P1000-PRO
P1000-PRO-GH
Turbojet Engines

Content

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Introduction

The JetCat-P1000-PRO type turbo-jet engine is designed as a propulsion unit for RC-aircraft and/or drones.

The engine can be lubricated by fuel with oil ad mixture, alternatively oil can be delivered via a separate miniature oil pump, which removes the necessity to add oil to the fuel.
The engine is equipped with a BLDC starter/generator, 2x BLDC fuel pumps, 3x fuel solenoids and electronic control system (FADEC type).
The engine may be modified based on customer specific requirements and to meet different operating / installation conditions.

Functional description

The JetCat P1000-PRO is a single-shaft engine comprising a single-stage radial compressor, annular combustion chamber, single stage axial turbine and fixed exhaust nozzle. At the compressor intake, there is a brushless starter /generator mounted which enables starting from the board network and allows for electrical power generation during engine run. Intake air is compressed in the radial compressor stage, proceeds through the radial and axial diffuser into the combustion chamber where it is mixed with vaporized fuel. Combustion gases generated by fuel burning in the combustion chamber expand through the single state axial turbine and the exhaust nozzle to the atmosphere. The gas exiting the exhaust cone produces the required thrust. The rotor of the engine is mounted on 2 ball bearings lubricated by a fuel/oil mix.

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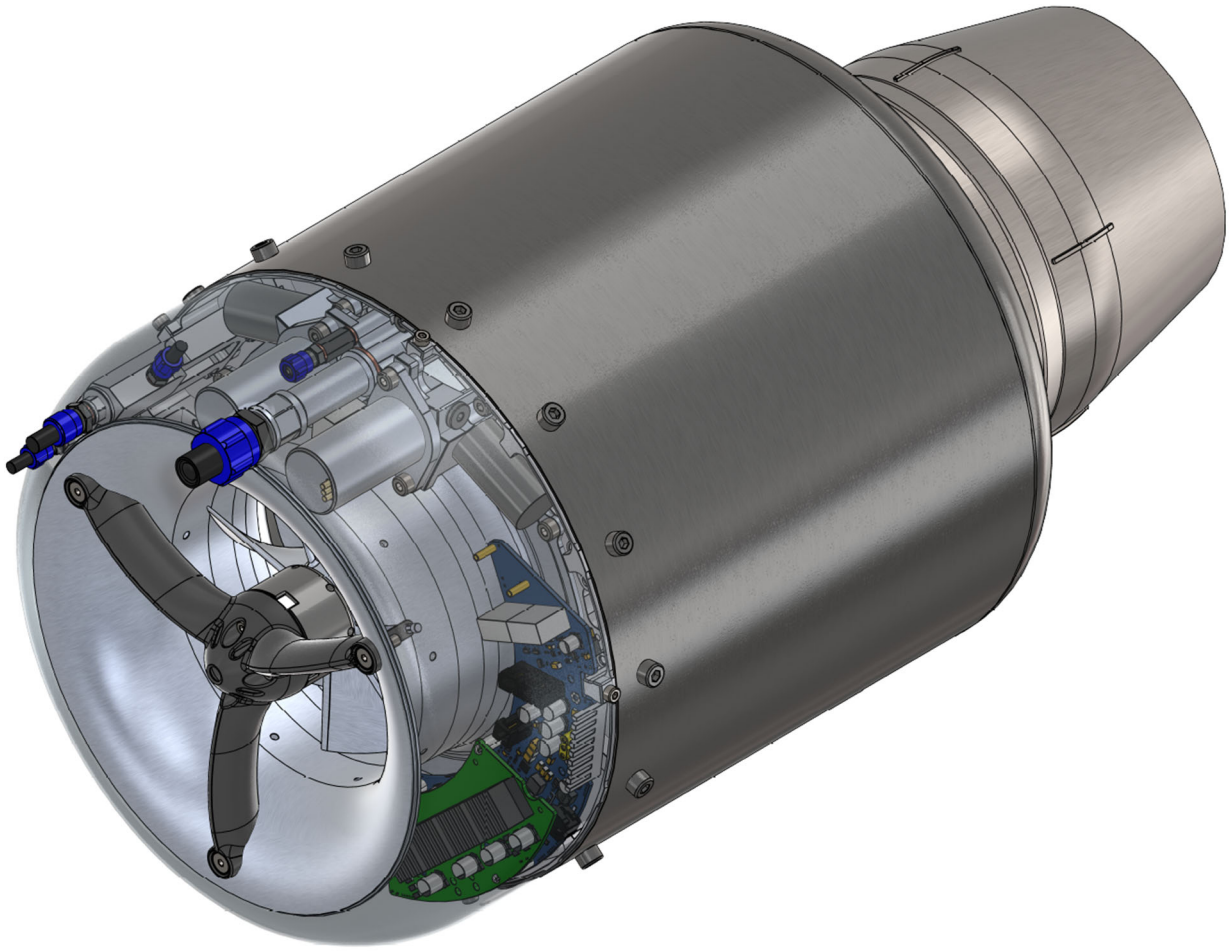
Control options / electrical interface

The JetCat-PRO engine series provides the highest level of integration and maximum ease of installation.
All peripheral systems necessary for the engines operation are fully integrated below the engines front cowling.

Highest level of integration:

There are no further external peripherals required like: ECU, pumps, valves, or igniter system.
All of this is integrated at the engines front end!
This tremendously eases the installation of the engine, reduces system complexity, and frees space for user payloads, otherwise occupied by engine peripheral systems.



Therefore, besides the supply battery, the fuel tank, there are no further external subsystems required!

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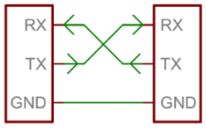
Engine Control Options

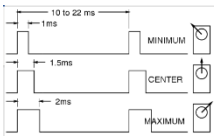
For engine control, per default there is a variety of control interface options already present, like:

Serial interface

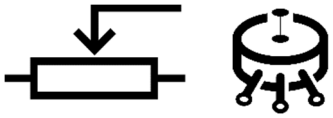


CAN-Bus

Servo-PWM



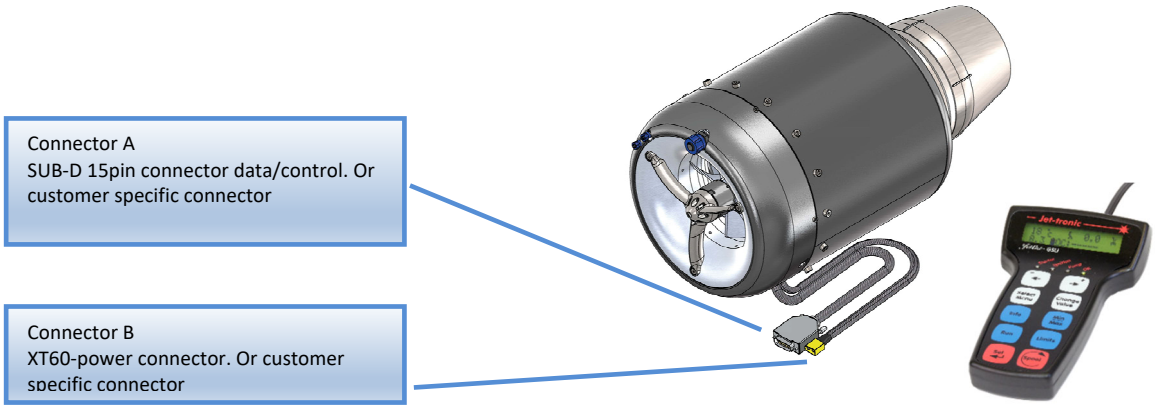
Analog control



- *Serial communication interface Rx/Tx (3,3V TTL or +/-12V RS232, RS485 optional). Baud rate: 2.4-115k*
- *CAN-Bus (2.0A-11bit or 2.0B-19bit. Bitrate: 125K-1Mbit/s adjustable)*
- *2x Servo PWM inputs for throttle/engine control*
- *Analog input for engine control (Start/Stop/Thrust control)*

The system allows to use a single control interface for engine control and data reporting or any mix, depending on user requirements.

The control signals are fed out on a pigtail cable terminated by a 15-pin SUB-D connector (other connector types available on request).
The power supply is made via a second pigtail cable with a XT60 connector for direct battery/power supply connection. Other power connector types possible upon request.



