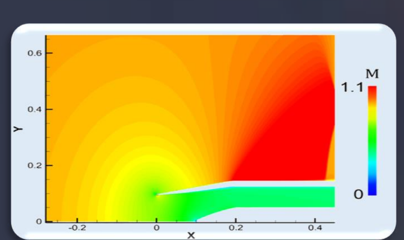
Adaptive Cycle Micro-Turbofan Engine

Michael Palman[1], Boris Leizeronok[1], Ron Miezner[1], Beni Cukurel[1], Valeria Andreoli[2], Udit Vyas[2], Guillermo Paniagua[2], Tayyip Gurbuz[3], Menal Ilhan[3], Sercan Acarer[3]

[1]Turbomachinery and Heat Transfer Laboratory, Technion – IIT; [2]Purdue Experimental Turbine Aerothermal Laboratory, Purdue University; [3]İzmir Katip Çelebi University

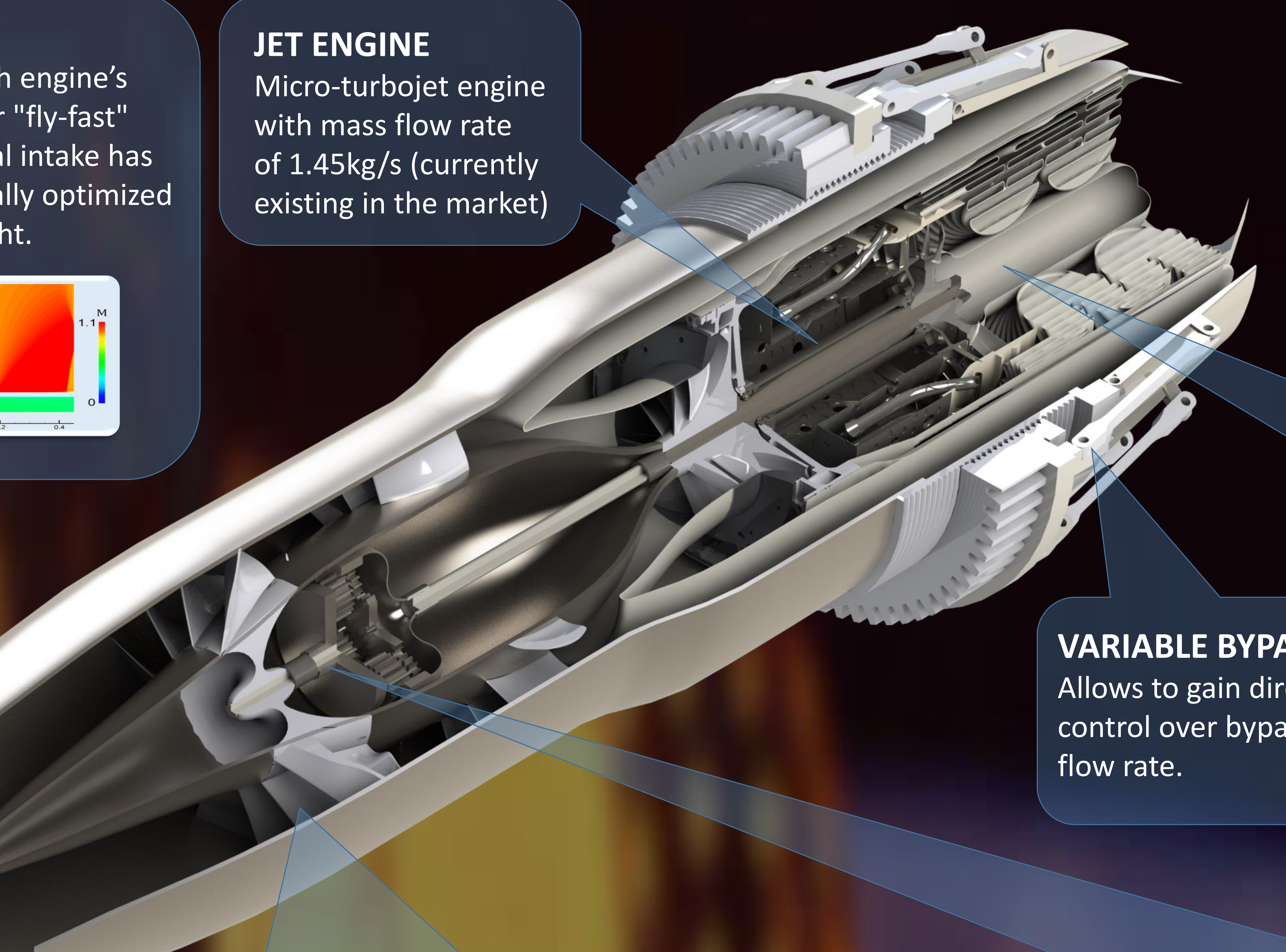
INTAKE

In order to match engine's requirements for "fly-fast" condition, special intake has been geometrically optimized for transonic flight.



JET ENGINE

Micro-turbojet engine with mass flow rate of 1.45kg/s (currently existing in the market)

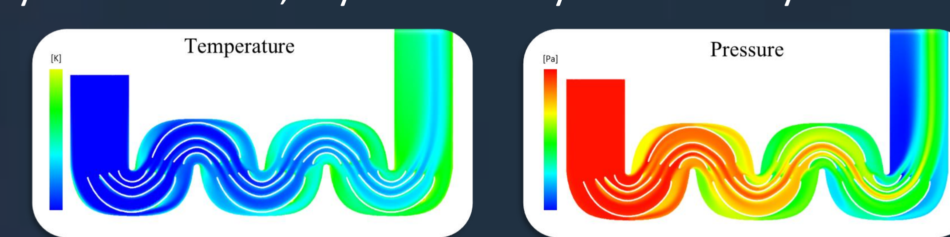


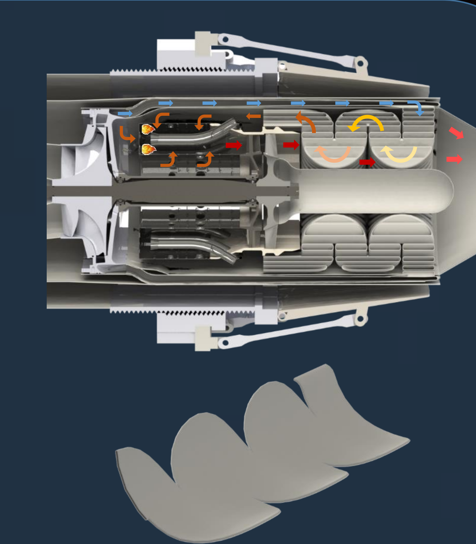
MOTIVATION

Aerial platforms experience vastly varying flight conditions. The engine demands rapidly change from takeoff to cruise, while the weather conditions have an additional effect on the propulsive system performance. Based on currently available technology, engine can be designed only for single operation condition. This approach means that the engine will spend most of its flight time in off-design conditions, which is highly impractical. Thus, evolution of next-gen turbofan engines would require adaptive operation cycles via accommodation of continuously variable planetary transmission. Along with variable bypass nozzle, it will allow for the core of the engine to remain at maximum efficiency throughout entire flight. Recuperation would further boost engine performance.

HEAT EXCHANGER

Heat exchanger consists of stacked together serpentine bent channels. Despite its relatively low efficiency (~40%) it has highly positive effect on thermodynamic cycle. Therefore, it yields 13% cycle efficiency increase.



