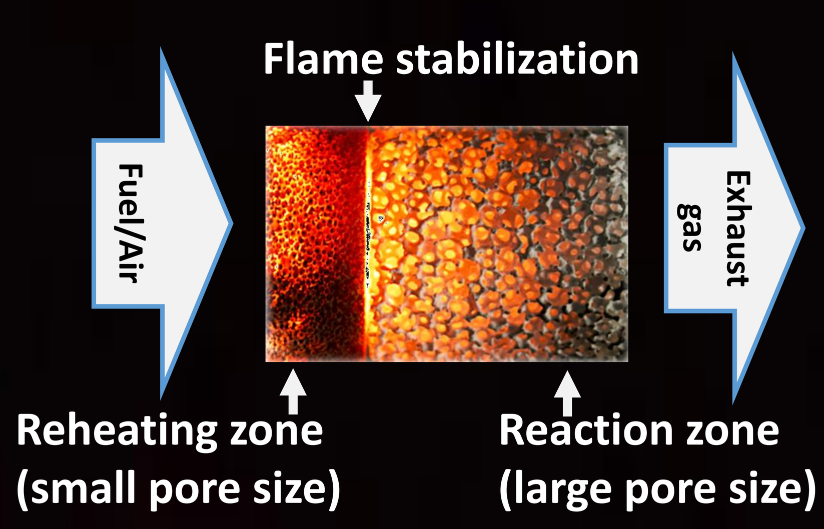
PRELIMINARY ANALYSIS

Preliminary compressor and turbine designs are generated with ANSYS Vista CCD / RTD tools and are finalized using ANSYS BladeGen. TIT of 1100K is assumed based on Inconel 718 material properties. Pressure ratio of 2.5 is proposed as compromise between turbine power generation and engine nozzle demand. Overall, these inputs result in 333 kW power turbine with 83% efficiency. Using AxSTREAM bearing design module with available turbine power allows to support steady bearing operation with power demand of up to 60 kW.



Jet engine equipped with such components will have thrust rating of about 650 N.





POROUS MEDIA COMBUSTOR

Surface area per unit volume of porous structure is very large, resulting in higher heat transfer between fluid and solid phases. Highly turbulent inner flow intensifies momentum heat/mass transfer and ensures flame stabilization over wide range of flow velocities and equivalence ratios. Along with radiation and conduction, porous media increases heat transfer from reaction zone to the upstream, preheats the incoming fuel-air gases and allows decreased flame temperature. Additional benefit of porous media is its convenience for additive manufacturing, since it acts as a self-supported structure.

REDUCED ORDER MULTIDISCIPLINARY OPTIMIZATION

Proposed project involves sophisticated multidisciplinary optimization of aerodynamics, thermodynamics, heat transfer, rotordynamics and stresses for turbomachinery and hydro-static/dynamic bearing components under 3D manufacturing limitations. Core of the design routine is the bearing performance.

SUMMARY

Goal of the project is to develop a ~650N thrust class micro-turbojet engine architecture towards additive pre-assembled manufacturing through a single uninterrupted print, significantly minimizing the cost to the end user. Requiring only a metal printer and an operator, cost of the engine will be diminished to capital equipment depreciation and raw material, with an expected cost reduced to approximately 3000 USD.