Information only
Details subject to change in final stages of development & certification programme

JS1 REVELATION

Jet Turbine Sustainer

Key Features

- M&D TJ42 jet turbine generating 40kgf at maximum speed of 100,000rpm, using Jet A1 or diesel fuel
- Engine controlled through infinitely variable setting throttle, with digital ECU controlling fuel flow and monitoring key parameters such as rpm and EGT, and with engine parameters displayed on a 57mm cockpit instrument
- Engine and mechanical systems mounted in monocoque carbon-fibre box, easily removable for maintainability
- Engine enclosed by cowlings and mounted on a single pylon
- Engine extension and retraction using an electrical linear actuator with sequencing to close engine bay doors in extended and retracted positions
- Three fuselage mounted fuel tanks with integral fuel quantity sensors and filters, maximum capacity 41 litres
- Fuel filler in engine box for manual or externally pumped refuelling and fuel drain in undercarriage bay
- Engine certification: EASA to CS-22 Subpart H
- Sustainer certification: SACAA to CS-22

The JS1-TJ has some **distinct advantages** compared to a traditional internal combustion glider sustainer:

- **Simple single lever operation** controls extension, start-up, thrust setting, shutdown and retraction
- **Minimal additional drag** in extended position due to small frontal area turbine with cowling and sequenced engine bay doors
- **Zero engine vibration**
- **No performance deterioration at altitude** avoids need for 'sawtooth' operation with multiple starts
- Ability to operate over **wide range of airspeeds** (enabling rapid flight out of severe 'wave down' conditions)

Jet Turbine Engine

The JS1-TJ uses the TJ42 jet turbine engine, manufactured by M&D Flugzeugbau (a German company based in Friedeburg, Lower Saxony). The TJ42 has been designed from the outset to be glider sustainer powerplant and certificated to CS-22.

The key features of the TJ42 engine are:

- Single spool jet turbine
- Two stage axial-centrifugal stator-less compressor with a compression ratio of 1:3.8
- Cannular combustor with multiple fuel injectors and combustion zones contained within a single annulus casing
- Glow-plug ignition system (used in start-up sequence only, ignites top combustion zone only)
- Single stage axial turbine with stators
- Convergent nozzle
- Front-mounted, direct drive electric starter motor for initial spool up

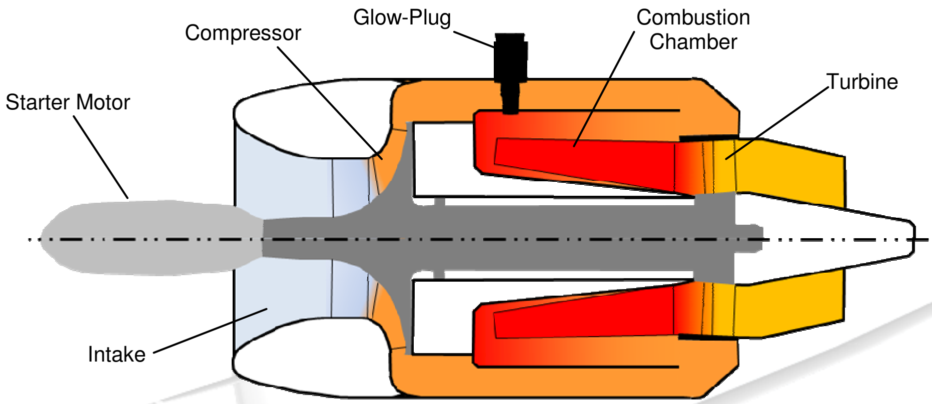


Figure 1
Illustrative Cross-Section of TJ42

The maximum thrust is 40kgf at 100,000rpm with estimated fuel consumption of ~66litres/hr. At 90% maximum rpm the thrust is ~30kgf with estimated fuel consumption of ~42l/hr. At the idle speed of 30,000rpm the thrust is less than 2kgf.

M&D recommends using Standard Jet A1 fuel mixed with 4.5% Aero Shell 500 turbine oil.