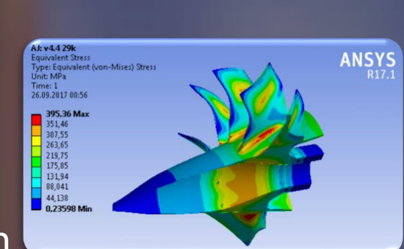


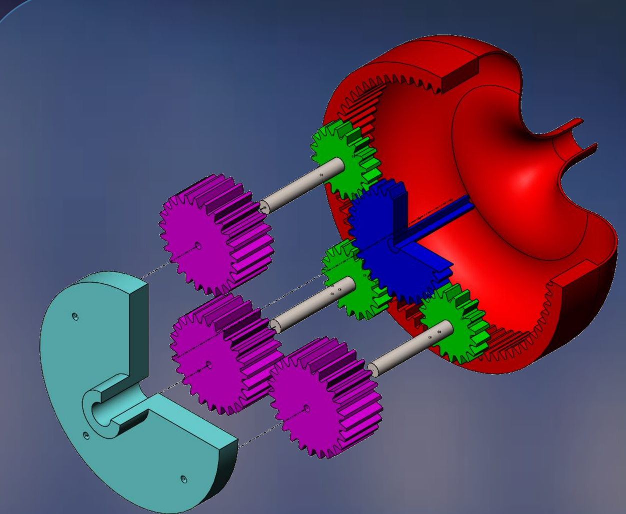
VARIABLE BYPASS NOZZLE

Allows to gain direct control over bypass mass flow rate.

FAN

To increase efficiency, non conventional hub-loaded fan was designed. Its hub performs as a booster for the core stream. Requirements of higher pressure in the core and lower pressure for the bypass result in highly twisted blade design. Therefore additional emphases on manufacturability and structural integrity were needed.

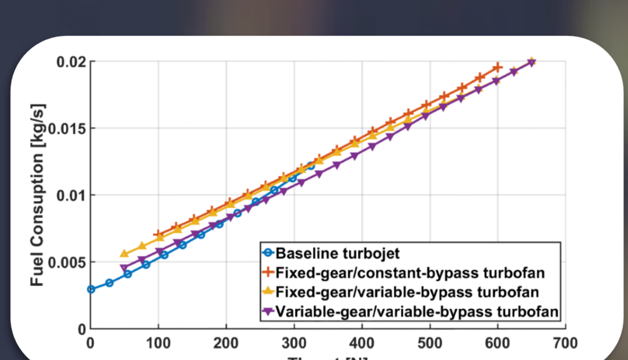




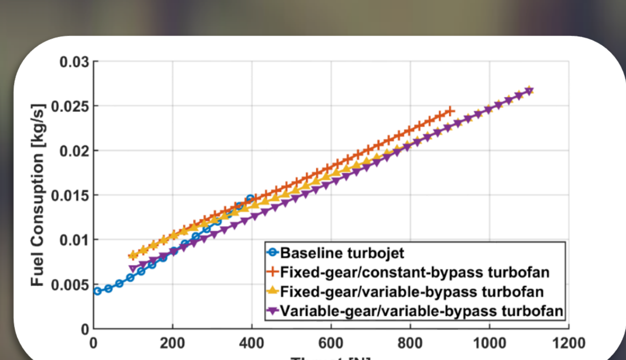
CONTINUOUSLY VARIABLE TRANSMISSION

Planetary gearbox operates by coupling the input and output shafts through a set of coaxial sun and ring gears, connected by power-transferring planet gears and their carrier. By introducing an alternator as a secondary external speed control input, typical planetary gearbox will perform in continuously variable drive-train mode. The continuously variable reduction ratio is achieved by powering the ring shaft and changing the relative speed between the planets' carrier and the sun.

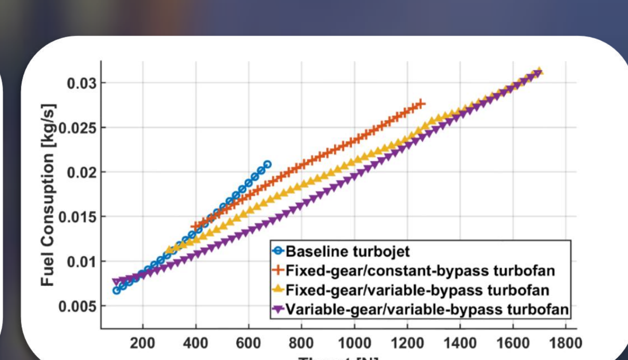
SIMULATION RESULTS



Fuel consumption vs. thrust for various engine architectures at cruise condition (h=9 [km],M=0.9)