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JetCat P1000-PRO engine features/functions

Integrated Engine sided Components:

- *ECU (electronic control unit)*
- *Brushless starter/generator, contactless operating to engine shaft*
- *2x Brushless fuel pumps*
- *3x Fuel & Kerosene-start solenoids*
- *Fuel filter*
- *Barometric altitude / pressure sensor allowing* for automatic engine tuning upon operation altitude.
- *4-pin Molex expansion connector (e.g., for smoke pumps/ oil pump / fuel transfer pumps)*
- *Bleedair port with integrated one-way valve (e.g., for pressurization of fuel system)*
- Direct quick start on kerosene
- Internal dual, high speed / low current plasma ignition system
- Air restart capability
- Automatic engine cool down cycle after shutting down.
- Reporting of fuel consumed / fuel flow rates / remaining fuel in tank.
- Engine power up via digital control signal → No external power switches required.
- Separate/redundant engine safety shut down input, for instant engine shut down from flight termination system. This will kill power to fuel pump and shut off safety solenoid valves on an independent path. Whilst ECU can stay powered on (for continued data reporting and or engine cool down).
- Monitoring and reporting of all engine life parameters / setpoints as well as currents / voltages (e.g., supply voltage / current, pump driving voltage).
- Automatic fuel purge / aspiration function
- High Performance ceramic bearings

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Technical data

Performance data

Applicable under ISA conditions (15 °C, ambient 101.325 kPa, v = 0 m/s)

Maximum thrust	1100 [N]
Idle thrust	45[N]
Maximum outer diameter	235 [mm]
Engine weight (with accessories)	11kg
Physical revolutions per minute	19,000 - 61,500 [RPM]
Compression	4.0
Air mass flow	1.8 [kg/sec]
SFC at maximum thrust	0.127 [kg/Nh]
Fuel consumption - idle running	550 [ml/min]
Maximum fuel consumption	2,900 [ml/min]
Exhaust gas temperature t4	max. 800 [°C]
Time of acceleration from idle to max	5 [s]
Time of deceleration to idle	5 [s]

Fuel /Oil

Jet A1 or equivalent mixed with 3-5% of turbine oil.
Oil types: JetCat turbine oil, Mobil Jet Oil II, Aero Shell 500, or Exxon 2388 (or equivalents)

Fuel purity must comply with class 10-11as per GOST 17216-71 or 7-8 as per NAS 1638

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Electrical

Power supply

Supply voltage	10 to 35V DC (ideal: 3-4s LiPo battery with 5000mAh) The chemistry (LiPo, LiFe, Lion, NiCad, Lead, NiMh), the cell count and capacity (mAh) of the actual used battery is user selectable!
Min battery capacity required for start:	> 400 mAh. With the generator option, although not recommended, battery can be totally disconnected after engine start-up. The system then can fully run on its own power generated.
Average energy requirement per start:	400mAh; peak current 25A @12VDC
Peak power consumption (at start):	220W for max. 30s
Power consumptions when running:	24W at idle ; 85W at max thrust. Note: Once engine is running these power demands are served via the integrated AC/DC converter/generator.

Generator function / AC-DC converter

Max. power output of the 3-phase AC generator is 500W / (1600W on -GH version)

The integrated power supply unit consists of the integrated three-phase generator, a rectifier, and a switched step up/down DC-DC power converter. This system will provide enough power to all internal consumers of the engine (ECU, pumps, solenoids) once the engine has been started up. Excess power is used to automatically re-charge the supply battery. The generator output voltage is rectified, and precision regulated to a constant output voltage via an integrated DC/DC converter. The output voltage and current are automatically matched to the selected (programmed) battery type and size. Therefore, the output voltage of the DC/DC converter is adjustable by the control system in a broad range from 10 to 30VDC.

The DC/DC converter can supply a maximum current of 15,6A. It can maintain a constant output voltage up to this limit. If the current limit should exceed this or a lower programmable limit, the output voltage will drop.

Output current limiting function: Depending on selected battery type/size not to over current the attached supply battery on charging, the system monitors the current flowing in the supply line, by this the current flowing back to the supply battery can be limited to a safe limit when charging/buffering a connected battery.

The generator is installed in the compressor intake; The rectifier and DC/DC converter are integral part of the front mounted ECU.

Max. output current:	15,6A
Output voltage range:	10-30VDC, Output voltage is automatically set according to the selected battery type, cell count and chemistry of the connected supply battery. As an option, the DC-converter output can be completely disconnected from the supply battery, then acting as an independent output with user programmable output voltage.

Max power output capability depends on selected output voltage (used battery type):

At 12,6V (3s LiPo), max power output is:	12,6V x 15,6A	= 196W
At 16,8V (4s LiPo), max power output is:	16,8V x 15,6A	= 262W
At 21V (5s LiPo), max power output is:	21,0 x 15,6A	= 327W
At 28V, max power output is:	28V x 15,6A	= 436W

From this output capability, the power required by the engine system itself must be deducted. At idle, the power consumption of the engine system is around: 24W@idle, at max power it is at around 85W.

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System allows for automatic (re-) charge / buffering of connected supply battery. When engine runs, there will be no energy taken from supply battery.

Diagram DC/DC converter power output, with 3-cell Lipo battery as engine battery

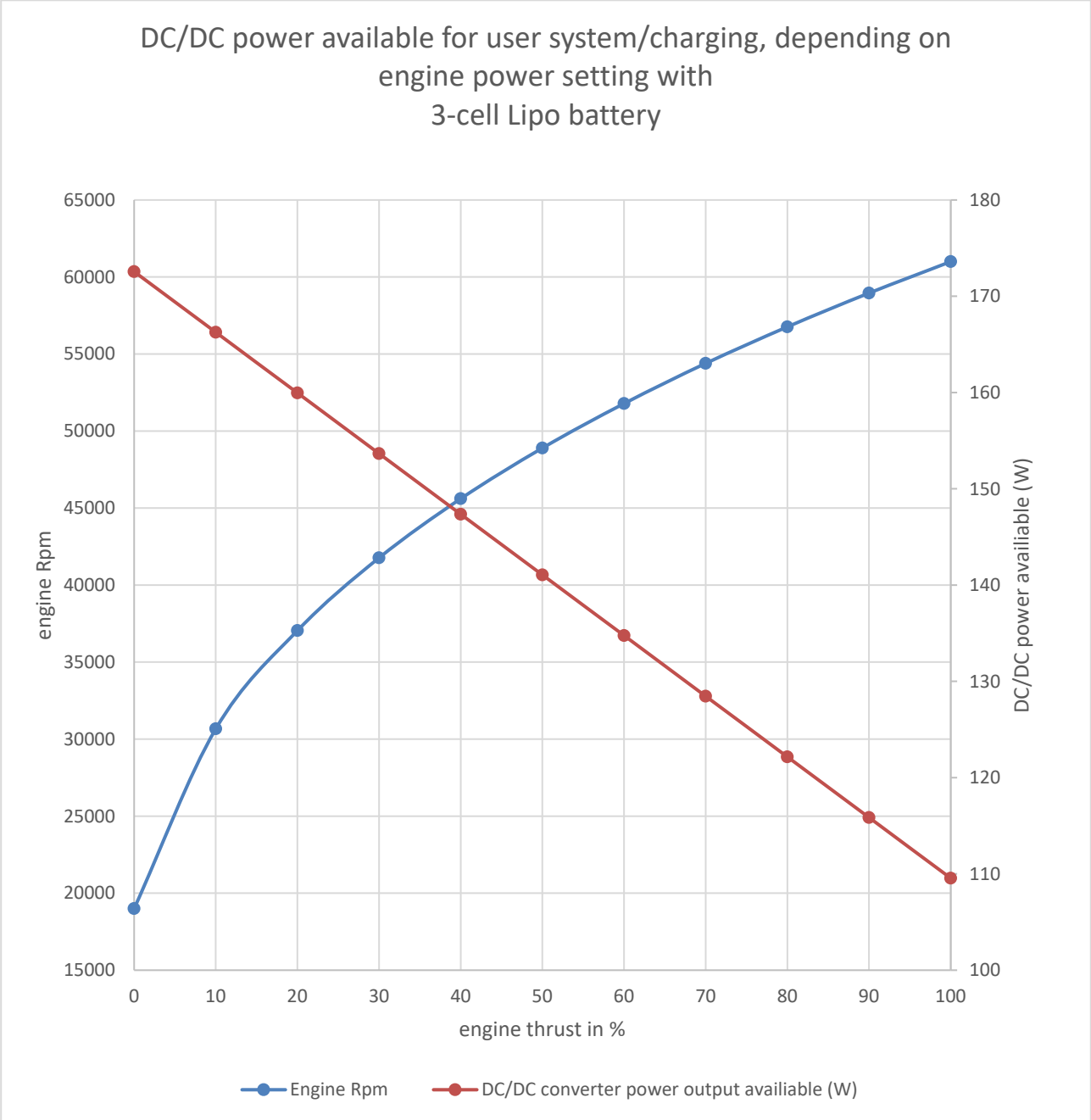

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Diagram DC/DC converter power output, with 4-cell Lipo battery as engine battery