The TJ42 has a kerosene start-up (as opposed to gas start engines) which eliminates the need for separate gas canisters and long complex start-up procedures. The start-up sequence is:

- Glow-plug heats up for 10 seconds
- Electric starter motor spools up engine to 8,000rpm
- Starter fuel solenoid pulses with fuel being injected into the top combustion zone only
- Fuel ignited in top combustion zone by glow-plug
- Engine spools up to 15,000rpm
- Normal fuel solenoid pulses with fuel being injected into all combustion zones (starter fuel solenoid closes)
- Engine spools up to idle speed of 30,000rpm
- Fuel rate controlled by throttle, and matched to density altitude and rpm by ECU

The shut-down sequence is:

- Fuel cut-off and combustion ceases
- With no fuel, the engine speed decreases and EGT decreases
- The ECU senses EGT and engine speed, and if the engine speed is too low to promote rapid cooling, the starter motor runs an automatic cooling cycle (spooling the engine up to 3,000rpm, then switching off)
- Once the EGT has dropped below 50°C the ECU signals that the engine can be retracted

The engine and pylon are enclosed by cowlings manufactured from fibreglass and aluminium (or possibly stainless steel subject to clarification of certification requirements).

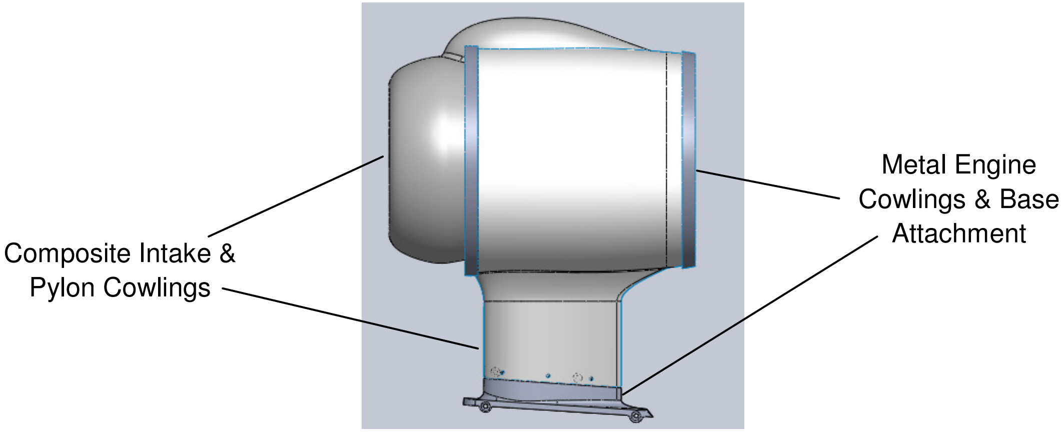


Figure 2
Engine Cowlings

Overall Installation

The engine and other mechanical parts are mounted within a monocoque carbon-fibre sustainer box which is bolted to the fuselage around the engine bay cut-out. Wiring harnesses have connectors at the sustainer box, and fuel lines have sealing, quick disconnect plugs. This modular design allows for easy access and good maintainability (allowing servicing and overhaul off the sailplane).

The engine bay is covered by three doors. There are two main doors on the port and starboard sides open during deployment and then close again once the engine has been fully deployed. A third ‘finger door’ sits within a U-shaped cover-plate and folds away to make an opening into which the pylon fits flush with the surrounding fuselage. In conjunction with a combined engine-pylon cowlings, this arrangement minimises the drag of the deployed engine. It is estimated that the deployed engine has less drag than an extended undercarriage.