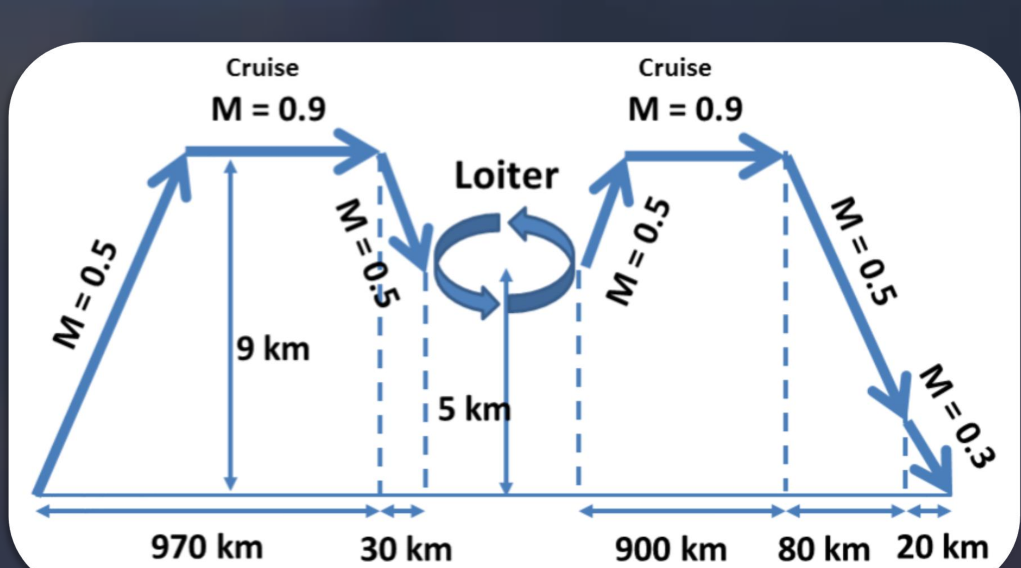
Fuel consumption vs. thrust for various engine architectures at loiter condition (h=5[km],M=0.3)



Fuel consumption vs. thrust for various engine architectures at take-off condition ($h = 0[km], M = 0$)

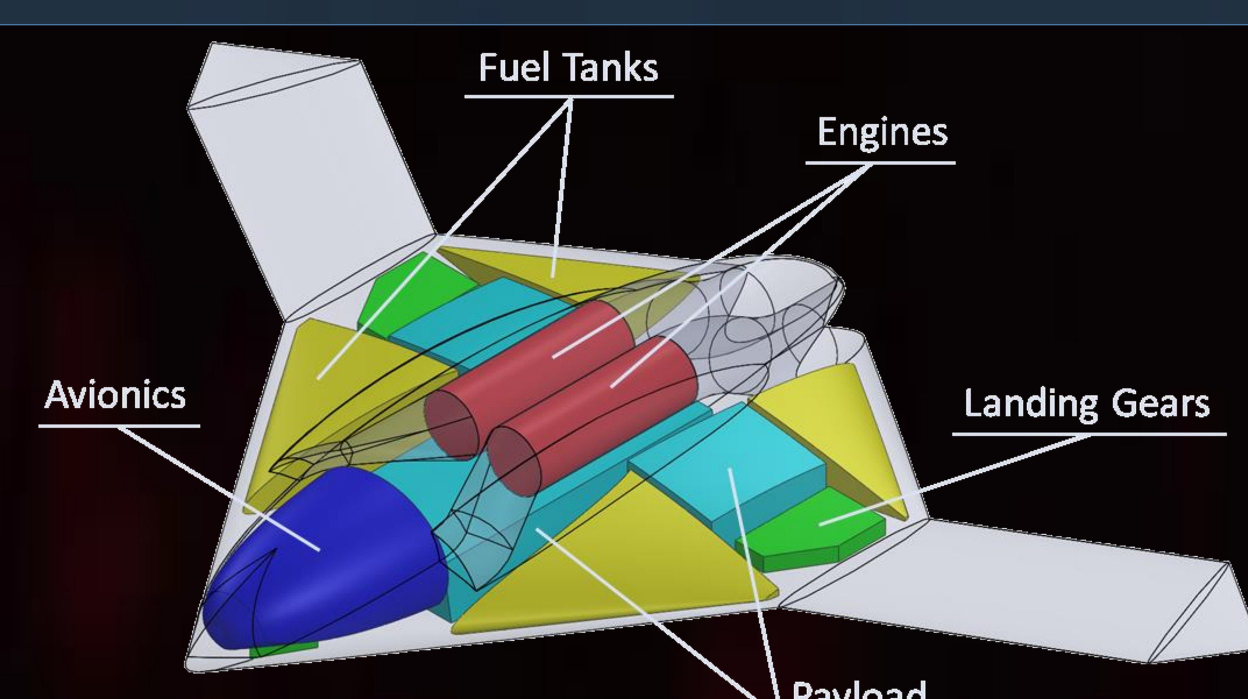
In three typical flight conditions the variable-gear/variable-bypass un-recuperated engine shows superior results.

