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ROTARY WING
RESEARCH AND DESIGN CENTRE
HINDUSTAN AERONAUTICS LIMITED
BANGALORE – 560 017

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TECHNICAL SPECIFICATION- ENGINE FOR RUAV

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
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CO-ORDINATION SHEET

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REVISION SHEET

FOR REVISED PAGES, SEE PAGE – 1

This document supersedes the earlier document No. RC/RUAV/PP&FS/TS/001, Iss-I, Rev-A, dated 29-05-2020.

REV	DATE	ORIGINATOR	CO-ORDINATION		
			-	-	-
A	24-07-2020				

Reason for Iss-I to Iss-II:-

Engine parameters, mission profile and 'g'-load values are revised.

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LIST OF ABBREVIATIONS

AKI	Anti-knock Index
ALT	Altitude
AMSL	Above Mean Sea Level
ATP	Acceptance Test Procedure
AON	Aviation Octane Number
ATR	Acceptance Test Report
ATF	Aviation Turbine Fuel
AUW	All Up Weight
Avgas	Aviation Gasoline
CAN	Controller Area Network
CCW	Counter Clock-wise
CDI	Capacity Discharge Ignition
CEMILAC	Centre for Military Airworthiness and Certification
COTS	Commercially Off-The Shelf
CS-E	Certification Specification Engines
D-level	Depot Level
DC	Direct Current
deg	Degree
DAL	Design Assurance Level
DOID	Design Organization Interface Documents
ECU	Engine Control Unit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FAR	Federal Aviation Rules
FHA	Functional Hazard Analysis
FMEA	Failure Mode and Effect Analysis
FMECA	Failure Modes and Effects Criticality Analysis
g	Gravity
GTV	Ground Test Vehicle
HAL	Hindustan Aeronautics Limited
Hrs	Hours
ICD	Interface Control Document
IFR	Instrument Flight Regulation
ISA	International Standard Atmosphere
Kg	Kilogram
km	Kilometer

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LCC	Life Cycle Cost
LRU	Line Replaceable Unit
m	Meter
MCP	Maximum Continuous Power
MIL-STD	Military Standard
min	Minute
P/N	Part Number
MAP	Manifold Absolute Pressure
MGB	Main Gear Box
Mogas	Automotive Gasoline
MON	Motor Octane Number
MTBF	Mean Time Between Failures
MTOW	Max. Take-Off Weight
NR	Rotor Speed
OCM	On Condition Maintenance
OEM	Original Engine Manufacturer
QTP	Qualification Test Procedure
QTR	Qualification Test Report
LCC	Life Cycle Cost
RGB	Reduction Gear Box (Engine)
ROH	Repair and Overhaul
RON	Research Octane Number
RPM	Revolution Per Minute
RUAV	Rotary Unmanned Aerial Vehicle
RWR&DC	Rotary Wing Research & Design Centre
sec	Second
SFC	Specific Fuel Consumption
S/N	Serial Number
TBO	Time Between Overhauls
TOP	Take Off Power
ToT	Transfer of Technology
TTL	Total Technical Life
V	Volt
w.r.t	with respect to
°C	Degree Centigrade
2D	2 Dimensional
3D	3 Dimensional
%	Percentage

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1. SCOPE AND GENERAL INFORMATION:

Hindustan Aeronautics Ltd. is developing single engine powered Rotary Unmanned Aerial Vehicle for the use of Indian Armed Services for troop logistical re-supply roles. This document defines the technical requirements of the engine intended for powering the RUAV with an All Up Weight of approx. 200 kg.

2. REQUIREMENTS:

2.1 MANDATORY REQUIREMENTS:

1. Type of engine to be Reciprocating Piston or Rotary Wankel engine.
2. Engine must be ECU operated.
3. Engine shall meet all the operational requirements as per in Para 3.1 to 3.4
4. Typical mission profile as referred in Para 3.6. Max. endurance of the engine shall be as specified in Para 6.
5. Dry weight of engine including all accessories as per Para 4.
6. Feasibility of engine installation within the envelope as referred in Para 5.
7. Self-contained engine lubrication system as referred in Para 6.
8. Self contained engine cooling system as referred in Para 7.
9. Self-contained engine fuel system fitted with engine fuel pump referred in Para 8.
10. Provision of centrifugal clutch as referred in Para 9.
11. Engine shall have provision to mount Starter and Generator either individually or Starter-generator as a combined unit as referred in Para13 and 14.
12. Direction of rotation of output shaft- CCW looking into engine output shaft
13. Provision to interface engine with remote pilot operation from the ground station.
14. Electronic Fuel Injection.
15. The engine shall have provisions for lifting for installation and storage purpose.