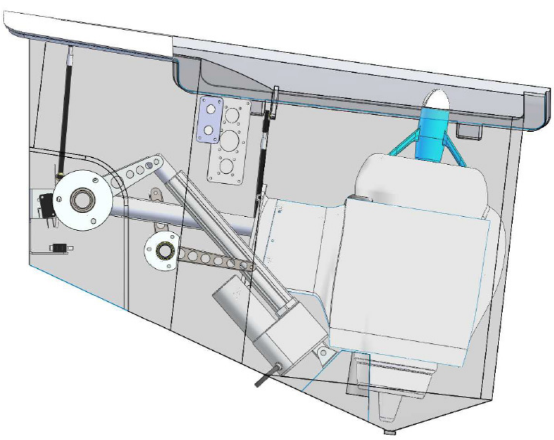


Figure 3
Engine Retracted

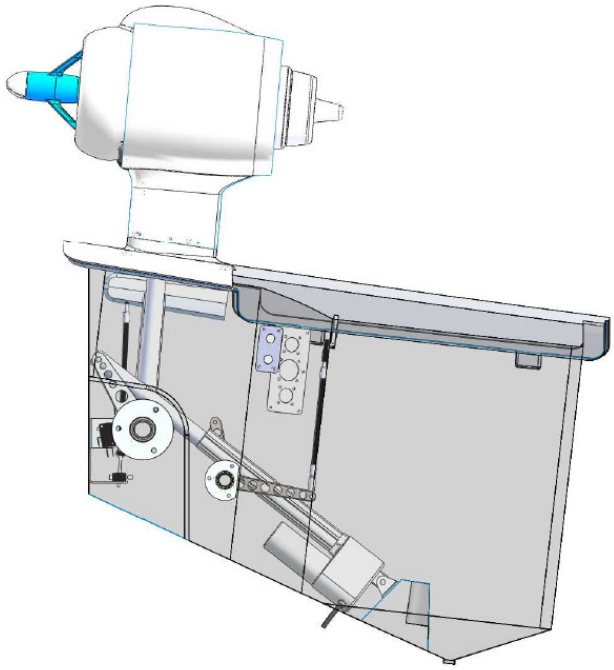


Figure 4
Engine Fully Deployed

In the deployed position the engine is angled 3° to direct the jet efflux away from the fuselage and fin. Also under consideration is supplementary post-curing of the fin leading edge to raise T_G (glass temperature) as extra thermal protection. (The desirability of this will be reviewed following thermocouple measurements during flight testing.)

The throttle is a sliding unit and is situated on the left hand seat panel lip. There is a master switch with safety cover and engine/system information is displayed on a digital display unit.

Structural Modifications

The fuselage is manufactured with an insert plug to produce the recess for the sustainer system doors and the aperture for the engine box cut-out. Fuselage reinforcements are bonded between Bulkheads 8 and 9. Structural testing for certification purposes proved the fuselage was stiffer with the aperture and the reinforcements than without.

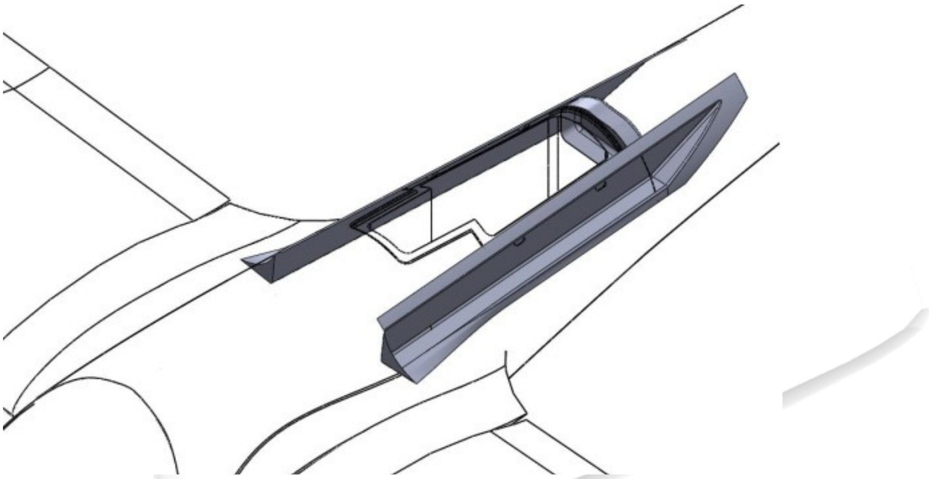


Figure 5
Fuselage Reinforcements

The monocoque engine box is made from carbon fibre reinforced composite material for minimal weight and adds to the overall strength of the fuselage. It is mounted to the recess lip with M6 bolts.