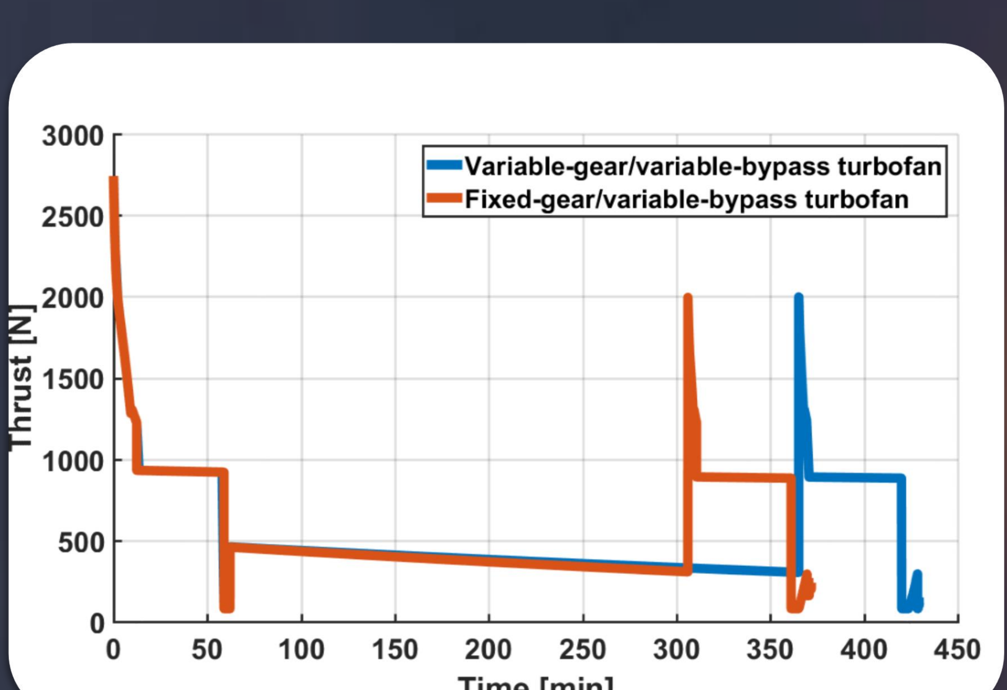
- For the high Mach number flight, conversion from turbojet to fixed-gear/fixed-bypass turbofan increases maximum thrust by 85%. Addition of the variable bypass yields 8% rise in thrust at improved fuel consumption. Finally, coupling of the CVT further reduces the fuel consumption by up to 7%.
- For the loiter condition, conversion of turbojet into fixed-gear/fixie-bypass turbofan effectively doubles the thrust potential of the engine. Addition of a variable bypass will further increase thrust by 22% and reduce fuel consumption by 7%. Finally, when CVT gearbox is introduced, the fuel consumption is further decreased for similar thrust levels, reaching up to 15% additional savings.
- In take off condition, the fixed-gear/fixed-bypass turbofan is capable of increasing thrust by 87%. In contrast, addition of the variable bypass increases thrust range to 1700N at lowered fuel consumption by up to 11.3%. In this case, the addition of the variable gear further reduces the fuel consumption up to 15%.