2.2 DESIRABLE REQUIREMENTS:

1. Engine SFC as per Para 3.5.
2. TBO of the engine to be above 500 hours.
3. Engine ignition with dual ignition coil.
4. Engine cooling system with liquid cooling.
5. ECU to include single engine safety features.
6. Engine should have been proven on Rotary Wing application.

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3. ENGINE OPERATIONAL REQUIREMENTS:

3.1 Temperature : -30 to + 55 Deg C

3.2 Altitude : Sea Level to 20,000 ft

3.3 Power rating:

Table-1- Power rating	
Rating	**Requirement**
Continuous Power (MCP) @ 18000 ft. (ISA+20°C)	**30 kW**
Peak power (TOP) @ 18000 ft (ISA+20°C)	**34 kW** for 10 minutes (max.)

Engine power at Sea Level (ISA+20°C) shall be specified by the engine supplier along with variation of power Vs altitude.

3.4 Engine output speed:

Engine's continuous operating speed shall be a fixed speed in the range of 5500 to 6500 rpm. Engine should run at constant speed for the varying power.

3.5 Specific Fuel Consumption:

Engine SFC to be less than **0.35 kg/kW- hr** at cruise / continuous operation.

SFC values for various power ratings referred in Table-2 shall be indicated by the engine supplier for estimating fuel required for the mission.

3.6 Endurance / Typical flight profile (Refer to Table-2):

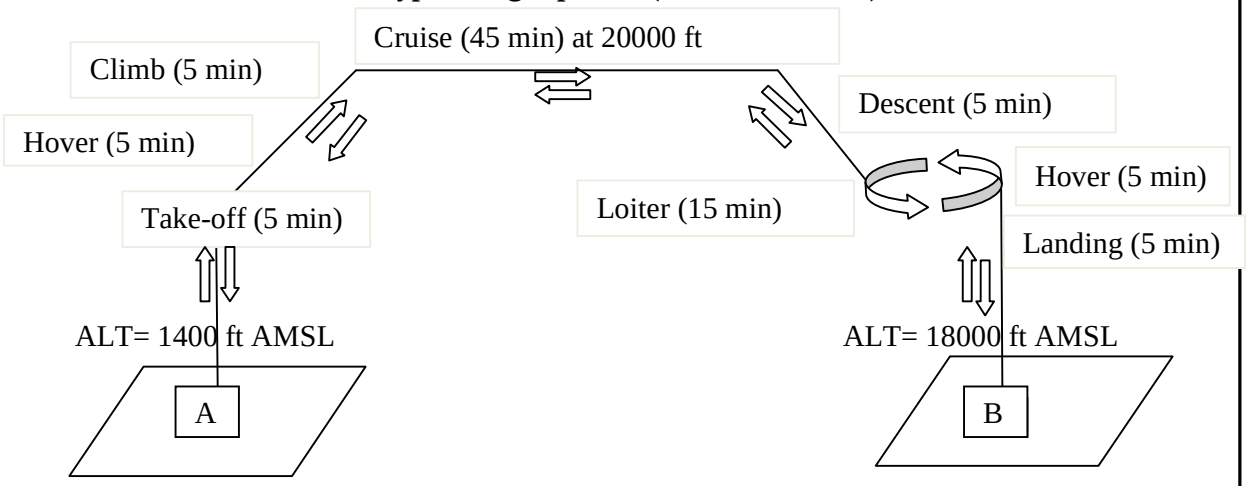

Fig-1: Mission profile (To and Fro from Point A to B)

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Table-2: Typical mission cycle		
Mission points	**Time duration (minutes)**	**Approx. Power required (kW)**
Take-off (Point A)	5	10
Hover	5	30
Climb	5	23
Cruise	45	19
Descent	5	15
Loiter	15	17
Hover	5	34
Landing (Point B)	5	10
Take-off (Point B)	5	10
Hover	5	34
Loiter	15	17
Climb	5	23
Cruise	45	19
Descent	5	15
Hover	5	30
Landing (Point A)	5	10
Total Endurance	**180**	

4. ENGINE WEIGHT:

Dry weight of the engine including engine cooling system, engine lubrication system, ECU, engine harness, engine exhaust, accessories and Reduction Gear Box (if any) excluding starter-generator shall be less than **52 kg**. Supplier shall provide weight break-down of engine and accessories.

