

Design Considerations for the 18000 Watt Drone Engine

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On this engine we need to know what are concessions we aren't going to make

The engine in its small (robot, 500 watts) version and in its large (drone, 18000 watts), the engine needs to be essentially completely silent and having no thermal signature

The engine will be fuel (energy density of fuel, and energy per unit of wt of fuel)

The engine will be Reciprocating Piston Internal Combustion type (RPIC). This method to convert chemical energy into mechanical energy is mature, robust, and well understood technology, so we will use this.

Cycling rate of this engine sets how fast it must push out exhaust gases, rate of exit of exhaust gases sets essentially all of the noise made by the engine, thus we will require a low cycling rate (beats per minute) (bpm) for the engine.

The drone and robot versions are for a military use, we want deep quiet standby to be feasible, thus a cycle rate for this engine needs to have no real lower limit. Upper limit will be 80 bpm but lower limit could be 80 beats/hr or even 8 beats/day, or even slower. A drone on ready standby or a robot in the forest on watchful waiting standby, etc.

Fuel injection and ignition gives the start of conversion of chemical potential energy into actually available mechanical energy. For the ability to have slow cycling rate, it is essential that the fuel cannot "decline" to ignite. Fuel will be pre-heated in a no oxygen setting to a temp above its spontaneous combustion temperature, so that when the fuel is injected into the combustion chamber it will already be at a temperature significantly above its spontaneous ignition temperature so that when the fuel contacts oxygen in the combustion chamber, it will always ignite, independent of the cycling rate.

This engine will use a modification of the free-piston style of RPIC configuration. There are several reasons for this, mostly related to having no lower limit on the bpm, but also based on considerations of no unnecessary weight or complexity.

The computational/control principle of this engine will be that a digital cpu system controls the drone. There will be a cpu of the drone (cpu-d) and a cpu of the engine (cpu-e). The flow is cpu-d does not really "run" the engine it just tells cpu-e what power it needs. And cpu-e does not really "run" the drone, it "runs" the engine so that the engine is "watched" and "modulated as needed" to give out the power that is requested by the cpu-d.

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The drone will have VTOL and also fixed wing flying ability. VTOL so that the drone does not need a runway for take off or landing. Fixed wing because energy use per unit of travel and per unit of time is so much more efficient with Fixed Wing. The drone will be able whenever it wants to switch itself from VTOL to fixed wing and vice versa.

The drone will have a control panel. The piloting/flight management of the drone will be (from a control of the details of flying) under the control of the algorithms and look-up tables of the cpu-d. The human pilot of the drone will have overall control of the flying features of the mission, but the pilot will not be required to control/manage the details of keeping the drone in a stable flying configuration. This is done so that use of this drone does not require a fully trained combat military aviation pilot. This feature is very important.

Payload max is set to 80lbs and the word max does not mean it sort-of can carry 80lbs. It will be able in a standard manner to carry 80lbs whenever it is asked to do so. All of its flying features will be based on it carrying 80lbs, but it can also fly with a lighter payload if requested. 80lbs is chosen because for a drone of this size with its flying specifications, the feeling is the military will want it to have an 80lb payload ability.

Fuel load on take off is set to 60lbs. The drone can fly with less than 60lbs fuel, as long as flying considerations are properly made based on the drone starting with a lower fuel load. 60lbs is chosen because the feeling is the military when it sees what this drone can do with its flying specifications and its 80lb payload, the military will agree that it can support the normal take off fuel load for this drone as 60lbs.

The drone engine has two sections. Section One converts the potential chemical energy of the fuel into useable mechanical energy. Section Two is a "Supercharger" type of setup. The purpose of the supercharger is to allow the engine to have its power output per unit of engine wt and its sfc (Specific Fuel Capacity) values. In addition the supercharger modulates and conditions the exhaust gases so that the drone has essentially no acoustic and also no thermal and no odor/fume signatures.

It is understood that the free piston configuration has many advantages, but the free piston setup also has many behavior sequences that can occur that would stall out or shut down the free piston cycling. The management protocols for the cpu-e are that this cpu-e has input from multiple sensors and it has control of many points or action areas of the cycling of the engine so that the cpu-e of the engine can watch for, notice, consider, refer to algorithms and look up tables and the cpu-e can use its multiple areas to control valves and other settings so that it can keep the free piston system working properly to "force" it to not stall itself.

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The designers have been on many committees. There is a phrase (this phrase is just made up) the phrase is: "The Waving of the Hands"

Experience is at committee meetings as a participant makes their point, or explains what happened, or where a fault might be assigned, or make a persuasion, etc., during that episode of speaking (for a lot of normal people) if the presenter "wanders" into a sub-section of their presentation where (and they know this) they are really getting into an area where they don't really know (in a full and complete manner) where they really do not know what they are talking about.

The notice is (if one will watch and perceive) as the presenter gets into the area(s) where the presenter does not fully know what they are talking about, the "Waving of the Hands" will start. Thus, while they are continuing to be talking, they will start waving their hands around.

We don't want this engine design to have sections where the "Waving of the Hands" occurs.