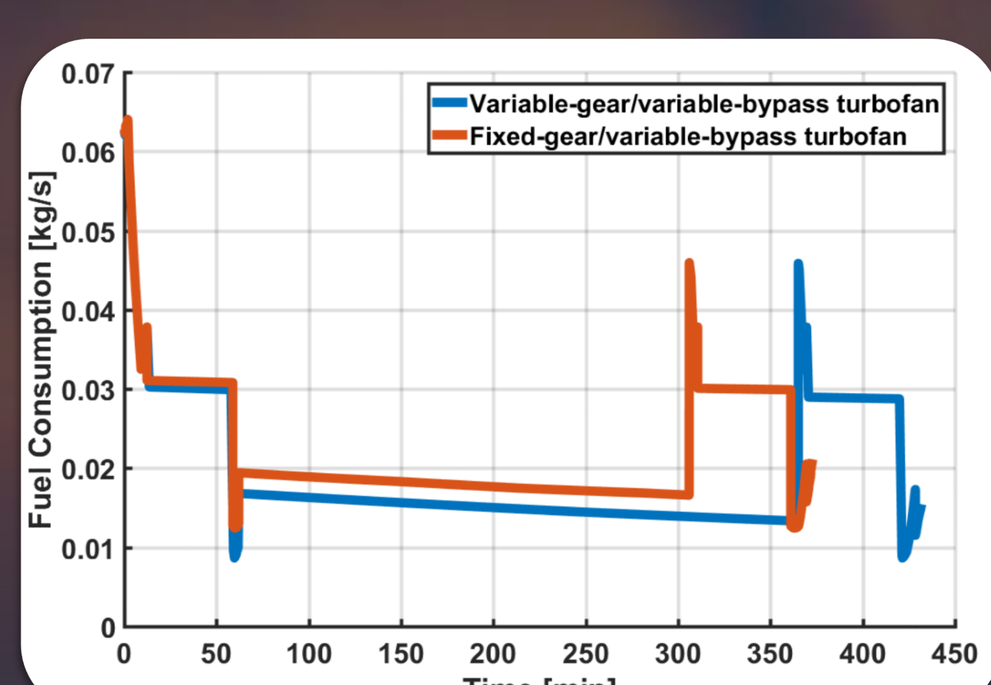
MISSION ANALYSIS

In order to evaluate engine performance in real life scenarios was conducted preliminary design of hypothetical flying platform. Such platform, powered by two un-recuperated engines will be able to take up to 478 kg fuel/payload. Then this UAV was examined in hypothetical Surveillance mission. The goal was to get to the targeted area as fast as possible and stay there maximum available time. The UAV equipped with variable-gear/variable-bypass engines showed clear advantage over the UAV with constant gear engines. It was able to stay above the target for 60 minutes more, which is 20% improvement of loiter time.





Thrust profiles for surveillance mission with fixed-gear/variable-bypass and variable-gear/variable-bypass turbofans with respect to mission time in [min]



Fuel consumption profiles for surveillance mission with fixed-gear/variable-bypass and variable-gear/variable-bypass turbofans with respect to mission time in [min]

CONCLUSIONS

Overall, variable-gear/variable-bypass configuration of the engine represents an efficient and versatile propulsion system. Suitable in a vast set of applications, and for any rapidly changing flight conditions missions.

FUTURE WORK

- Parts optimization and integration
- Engine prototype assembling and confirmation of simulations results

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The project was supported by NATO Science for Peace and Security (SPS) Programme under grant G5202 and by U.S. Office of Naval Research Global under award N62909-17-1-217