5. ENGINE INSTALLATION REQUIREMENTS:

It is planned to install and couple the proposed engine with rear end drive at the forward of Main Gear Box in the Front Fuselage of the RUAV as shown in Fig.-2 and Fig-3.

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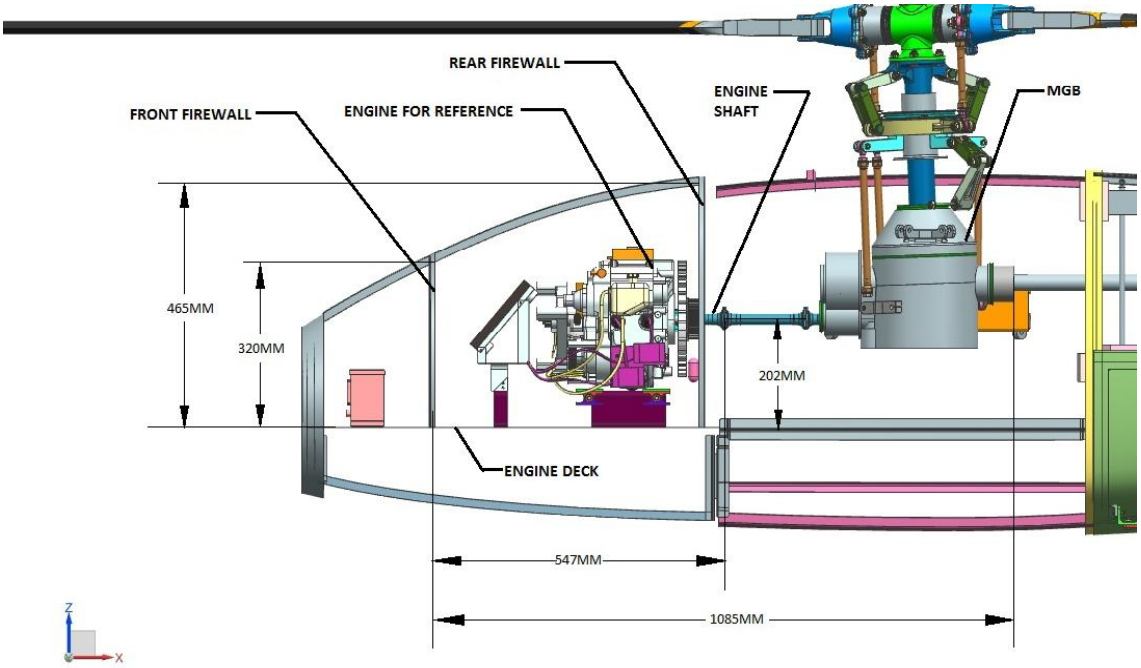

← **FLIGHT DIRECTION**

Fig.-2: Representative engine installation envelope in RUAV

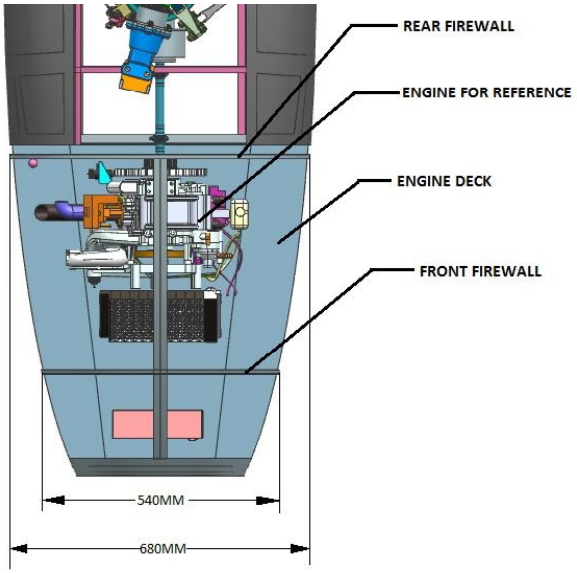

Fig.-3: Representative engine installation envelope in RUAV

Note:
Dimensions are indicative, to be finalised after the selection of engine.