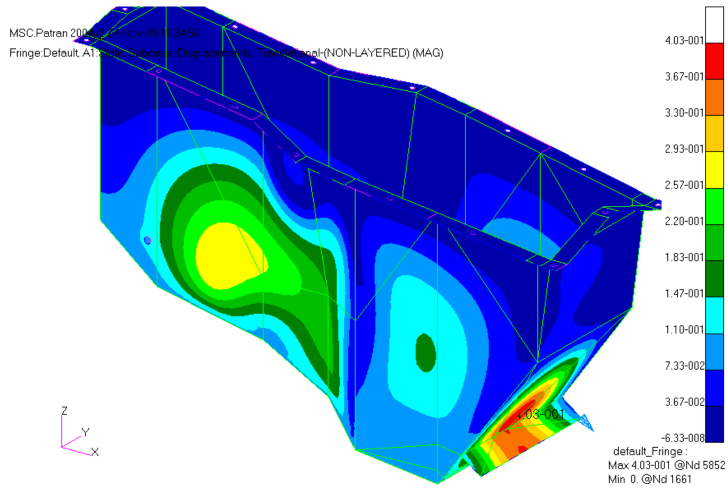


Figure 6
Engine Box Stress Analysis Plot

Extension-Retraction System

The engine is mounted on a simple, single tubular pylon driven by an electro-mechanical linear actuator. The sliding throttle has detents for engine deployment and retraction, and the throttle position signals the actuator to operate via the ECU. The actuator has built-in microswitches to limit the fully extended and retracted position, and in addition there are physical stops fitted to the engine box.

The kinematic system is designed according to CS-22 load requirements. The static loading capacity (locking) of the actuator can withstand all forces in the flight envelope. Precision bolts are used throughout in the system minimising play and the actuator in combination with the physical stops provides positive locking of the engine in both extended and retracted positions.

Sliders operating in profiled cut-out arms connected to the pylon open and close the main doors in sequence as the engine deploys and stows again. A sprung loaded arm operates the small ‘finger door’. The main doors can be opened without electrical power (or in the event of a mechanical or electrical system failure) for access and maintenance.

Extension time is ~10 seconds. The time from pilot selection of extension to full thrust will be determined during flight testing.