The designers of the engine have the belief that the electric motor/geahead versions of drones is their preference and is (their opinion) the only reasonable set or type of drones. It is the opinion of the designers of this drone engine that the electric drone folks will stand ready to criticize and argue this engine design is "crazy talk" and it will "fail." Of course, the electric drone folks are welcome to make their points and welcome to believe what type of drone design is the "best" or "most reasonable" or "most likely to actually work properly."

But because of this almost surely to occur opposition to this engine design, it seem reasonable that the designers of this drone engine do not want any portions of the engine design discussion to include areas of the "waving of the hands."

This free piston engine design requires a set of actions to occur in a specific sequence, and these actions need to: 1) occur properly, 2) occur in their proper place in the overall sequence, and 3) not take any longer to "do their action" than is the time amount given to them.

All of these sequences involve physically real items or collections of items:

a) doing something and/or b) moving somewhere. Thus the design discussion must include explanation (without the waving of the hands) based on science and math of how both a) and b) can occur in the time amount given to them. This suggests that a timeline needs to be created listing the sequencing of how chemical energy is converted to mechanical energy and listing all the actions of the sequence, including their place in the sequence and the time amount given to them to do their activity.

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Currently (this is an example conversation)

“So, Dr. Gray, the tungsten slug and the combustion free piston assembly needs to go (after it created mechanical energy) from its Bottom Dead Center (BDC) back to its Top Dead Center (TDC) in order for a new cycle to become possible?”

Dr. Gray replies: “Yes”

“And, Dr. Gray, this happens over a time interval of 34 msec and requires 1000 watts to move this much wt over its 8 inch stroke in the time interval listed?”

Dr. Gray replies: “Yes”

“So, Dr. Gray, where did tha 34msec come from?”

Dr. Gray replies: “Yes, ummm, (the waving of the hands begins), it was a Google Ai calculation”

The designers do not want that conversation above. The max bpm of 80 was chosen because this engine design has so many actions that must physically occur at their proper time and use only the msec given to them, that faster bpm than 80 seemed to have too much risk of failures and also as bpm rises, the management of exhaust gases begins to lose its ability to make the thermal and acoustic signatures to be essentially zero.

It seems reasonable to postulate that the 80bpm will be the most “stressful” timeline for the engine, so we will discuss this timeline. Of note, 80bpm gives a total of 750msec as the time available for all the actions in the sequence to occur.

The nature of the timeline arises from what we want the engine to do. It is reasonable that the max mechanical output value requested of the engine will be the most stressful timeline for the engine to deliver. So we will start with that timeline.

The max engine output requirement arises from the action that requires max energy output from the engine. In this drone design, we are using the concept of “Excess Power Transition” The vertical thrust at take off is 110% of the take off wt of the drone. This allows the drone on taking off, over about 30 sec, to rise to (we define as) a safe altitude for transition of 400ft. The drone will have a + vert vel of 40 ft/sec. At 400 ft alt, props are powered down, the upper props told to give a pulse, (powered down props means no gyro effects), the pulse gives the drone a rapid nose pitch down rotation from nose up/tail down to back up/stomach down. Props then brought back to full thrust (now as horiz thrust) drone accelerates its horiz vel over 2 sec to a value where wing lift = drone wt. The drone is now in stable fixed wing flying. Because it started this with a + vert vel of 40 ft/sec it converts to stable fixed wing flying and is still at 400ft altitude. This being a safe, reasonable, and unlikely to cause a crash method of transition.

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We can use 110% of take off wt as max vertical thrust event to go to our propeller values to obtain prop rpm and prop torque. In order for this excess power transition principle to be always available, this 110% of take off wt needs to be an engine output power that is available as a continuous engine output value. We can go to and use this 110% of take off thrust whenever we want and for as long as we want (providing, of course, that there is sufficient fuel available for the engine to create this power output).

Prop rpm/torque (since this is a distributed hydraulic propulsion design) will give us the needed L/min flow rate and psi pressure needed for the hydraulic motors of the prop. At our max hyd pumping rate of one pumping cycle at 80bpm, this will define for us the dimensions of the hyd pump, since we set its stroke at 8 inches. These values will be required and any other significant wattage uses needed for the cycling of the engine will need to be added to these required thrust related values to give us a final overall value for what is the max mechanical energy output needed as an available continuous power output from the engine.

This will allow us to do the calcs to get the power output. These calcs will allow us to specify the combustion assembly piston diameters (stroke length is set at 8 inches). This will allow us to create spreadsheets of the thermodynamics and kinetics of this engine for these specified max continuous power output levels.

We know all the activities of one complete cycle of the engine, thus we can create a timeline including the timeline subsection of combustion and creation of mechanical energy and the timeline subsection of the functioning of the supercharger.

Stability features have been added to the engine design to give the cpu-e abilities to notice and mitigate engine events that could lead to an engine stall. These changes alter what is required from the supercharger in terms of its piston diameters.

A timeline was created by Dr. Gray just to show how to visualize the timeline. It was based on the spreadsheets for the 5000 watt engine. The only absolutely known time points on this timeline is start at 0 msec and end at 750msec. All values in between are based on the intuition of Dr. Gray and the waving of the hands. We will need to calc the kinetics and thermodynamics spreadsheets for this 18000 watt (and it may be it becomes a little more than 18000 watts in order for optimizations against engine stall events to become optimizations that are present), and remembering this is a dual engine configuration to mitigate resonance issues from this pulse cycling free piston engine design.