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The engine installation will be of closed type i.e. within the airframe with adequate accessibility for maintenance. To accommodate the engine within the given dimensional envelope, belt drive arrangement (if required) can be provided by the supplier to position the engine output flange in line with main gearbox input flange, as a part of engine. The engine is mounted horizontally in the nose cone section of RUAV using suitable mountings as per the installation requirement of the engine. The engine drives the gear box through a flexible drive shaft to take care of any misalignment. Overall dimensional envelope and center of gravity position are to be provided by the engine supplier.

6. ENGINE LUBRICATION SYSTEM:

Self contained engine lubrication system is required. It should ensure safe and continuous running of the engine under all operating conditions on ground and in flight. Oil tank should be tested to the max. operating conditions. Oil tank should have interface for gravity filling and visual level indication on the oil tank. Engine should be capable of operation without any oil replenishment for **5 hours** of engine operation.

Supplier shall specify the details of normal operating oil pressure and temperature with limits and lubrication oil to be used at different operating temperature.

7. ENGINE COOLING SYSTEM:

Self contained cooling system is required for the safe engine operation under all operating conditions on ground and flight. Type of engine cooling with details of coolant used, normal operating temperature with limits of engine and accessories (both surface and air) to be specified by the supplier. Supplier to indicate the details of air mass flow requirement for adequate engine compartment cooling.

8. ENGINE FUEL SYSTEM:

Engine fuel system to be integral part of the engine with fuel pump. The engine fuel system should be provided with fuel filter with bypass feature, in order to ensure continued supply of fuel to engine in case of fuel filter clogging. There shall be a fuel filter pre-clog indication through the ECU. Supplier to provide required instrumentation for the engine fuel system and interface with ECU.

Engine fuel shall be gasoline (Avgas). Supplier shall indicate various fuels / fuel mixtures permitted for use on the engine along with restrictions, if any. It is desirable to operate the engine with mixture of bio-fuel / green fuel blended with normal operating fuel.

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RUAV fuel feed system consists of fuel tank fitted with a booster pump to supply fuel to engine fuel pump. The booster pump is provided with by-pass feature, to ensure fuel supply to engine by suction feed in case of booster pump failure. Hence, engine fuel pump shall be capable of operating / starting in case of failure of aircraft booster pump up to operating altitude by suction feed in emergency mode. Engine supplier to specify the suction head for the engine fuel pump.

9. CENTRIFUGAL CLUTCH:

Engine shall be fitted with Centrifugal Clutch to off-load / relieve the rotor system inertial loads during starting. Centrifugal clutch shall be designed to engage above IDLE speed and disengage below IDLE speed so as to dis-engage and engage Main Rotors without the need to switch-off / re-start the engine during temporary stoppage of RUAV. These values will have to be mutually discussed and fixed prior to design / manufacturing of the Clutch.

In case of engine failure, RUAV has to go into auto-rotation mode to land safely. In order to disengage engine from main rotor, an overrunning clutch or freewheel is used at the main gear box drive input (HAL scope item).

10. VIBRATION ISOLATION / SHOCK MOUNTS:

Engine supplier should specify and provide the required vibration isolation mounts to be used at various locations for the installation of engine on the fuselage along with the engine.

11. ENGINE CONTROL UNIT:

ECU shall be operable with a nominal power supply voltage of 28V DC as per MIL-STD-704F (range of voltage shall be 16 v to 31.5 v considering voltage drop due to aircraft battery during engine starting). Software of the ECU to comply with DO 178 DAL C and hardware design of the ECU to comply with DO 254 DAL C (if applicable). Supplier shall provide justification if the DAL proposed by the supplier is lower than specified DAL.

ECU shall manage automatic engine start/ restart throughout the operating envelope.

The ECU shall have engine health, failure data logging facility for trouble shooting and health monitoring purpose.