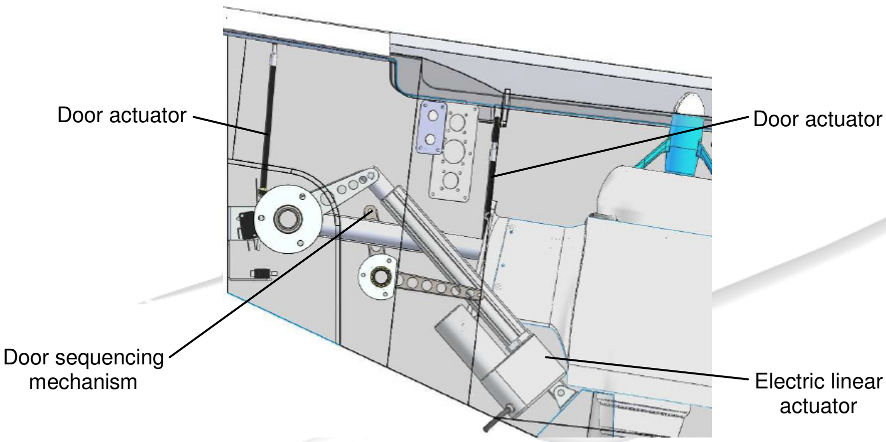
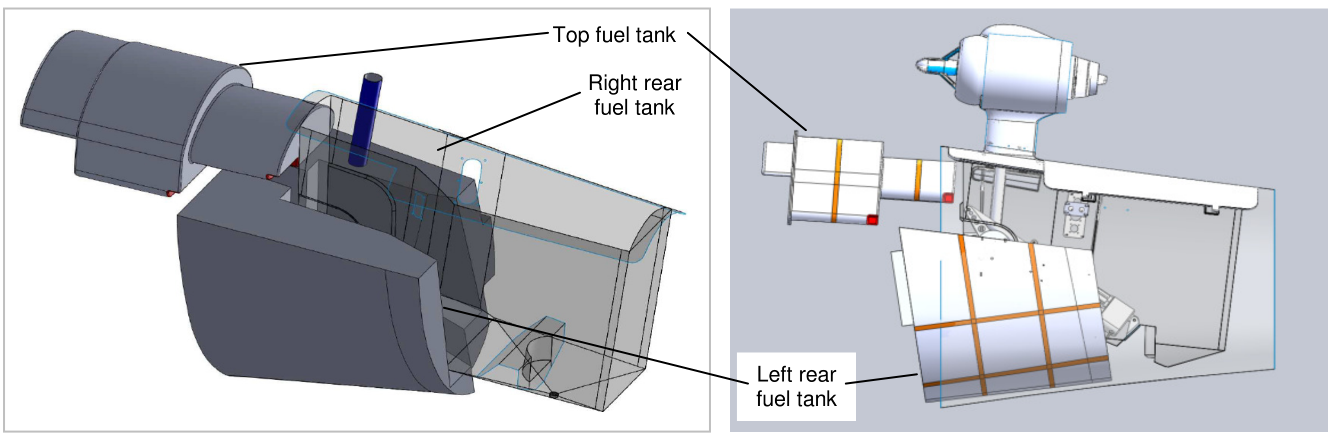


Figure 7
Extension-Retraction System Schematic

Fuel System

There are three inter-connected fuel tanks, a top tank forward of the engine box and two rear tanks located either side and below the engine box. The capacities of the tanks are: top tank 11 litres; left main tank 16 litres; right rear tank 14 litres; giving a total capacity of 41 litres.



Figures 8 & 9
Fuel Tank Arrangement

All tanks are constructed from fibreglass with copper strips inbuilt for static electricity protection. The tanks have lugs and fittings to securely attach the tanks to the fuselage structure, while allowing ready removal.

Aluminium piping is used to connect between the tanks, fuel panel, engine, fuel filler and fuel drain. Sealing quick-disconnect junctions are used wherever possible (to minimise installation and removal times for ease of maintenance).

The fuel pickup is situated in the left rear tank with a fuel strainer attached to prevent foreign objects from entering the fuel line. In addition a universal fuel filter is installed between the fuel pickup and the fuel panel and another fuel filter is installed between the fuel panel and the engine. The filters are standard items.

The fuel filler is a quick-disconnect located in the engine box, accessible when the engine is halfway extended or one of the main doors is disconnected. A fuel filling kit consisting of an electrical pump and tube with connector will be provided as standard.

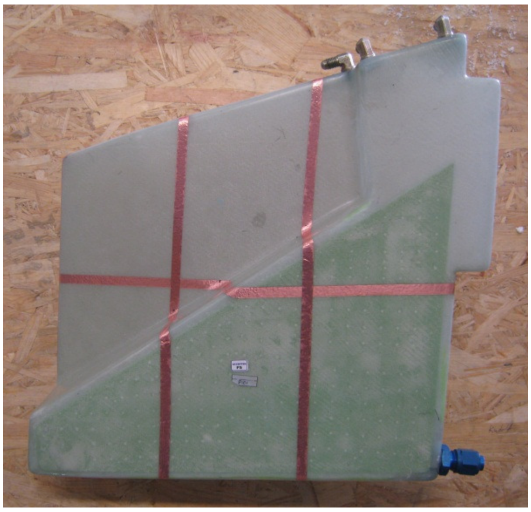


Figure 10
Left Rear Fuel Tank

The fuel drain connects from the left rear tank to a drain valve located in the rear of the main undercarriage bay. The fuel overflow (breather) also vents to the main undercarriage bay to avoid any fuel leakage onto the sailplane.