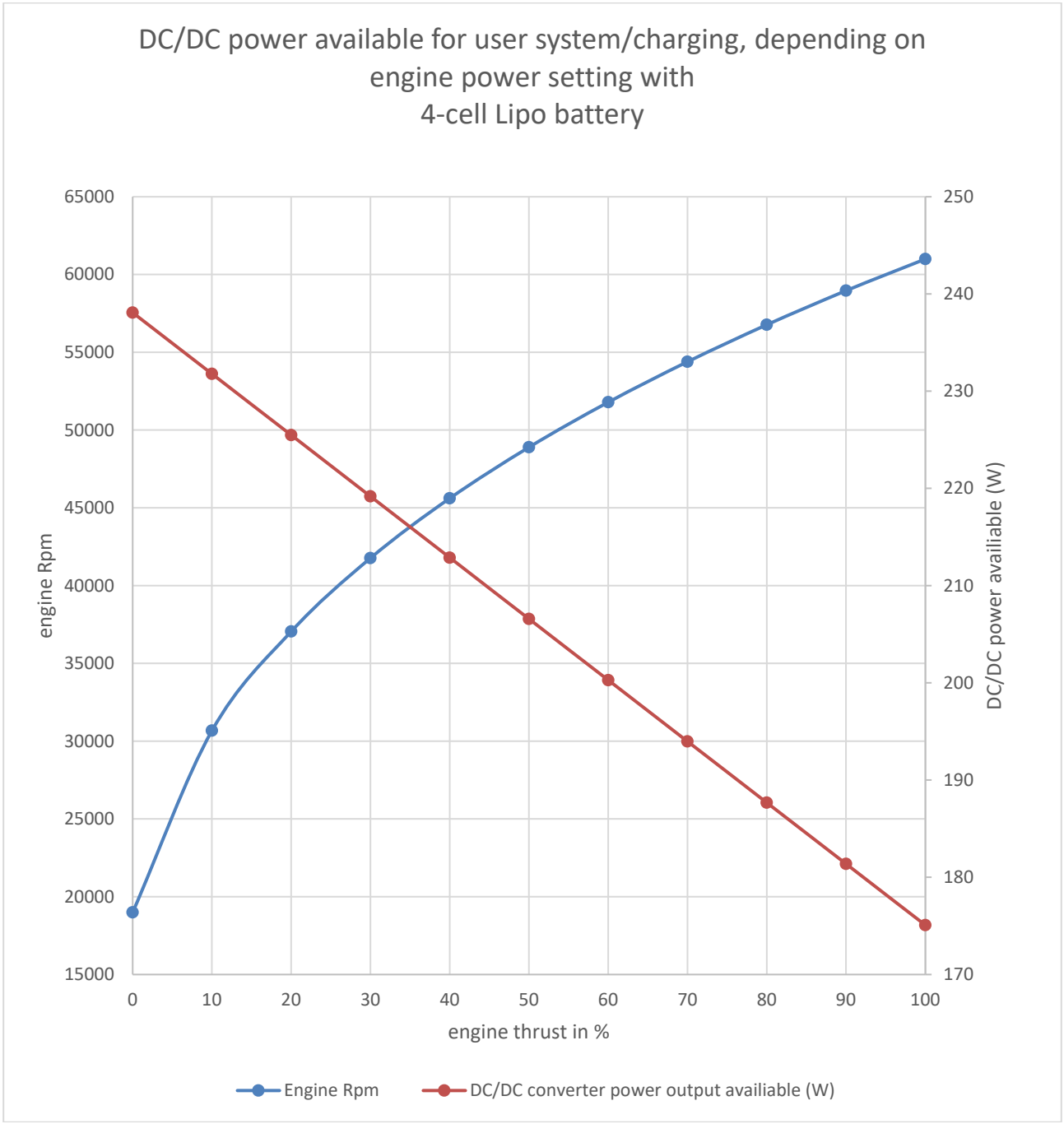

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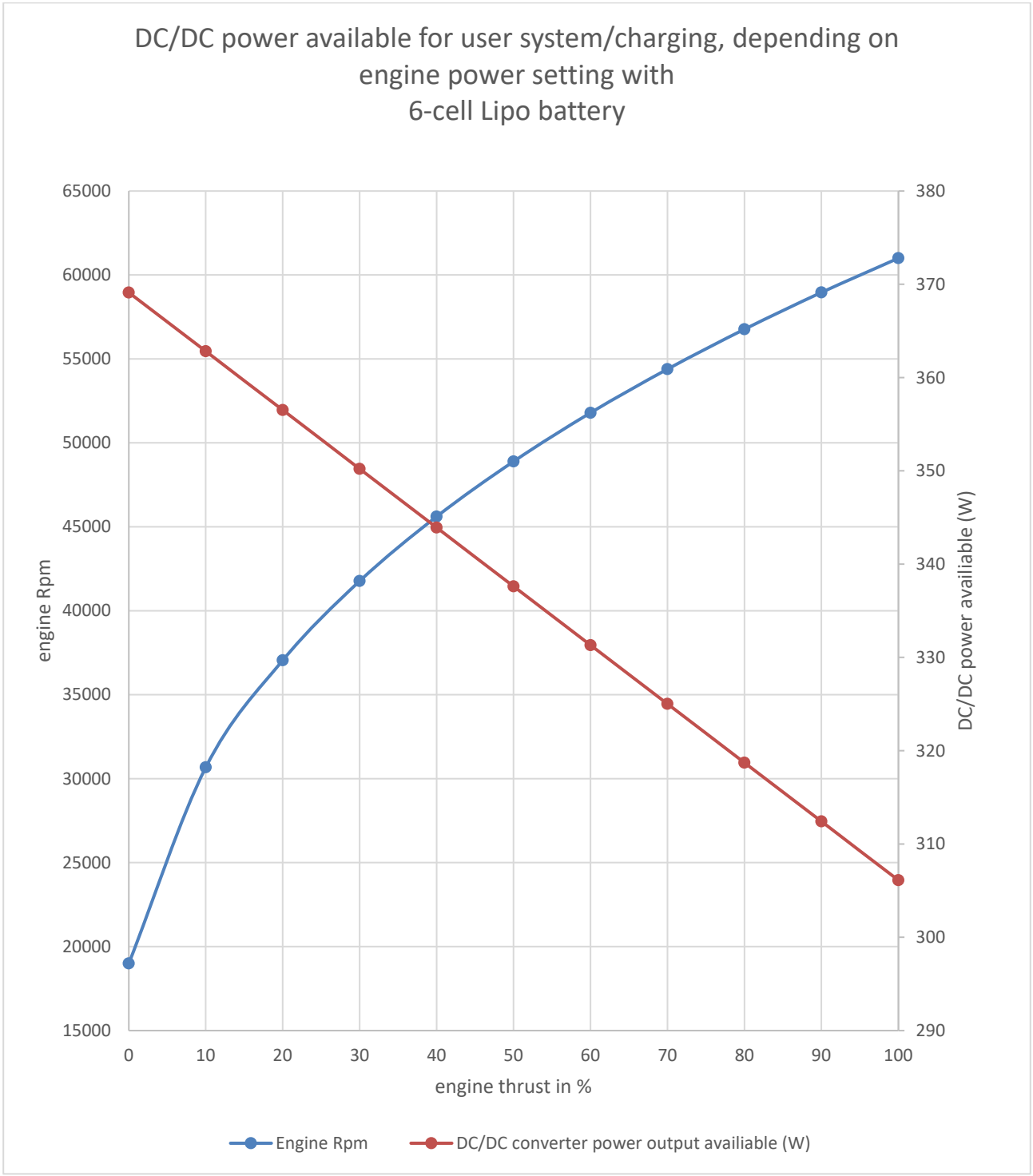
Diagram DC/DC converter power output, with 6-cell Lipo battery as engine battery



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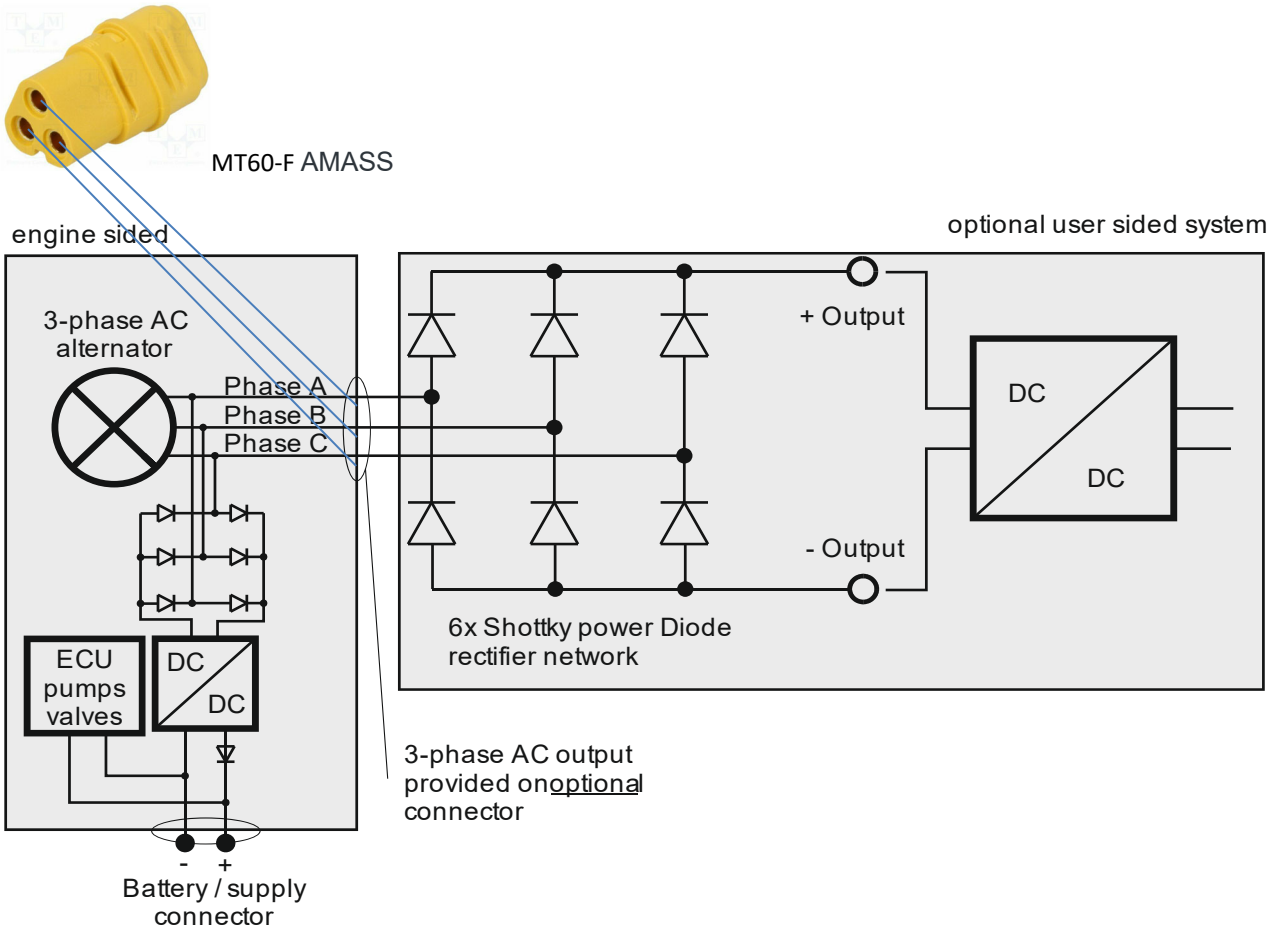
3-Phase generator output option

As an option, the 3-phase AC power output of the alternator is provided on a 3-pin generator output pigtail cable. Typically, this can be used to feed generator power into user specific circuits like external AC/DC rectifiers and/or higher power AC/DC converter circuitry. The 3-phase AC output follows a sine curve with 120° phase shifted outputs between phases A/B/C.