Necessary hardware and software required for downloading and processing the Engine data shall be provided by the supplier for post flight data analysis.

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12. ENGINE INSTRUMENTATION:

Engine supplier shall provide required instrumentation on engine interfaced to ECU to ensure measurement, recording, monitoring and control of the engine. As the RUAV will be operated remotely, the interface details of engine ECU output- both analogue and digital parameters for the engine health monitoring shall be provided by the engine supplier.

13. STARTER:

Electrical Starter capable of starting the engine using external power supply as well as batteries with a nominal power supply voltage of 28V DC (range of voltage shall be 16 V to 31.5 V considering voltage drop due to aircraft battery during engine starting) to be provided. Starter shall be capable of attempting at least 3 consecutive starts with a time gap of 1 minute between starts. Max. weight shall be less than 2 kg.

The supplier shall provide the details such as make, model, rating including input electrical power requirement (starting current nominal and peak, voltage, etc.) of the starter offered.

14. GENERATOR:

2 kW DC generator is required for powering of electrical systems of RUAV. Generated voltage shall be 28V DC nominal. Voltage shall be 28±2V in the entire speed range of the engine. Max. weight shall be less than 3 kg.

The supplier shall specify the make, model, rating of Generator offered.

Supplier shall provide interface requirements with electrical system of RUAV.

Option of individual Starter and Generator or option of Starter-Generator as a single combined unit is acceptable.

15. MECHANICAL AND ELECTRICAL INTERFACES:

Specific adaptations, in terms of mechanical and electrical interfaces, should be carried out for integration of the engine and accessories within the envelope of RUAV.

Interface Control Document with details shall be supplied for the following:

a. MECHANICAL INTERFACES:

i. Engine output shaft interface
ii. Engine air inlet, exhaust / muffler / silencer (position, type, dimensions)
iii. Overall dimensional envelope (including center of gravity position).
iv. Interface details for mounting of accessories such as Starter / Generator
v. Engine mounting interface

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vi. Engine oil filling port / drain locations.
vii. Fuel inlet to engine and fuel drain locations
viii. Oil cooling interface details
ix. Provision for mounting vibration sensors. Supplier is required to supply vibration sensors during initial prototype testing of RUAV.
x.

b. ELECTRICAL INTERFACES:

i. Engine and ECU interface with the autopilot hardware of the RUAV shall be of CAN Bus/ RS485 standard and discrete signals.

ii. Electrical interfaces of the engine, ECU, instrumentation, starter and generator shall be provided by the engine supplier.

iii. Details of the digital and analogue interfaces of ECU shall be supplied by the supplier. In case, any minor changes or additional requirement of the data in the digital bus is required to be made as part of adapting the system to RUAV platform, supplier shall be ready to incorporate the same.

iv. Necessary corrections / amendments / inclusions to the ECU interfaces shall be taken up by the supplier based on the development flight feedback before the certification of the RUAV.

v. Engine accessories shall be operable with a nominal power supply voltage of 28V DC as per MIL-STD-704F (range of voltage shall be 16 V to 31.5 V considering voltage drop due to aircraft battery during engine starting).

16. ENGINE STARTING REQUIREMENTS:

Starting envelope:

Temperature: -30°C to + 55°C
Pressure altitude: Sea Level to 18,000 ft

The engine must be capable of internal start with helicopter battery after an overnight cold soak at-30°C as well as mid-air start, up to an altitude of 18,000 ft with in-built oil heating provision (if required).

Supplier shall provide starting envelope of the engine i.e. Altitude Vs Temperature.

Engine should be capable of producing power to take-off within minimum time after the start of engine at -30ºC.

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17. SERVICE CEILING:

Altitude envelope of the engine should be 0 to 20,000 ft.

18. ENGINE ATTITUDE LIMITATION:

Table -3- Attitude limits of RUAV:		
Conditions	**Pitch**	**Roll**
Steady state operation	$\pm 10^0$	$\pm 25^0$
Transient operation	$\pm 30^0$	$\pm 30^0$

Supplier to specify the duration for transient operation of engine, if limited.

19. 'g' LOADS:

The engine and its systems should be cleared for operations up to instantaneous load factors of + 1.7'g' at sea level.