Fuel from the pickup in the left rear tank passes (via a filter) to an automatic shut-off valve controlled by the throttle and then to the fuel panel. This consists of:

- Manual shut-off valve
- Flow meter
- Fuel pump
- Manual throttle valve
- Starter fuel solenoid with a fuel line feeding the top combustion zone only
- Normal fuel solenoid with a fuel line feeding all combustion zones

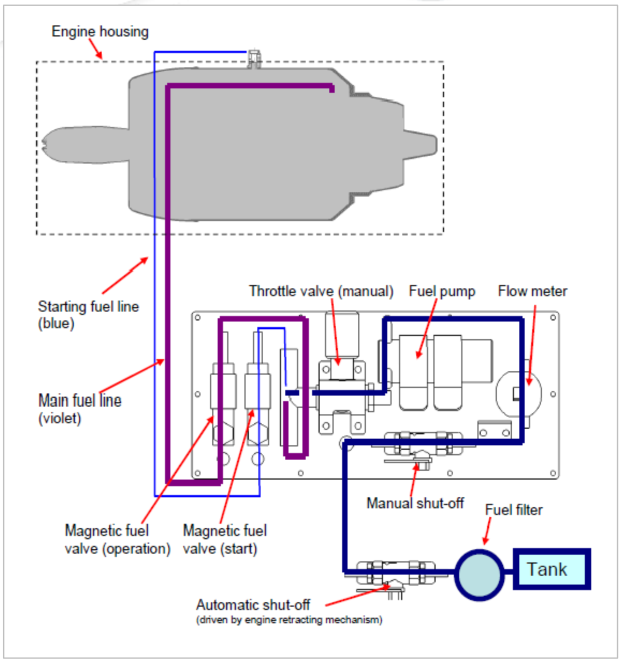


Figure 11
Fuel System Schematic

Electrical System

The engine electrical system includes the ECU (Engine Control Unit), limit switches, engine display unit, engine master switch and throttle which are inter-connected via a wiring loom.

The ECU is a digital electronic unit that controls receives inputs such as throttle setting, engine rpm and EGT (Exhaust Gas Temperature) and controls the fuel pump rate, fuel solenoids (open/closed/pulsing) and glow-plug ignition. The ECU includes a memory card that records a number of parameters such as throttle setting, engine speed and EGT, and also data points/records such as number of start-ups and error log information.

Limit switches in the front of the engine box are operated by a bell crank when the engine is fully deployed and by a cam when the engine is fully retracted. The ECU will not initiate the starting sequence if it does not receive the signal from the deployed limit switch. If the deployed limit switch fails while engine is running, the ECU will simply cut the engine power and register an error on the engine display (and the pilot can select to retract the engine by moving the throttle to the retracted position). In the event of a limit switch failing while the engine is being retracted or deployed so that the engine reaches the physical stops, the ECU will stop the engine and give a kinematic error on the engine display.

Electrical power for the sustainer is provided by Li-Ion batteries, replacing the standard sealed lead-acid batteries and situated in the standard battery compartments in the centre table. Battery voltage is regulated to avoid over-voltage being applied to the glow-plug and ensure fuel pump rates match the ECU logic.

Control & Display System

The pilot controls the engine with a sliding throttle unit situated on the left of the seat panel lip, behind the aircraft trim control/indicator. The throttle is a sliding unit with detents for engine shutdown, engine deployment, start/idle, and variable range to full throttle.

The engine has an automatic start-up sequence that will start only once engine is fully deployed. Throttle control will only be given to the pilot once the desired rpm is reached according to the throttle setting selected.

The engine display is positioned on the instrument panel according to customer preference. The display shows engine speed, EGT, fuel consumption, fuel quantity remaining, battery voltage and hours of running time. Lights on the display indicate whether the engine is fully extended (green), being extended or retracted (yellow) or fully retracted (red).