The 3-phase AC alternator output is provided on a 3-pin "MT60" type connector (female) on P1000-PRO-GH.
On the P1000-PRO the AC-output connector is not present per default, but available as an option.



In case the 3-phase generator output is used, the user system must absolutely make sure that the following conditions are always met:

1) No generator loading during engine start-up or cooling phase → To avoid interference with engine start-up where the alternator is used/ actively powered as a starter motor by the ECU system, the user sided power conditioning system must be safely disabled until engine has reached idle rpm!
2) Generator loading by external circuitry is limited to below shown diagrams (depending on actual alternator size installed with engine).
   The user system must make sure that these limits are not exceeded at any time, otherwise damage of generator and/or coupling system may result!
   Typically this can be accomplished by reading/observing the engine state through one of the data interfaces (CAN-Bus or serial data connection).

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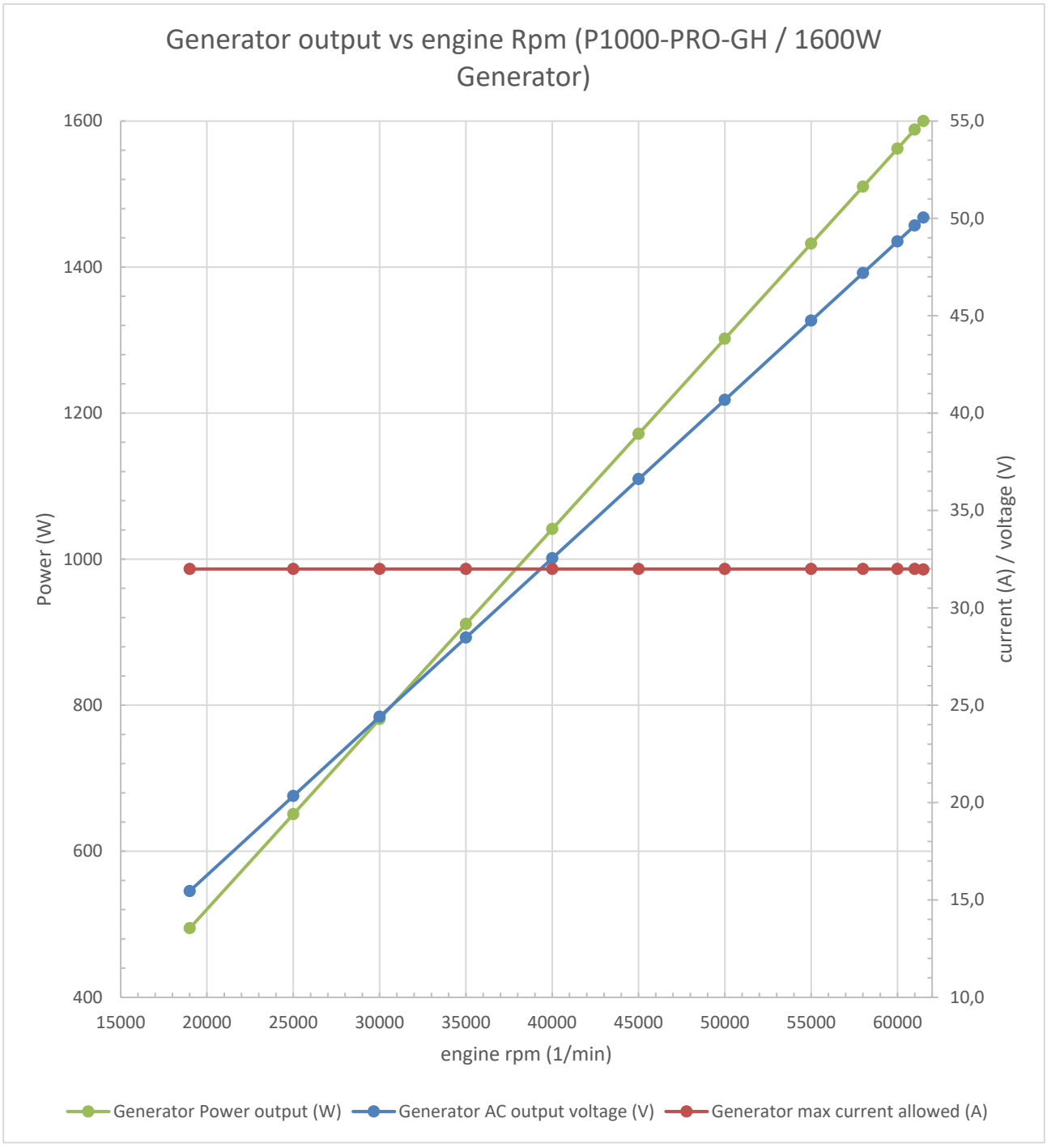
Diagram: P1000-PRO-GH Generator performance data vs engine rpm (1600W)



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Delivery content

The engine assembly consists of:
1x engine, including pigtail cables (2x) for power and control/data.

Options:

- Engine clamps
- PRO-Interface
- USB/serial adapter
- Oil pump
- Smoke pump

Operating conditions

Operating conditions for engine start

Ambient temperature range	- 40 to + 50 °C
Altitude range	0 to 6000 m
Flying speed range	0 to 150m/s
Engine position	arbitrary
Inlet fuel pressure	0 to 50 kPa (0-0.5bar)

Operating conditions for engine operation

Ambient temperature range	- 50 to + 50 °C
Altitude range	0 to 10000 m
Flying speed range	0 to 0.9 M
G in engine axis	+ 20 g
perpendicular to engine axis	± 8 g
Time at full rpm	No limit

Operating limitation

Max EGT at starting:	900 °C max. for 3 sec.
Max EGT normal operation:	750 °C
Typical starting time:	35 sec
Restart after unsuccessful start:	5 sec
Restart after previous operation:	25 sec

Time to inspection

50 hours of operation

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Fuel system

Fuel is drawn from the external tank via an external to be provided 50 µm filter. There is no further external fuel valve required or recommended. From the engine sided fuel inlet port, the fuel is routed directly to the brushless fuel pumps and from there though a 25um integrated post filter before going into a set of solenoid valves.
The pump/solenoids are controlled by the ECU, depending on the actual operation condition. The engine front mounted fuel supply manifold comprising the fuel inlet/fuel pumps/ post filter and solenoids is machined out of a single full metal piece, no further pipes or tubing's.

Bearing lubrication and cooling system

There are two options for lubrication:

A) Lubrication via oil mixed to fuel

Bearings are cooled and lubricated via the fuel to which 3-5% oil have been added. A small amount of the fuel is then internally routed to the bearings for cooling and lubrication. In this option the "oil in" port must stay blocked/is not used.

B) Lubrication via separate oil pump

This option utilizes an external "positive displacement micro dosing oil pump". The oil pump is powered and controlled directly from the engines ECU. The connector to the oil pump is made via the 4-pin Molex expansion connector provided on the engines front.
The oil pump aspirates oil from an external provided small size oil reservoir. The output of the oil pump is then routed via a 4mm tubing to the "oil in" connector at the engines front. The oil delivered via the oil pump is then internally mixed with fuel. The resulting fuel/oil mix then is routed to the bearings.
The oil pump has sensing inputs for optional level detectors mounted at the oil reservoir. In case the level detector shows too low oil level, an engine start is inhibited, and an error message is raised.
The oil consumption is very low and max. 30ml/hour. This means with an oil reservoir size of e.g., just 300ml, the engine can be run for about 10hrs.

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Fuel priming, integrated fuel priming feature.

For easy fuel priming, the P1000 engine provides an integrated “fuel prime” feature/function
This allows for automatic easy and safe fuel system priming (fill / deaerate fuel supply lines).
The priming function can be activated either manually via the GSU or by commands sent via the data interfaces or fully automatically prior to an engine start.

Bleedair port, Pressurization of fuel tank

The bleedair port can provide compressed air derived from the engine’s compressor stage.
To avoid any possible reverse flow back into the engine, an internal one-way valve is provided on the engine side ahead of the bleed air outlet. As the bleed air can be hot/warm, the use of a Teflon/PTFE tubing for the first 20cm is mandatory!
The pressure on the bleedair port depends on the engine’s operational rpm. On full power a pressure of up to 2,7 bars can be reached!
In case bleed air is not required/used, please block the outlet by a piece of crimped Teflon tubing.

Typically bleed air is used to pressurize the onboard fuel system to avoid degassing/bubbling of the fuel on high altitude operation of the engine (>5000m).
For full operation of this feature an additional pressure relief valve must be fitted in front of the fuel tank in order not to over pressurize the fuel tank!
The pressure relief valve should have a recommended relief pressure of 0,4 bars.

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Control system

The engine´s control system (ECU comprises a 32-bit microprocessor, driver circuitry for pumps/solenoids, and the optional AC/DC converter). It controls safe operation of the engine including engine starting, maintaining required speed, stopping and cooling of the engine after shutting down.

The ECU has inputs for:

- Engine RPM
- Exhaust gas temperature (thermocouple)
- Barometric sensor

The ECU has outputs to control:

- Front side integrated BLDC starter-generator
- 2x Fuel pumps with BLDC motor, fully encapsulated, seal free
- 1x Fuel Filter downstream of the pumps
- 3x Solenoids (2x main fuel, 1x start fuel)
- 2x Maintenance free plasma ignition system
- Power to ignition system
- Output voltage and current of the optional AC/DC converter

All above functions/devices are installed at the engine's frontend, no external equipment required.