20. TROPICALISATION:

The engine and its systems must be tropicalised and cleared to operate under the following conditions:

- Operating temperature: -30° C to +55° C.
- Relative Humidity : up to 100%

21. OPERATION IN ICING AND DESERT CONDITIONS:

Engine should be capable of operating in Icing and Desert conditions.

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22. ENGINE CERTIFICATION REQUIREMENTS:

The proposed engine shall be proven one, by way of usage in unmanned air vehicle systems, (UAVs/ RUAVs) being operated presently worldwide for either Military or Civil applications.

Supplier to furnish compliance matrix (indicating full compliance, partial compliance or non-compliance) with respect to applicable tests specified in FAR-33. Mode of compliance such as by testing or analysis or similarity to be indicated

Supplier to produce available test report for the following tests carried out already on the proposed engine or similarity or analysis (wherever applicable) in order to meet the requirements as per this technical specification.

1. Altitude performance test demonstrating the requirements as per Para 3 and 16.
2. Mission test demonstrating the engine TBO.
3. Vibration test in order to ensure that Engine and ECU are cleared for the frequencies and their harmonics for the estimated Main and Tail rotor frequencies of the RUAV (Refer **Table-4**).
4. EMI/ EMC testing of engine and ECU compatible with MIL-STD-461E or F fully or partially to meet the requirements as per **Table-5**.
5. Environmental test compatible with MIL-STD-810G or equivalent.

Notes:

1. Extent of compliance of proposed engine with respect to this specification shall be indicated in case of partial compliance.
2. Engine supplier can substantiate / complement the HAL's specification requirements based on past data of engine used on other similar platforms.

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Table -4- Operating frequencies of RUAV:	
Main rotor (MR) frequency	14 Hz (1 ω); 28 Hz (2 ω)
No. of MR blades	2
Tail rotor (TR) frequency	66.86 Hz (1 ω); 133.73 Hz (2 ω)
No. of TR blades	2

Table-5- EMI/ EMC test requirements:

Test Description	**Purpose**	**Limits**	**Remarks**
a) CE102 Conducted Emissions, power leads 10kHz to 10MHz	Electromagnetic emissions from equipment should not exceed the specified limits for power input leads including returns.	As specified in Fig. CE102-1	As per section 5.5 of MIL-STD-461F
b) RS101 Radiated susceptibility, magnetic field, 30 Hz to 100 kHz.	To verify the ability of the equipment to withstand radiated magnetic fields.	Engine shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the magnetic fields shown in Figure RS101-2.	As per section 5.20 of MIL-STD-461F
c) RS103 Radiated Susceptibility, Electric Field, 2 MHz to 40 GHz	To verify the ability of the equipment and associated cabling to withstand electric fields.	Equipment shall not exhibit any deviation from tolerances indicated in the specification, when subjected to the radiated electric fields listed in Table VII and modulated. Up to 30 MHz, the requirement shall be met for vertically polarized fields. Above 30 MHz, the requirement shall be met for both horizontally and vertically polarized fields.	As per section 5.21 of MIL-STD-461 F The equipment should be qualified for at least 60 V/m

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23. MAINTENANCE AND OVERHAULING:

Engine periodic servicing and overhauling, TBO aspects shall be indicated. Supplier has to provide the detailed procedure of carrying out periodic servicing and overhauling of the engine.

24. DOCUMENTATION:

24.1. Following documents and data shall be provided along with proposal:

1. Para-wise compliance matrix against the Technical Specification indicating means of compliance.
2. Compliance matrix sought vide Para 22.
3. Specific installation requirement w.r.t. engine bay ventilation, exhaust ducting, etc., if any.
4. Total in-service life (in calendar period) / TBO of engine (in hours)
5. Total storage and operational life of engine (in calendar period)
6. Shelf life of engine LRUs and components
7. Data on assured MTBF and TBO based on either theoretical estimate or on field failure data of engines already in service on other UAVs.
8. Lead time for the supply of engine for prototype and production Helicopters.
9. List of other programmes (including civil and military) where the supplier has commissioned engines for UAVs along with the duration of operation.
10. Certification/ accreditation obtained relevant to the proposed engine.