Figure 12
Engine Display

Nose Ballast System

Fixed nose ballast weights enable a minimum pilot weight of 55kg for the pure sailplane. The ballast system allows for configurations of 2, 4, 7, 9 and 11 kg to be added in the nose.

The sustainer installation and fuel tanks are aft of the aircraft empty centre of mass so ballast weights will normally be used to offset the weight of the sustainer installation and fuel.

The standard battery in the fin will not be used when the sustainer is installed as this also assists with moving the centre of mass forward (and the additional electrical power capacity is not necessary with the Li-Ion main batteries replacing the standard lead-acid main batteries). If fitted, the brass hub tailwheel will be replaced with a Vesconite tailwheel hub.

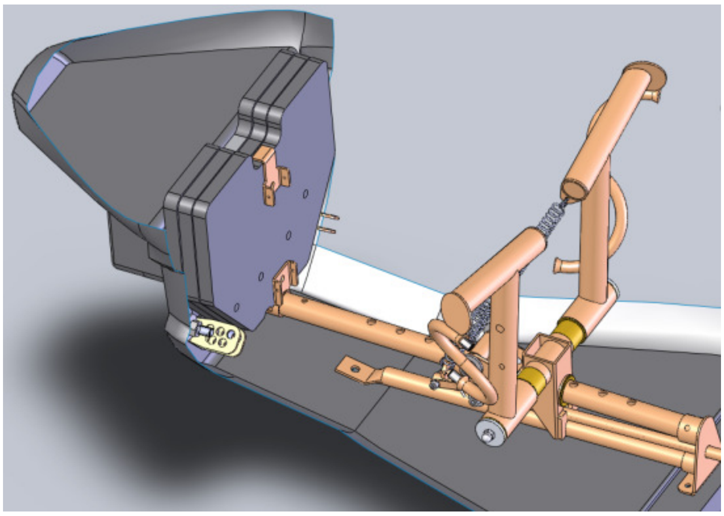


Figure 13
Nose Ballast System

Engine Maintenance & Overhaul

Other than simple inspections there will be no routine maintenance of the engine itself. The major maintenance interval of the engine is based on the proven safe life of the critical engine components, the turbine and the compressor. This is determined by the number of start-shutdown cycles (and not factors such as total engine running time or with any extended interval for operating at reduced EGT).

The initial TBO (Time Between Overhaul) will be set at 500 cycles, typically enough for 4-5 years use. M&D Flugzeugbau plan to progressively extend this TBO as in-service experience increases.

As the TBO approaches, the owner-operator will advise Jonker Sailplanes / M&D Flugzeugbau. A replacement engine will be supplied and the existing engine returned to M&D Flugzeugbau. The engines will be exchanged according to the Maintenance Manual procedure. The returned engine will be stripped and the turbine and compressor replaced, together with the main bearings. Other items will be inspected and replaced on condition. This overhaul will 'zero-life' the engine, i.e. it can be considered as new.

The cost of the overhaul will be the cost of a new turbine, a new compressor and new main bearings, plus items replaced on condition, installation labour and shipping. This cost has yet to be determined but is expected to be no more than the equivalent for traditional internal combustion sustainers.

Routine maintenance of the sustainer installation such as lubrication and cleaning may be performed by the owner-operator. Minor services should be performed by a JS-approved Aircraft Maintenance Organisation at the times as specified in the JS1 Revelation Maintenance Manual.

Other Information

The engine is being certificated by EASA to CS-22 including Special Condition to CS-22, Subpart H for turbine engines in powered sailplanes.

The JS1-B-TJ jet turbine sustainer is being certificated by SACAA to CS-22 with a Special Condition for the turbine-related aspects. It is classed as a major modification and will be an amendment to the Type Certificate Data Sheet.

Certification requirements CS-22 require sufficient margin between V_H (airspeed with engine operating) and V_{NE} therefore the maximum airspeed with the engine operating will be 200-215kph (or 109-117kts).