ECU monitors engine performance and control systems.

The ECU supports controlled acceleration and deceleration of the engine under all conditions. Engine operation can be controlled and monitored via a serial bus or CAN bus from a master control system. The user software allows the identification of remaining TBO, statistical data, Engine start/stop control, monitoring of real time parameters like: rpms, EGT, fuel flow, remaining fuel, voltages, currents etc.

Expansion output (4 pin Molex, data and power) provided for:

- External devices like oil feeder pump, smoke pumps / feeder pumps, light control system, GSU etc.

Ignition system

The integrated ignition system consists of high-pressure fuel evaporation system assisted by an integrated dual plasma ignition system.
The fully integrated ignition system is active only for a limited time until stable combustion is reached.

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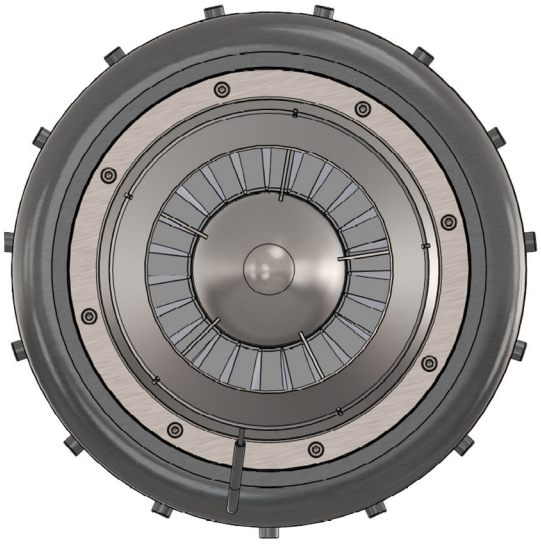
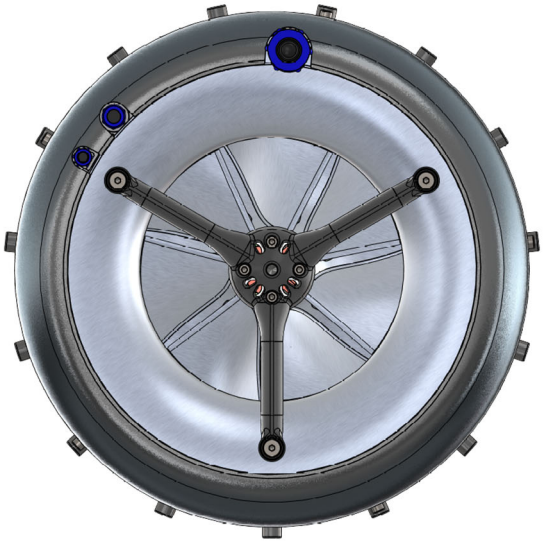
Appendix

Engine pictures

P1000-PRO





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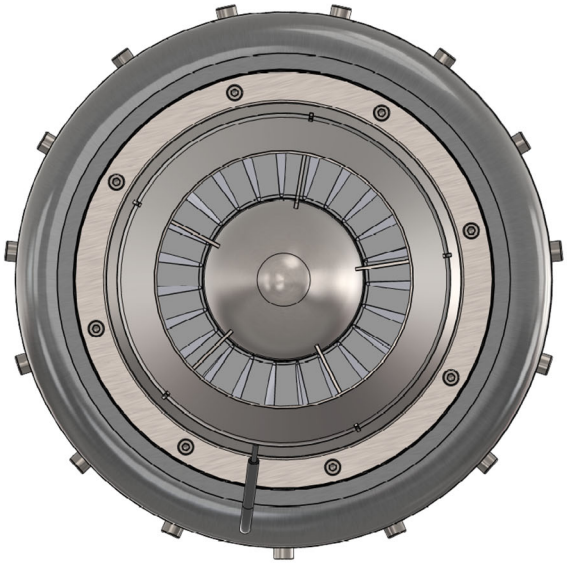

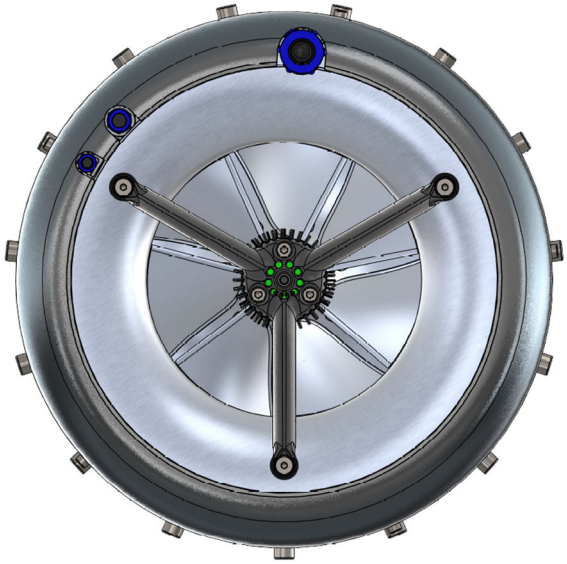

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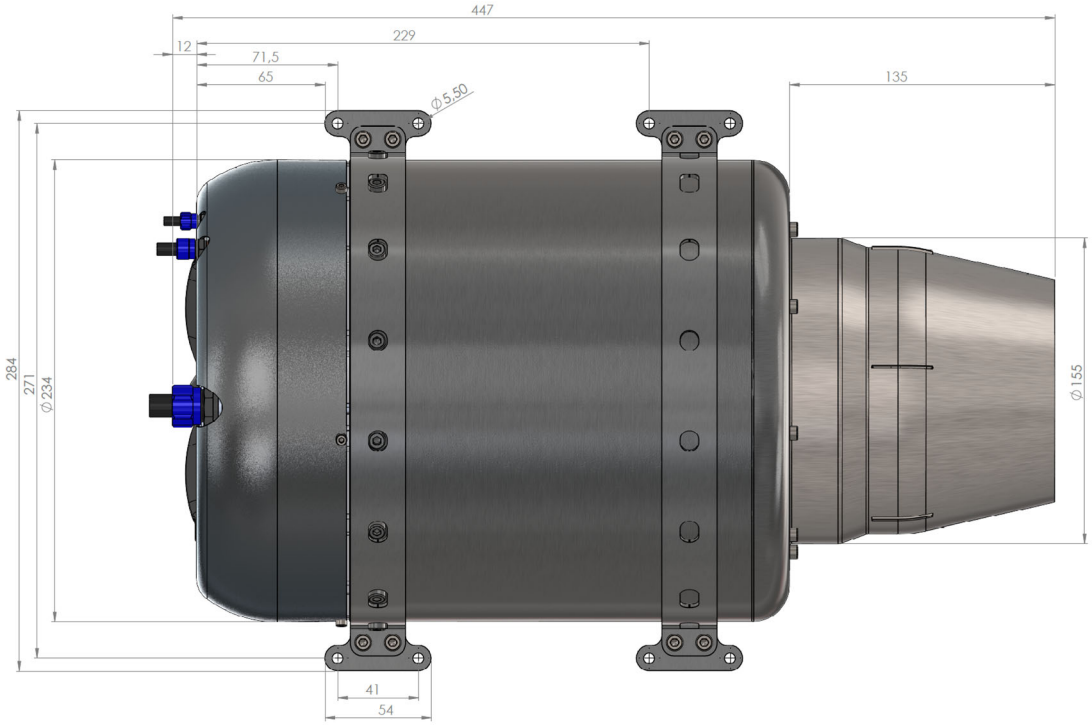
Engine Dimensional Drawings

P1000-PRO



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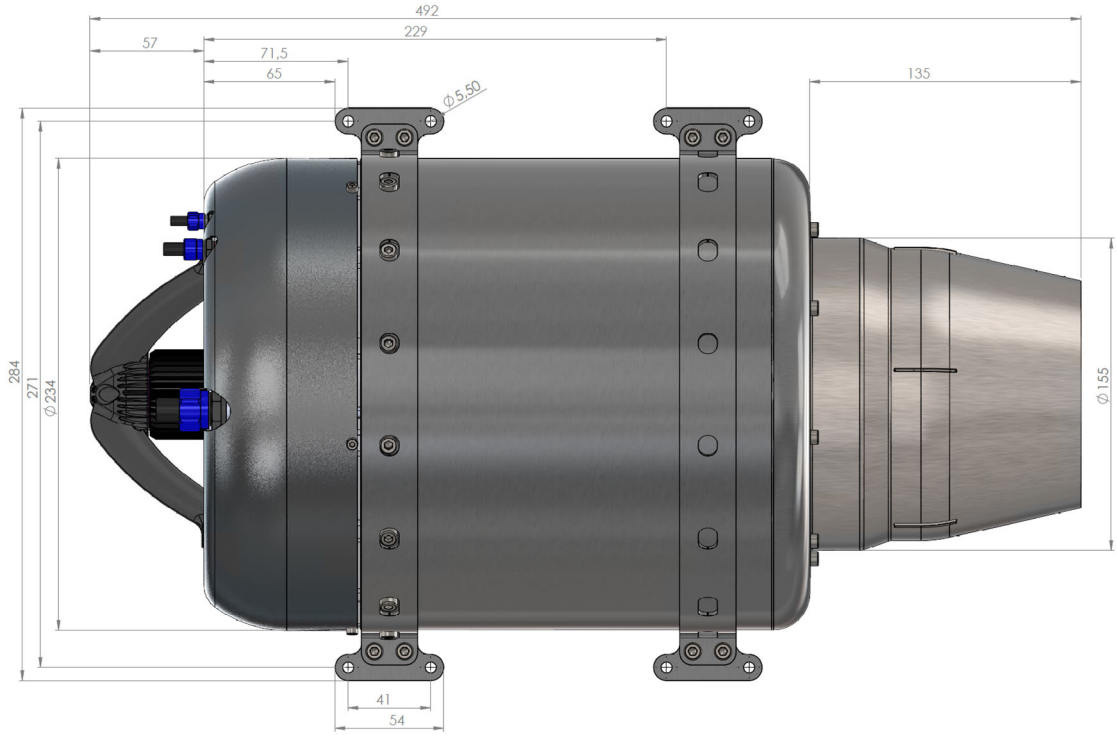

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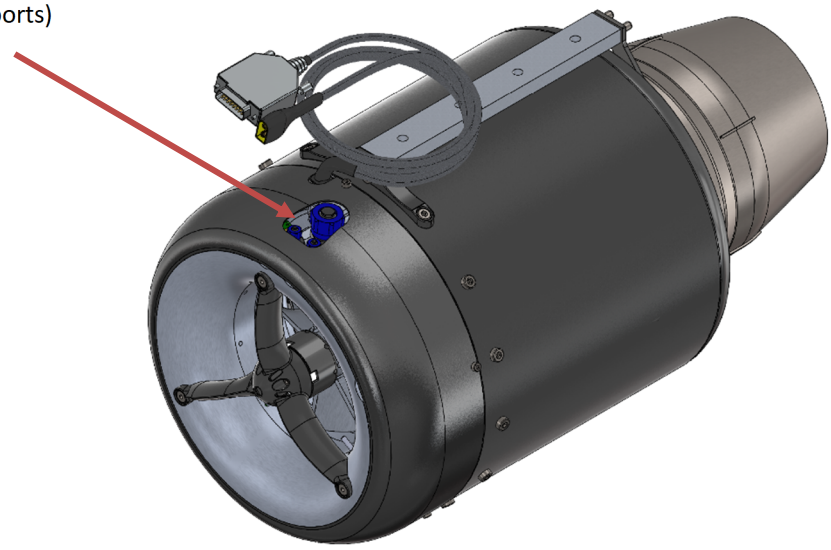
Engine mounting and fuel inlet options

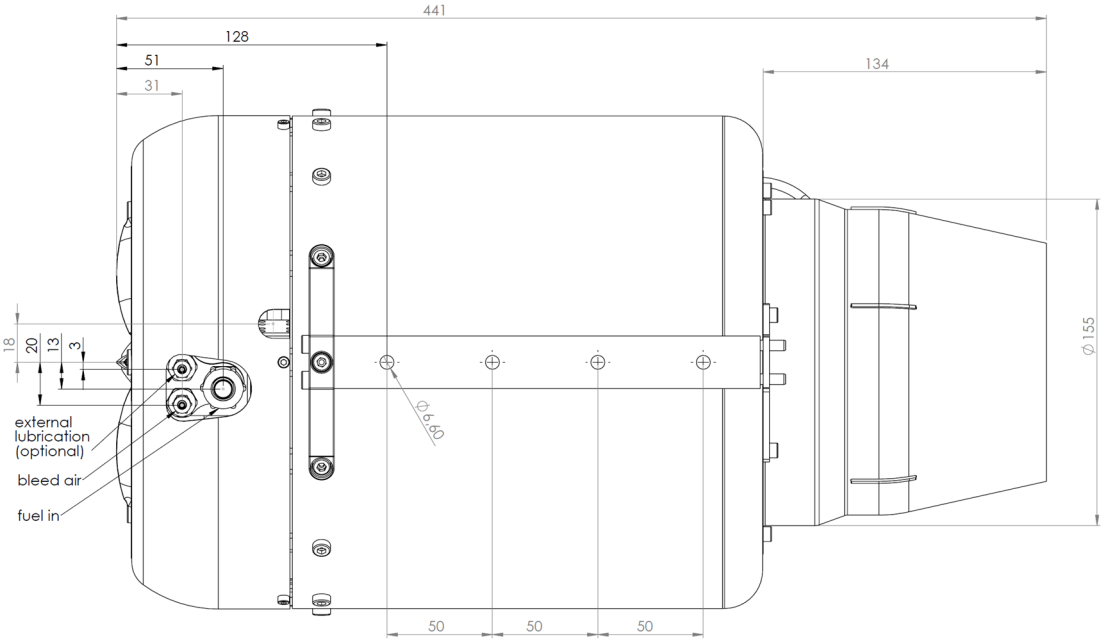
Besides the standard „clamp mounting“ of the engine there is also a “pylon type” and/or “frame mounting” option available.

Pylon mounting option / Radial fuel inlet option

In addition, the fuel port can be modified such that the inlets are coming in radially instead of axially.

As an option the engine can be provided in a setup were the fuel (and the other ports) are entering radially:





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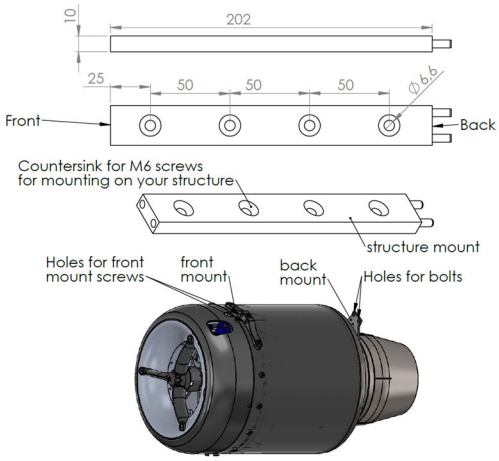
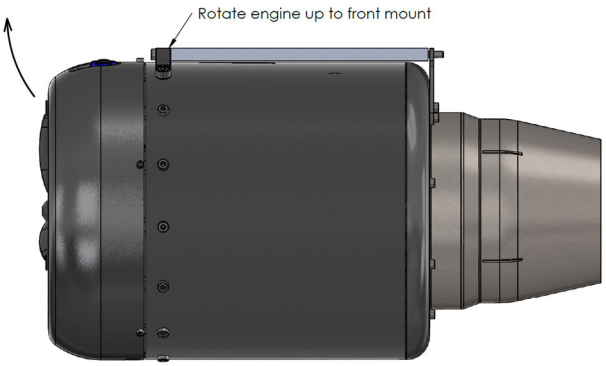
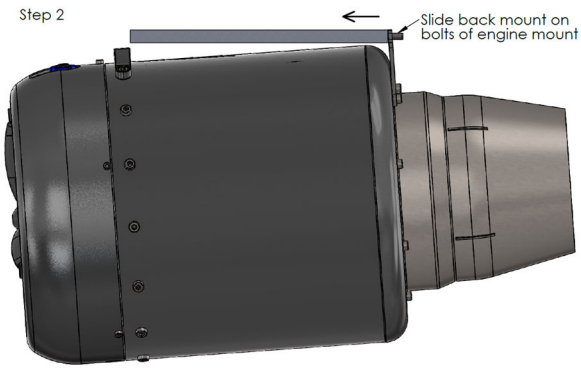
Step 1: fix engine mount to your structure



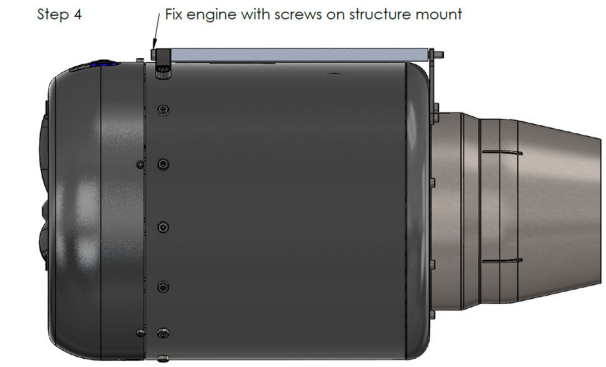
Step 3:

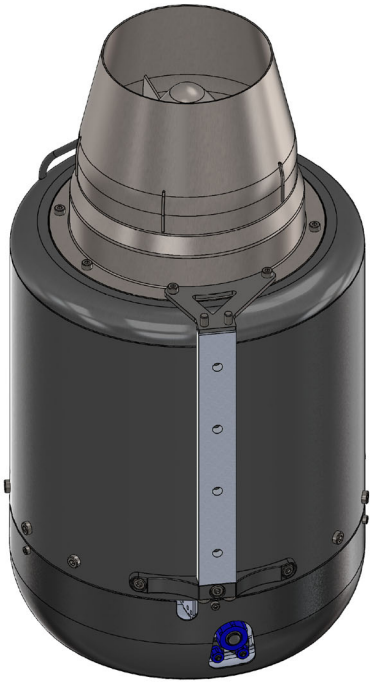


Step 2



Step 4





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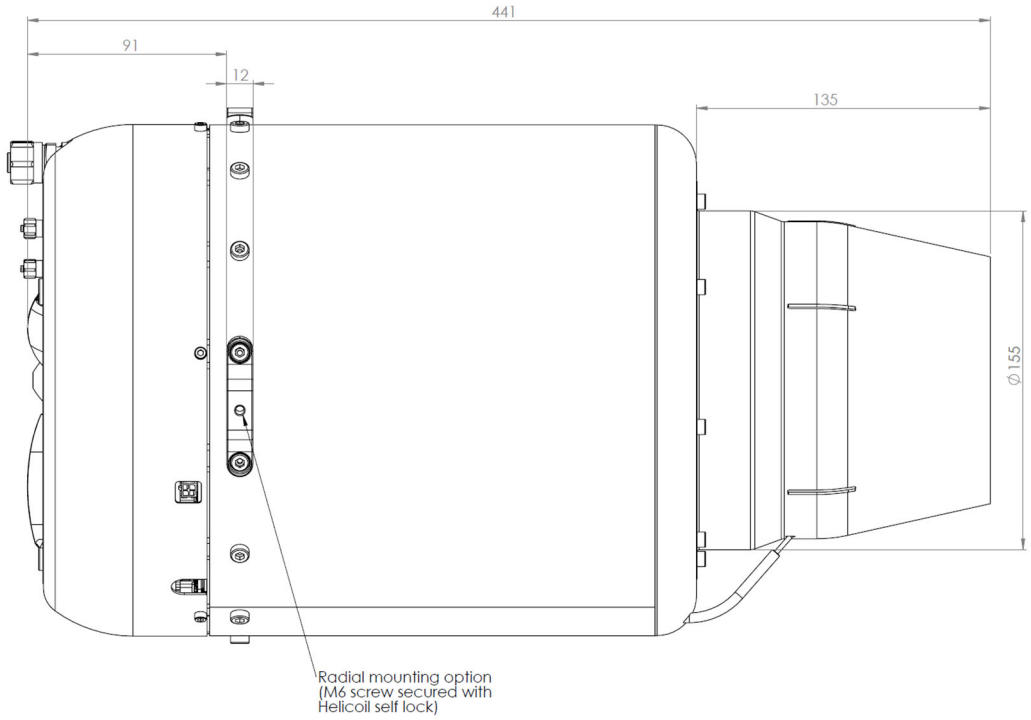
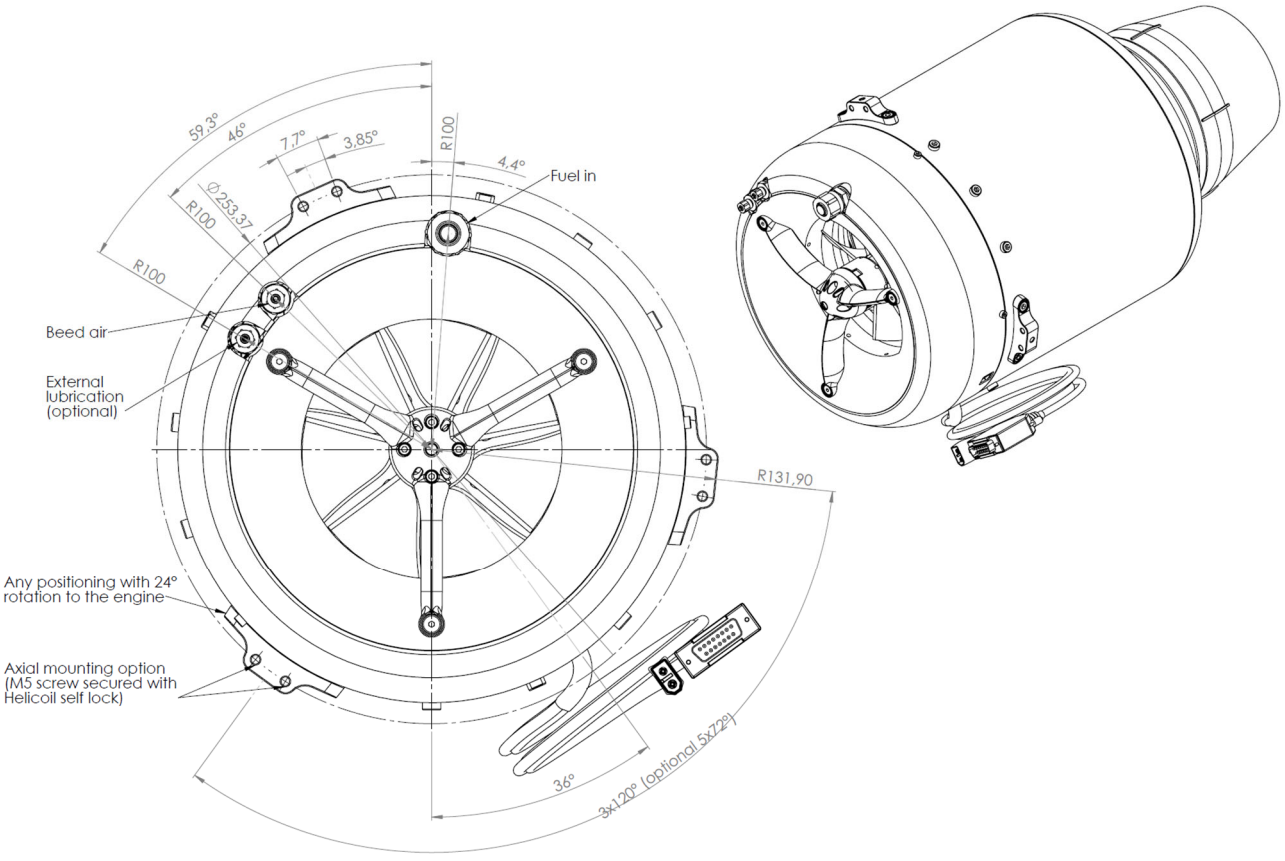
Frame mounting option





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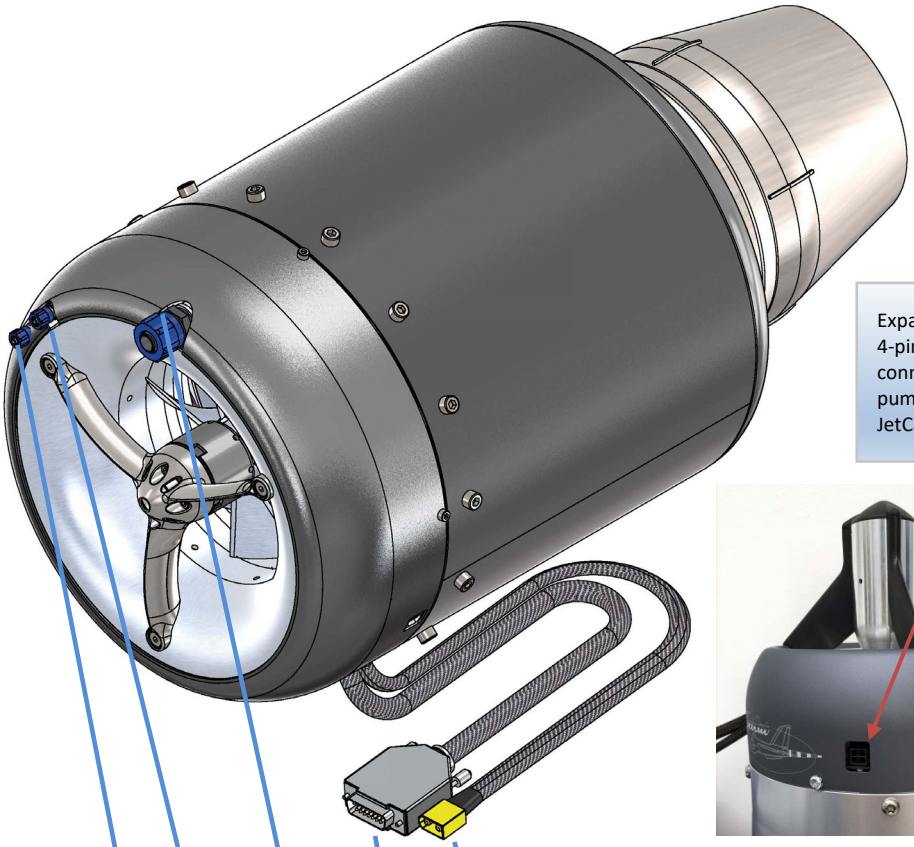
Connections on the engine, overview



Expansion connector C
4-pin Molex connector. For connection of GSU or smoke pump / oil pump or other JetCat accessory.

Connector B
XT60-power connector. Or customer specific connector

Connector A
SUB-D 15pin connector data/control. Or customer specific connector

Fuel inlet, fuel pump is inside of engine!
Do not use a filter in the suction line just an UAT air trap or large felt clunk.

Bleed air output port.
Can be used to pressurize fuel tank for high altitude operation.
Inside of the engine there is a one-way valve fitted which prevents reverse flow into the engine. If bleed air function is not needed, please block this port by a piece of tubing.

“Oil in” port, option
If not used, port must be blocked

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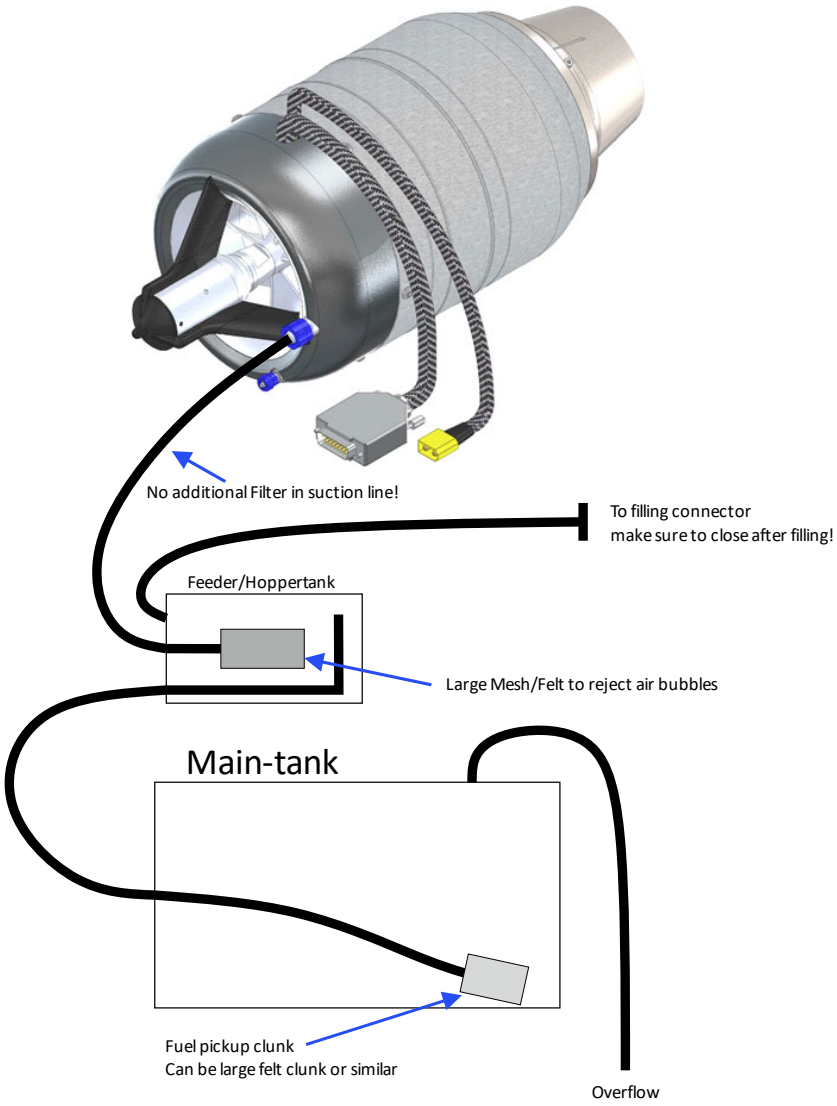
Fuel Connection Diagram, Standard



Do not use a filter in the suction line to the engine just an UAT air trap or large felt clunk!!!
On engines above 400N thrust two felt clunks in parallel might be needed not to restrict flow, or one high flow felt clunk from JetCat.

☞	The fuel demands are high, especially on larger engines, and require large tubing interconnecting the tanks. Use short connections and large diameter tubing's.

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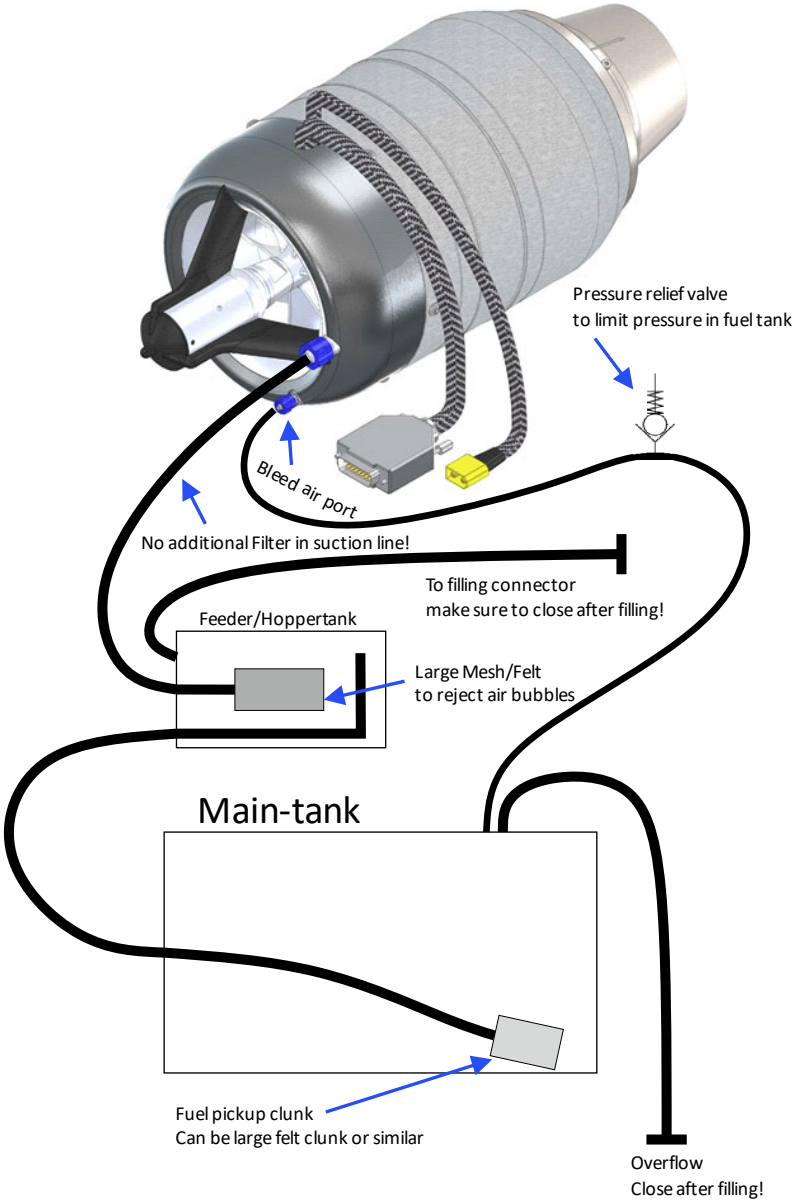
Fuel Connection Diagram, pressurized fuel tank



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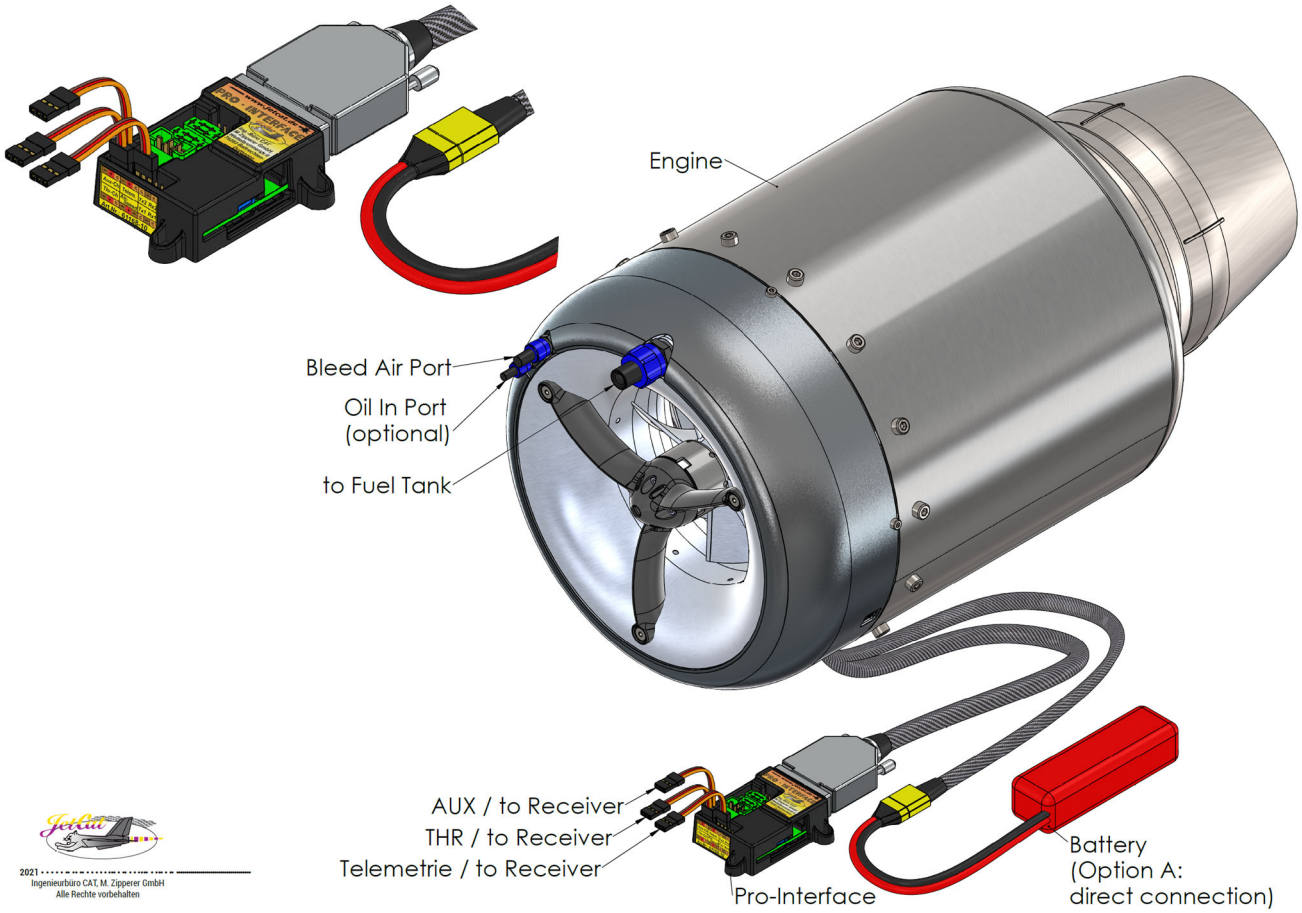
System Connection diagram example with PRO-Interface



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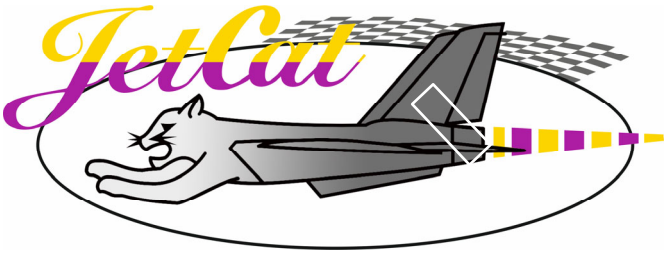

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