24.2. Following documents and data shall be provided at the time of supply:

1. Complete set of documentation including engine 2-D drawings, 3-D mock up, installation manual along with the details of ECU, engine systems and LRUs.
2. Interface definition for starter / generator and starter drag torque curves.
3. Wiring schematic diagrams
4. Electrical interface control documents covering analogue, digital and functional interface definition of engine control system.
5. Control system functional description
6. Illustrated Parts Catalogue
7. Troubleshooting / Fault tracing Manual
8. Periodic Servicing Schedule
9. Storage, preservation and storage servicing details of engine and LRUs.
10. Standard of preparation (SOP) of engine.
11. Engine Maintenance and overhaul Manual
12. FMEA / FMECA document
13. List of Ground Support Equipment with their storage and maintenance instruction
14. Maintenance tool catalogue including description and reference of tools
15. Test procedures, test reports, similarity analysis reports and technical justification reports as per Para 22.
16. Operational history of engine on rotary wing application.

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25. PRODUCT SUPPORT:

i. Supplier shall provide following support for engine, ECU and other accessories during the development and production phase of RUAV:

1. Technical support (on-site or off-site) during prototype integration, ground/ flight testing and certification with respect to resolving technical problems, snags / defects/ failures observed during operation. Detailed defect investigation reports in respect of failures during development and qualification testing and defects reported during production operation along with the improvement taken should be provided to HAL.

2. After certification on helicopter, update on any part number changes, revision / issue changes, modification status etc. along with reason /justification and support documents such as ECN/ SB/ SIL / SL, etc. as applicable

3. Any improvement implemented due to technology upgradation, internal improvements, etc. to be informed to HAL.

4. Issues with regard to obsolescence and actions to overcome the same shall be informed well in advance to HAL for supporting the existing fleet.

5. Necessary approval and documents which are required to be delivered in the production phase for Maintenance, Repair and Overhaul (up to D level) by HAL

6. Supplier shall provide spares including consumables such as lubricants, gaskets, seals, etc. for supporting at O, I and D levels of maintenance.

7. Ground support / handling equipment (engine stand), special tools required for the engine installation, removal and servicing, ECU data / software upload / download tools, etc. shall be included in the supply.

ii. Supplier shall quote for the option of ToT for ROH of engine at HAL/ India:

1. Scope of maintenance ToT covers Scheduled Overhaul of engine including all its sub-systems and unscheduled repairs.

2. HAL reserve right to carry out maintenance in-house or sub-contract to its established vendors in India.

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26. TRAINING REQUIREMENTS:

The suppler should provide a comprehensive proposal covering the following training requirements:

26.1. Training Requirements during Development Phase of RUAV:

It is required to provide technical training to HAL personnel in following aspects of the engine:

- Installation and integration aspects
- Maintenance and troubleshooting aspects
- Engine control laws
- ECU software, data uploading / downloading
- Engine performance data analysis

26.2. Training Requirements during Production Phase of RUAV:

During production phase, it is required to provide technical training to HAL personnel covering various aspects of engine, assembly, testing, repair & overhauling and defect investigation of engine, engine LRUs and other engine accessories.

26.3. Training Requirements for Field Servicing and On-site Support:

The supplier should provide training for field servicing and onsite support and this training should cover "O" and "I" level maintenance activities, defect investigation for engine, engine LRUs and other engine accessories.

27. PACKING, STORAGE AND DELIVERY REQUIREMENT:

27.1. Packing / delivery:

Packing/ delivery of engines shall be the responsibility of the supplier and shall be in accordance with the procedure normally followed for similar equipment. The units shall be preserved in the original packing until they are required for use. Details of protection/ preservation shall be mentioned.

27.2. Storage:

Proposed storage temperature shall be -54° C to +85 ° C

Shelf life and storage requirements should be specified by the supplier).

27.3. Name plate and product markings:

Name plate or product marking shall specify the following:

- Name of the item
- Supplier's name
- Part number
- Serial number
- Revision and modification status
- Manufacturing date

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28. EXPECTED DELIVERY SCHEDULE:

Table-6: Delivery schedule

Sl. No.	Activities / Supplies	Proposed Delivery Schedule	Remarks
1	Customisation, review and clearance for manufacturing	T0+3 months	
2	Engine No.1	T0+9 months	Shipment-I
3	Engine No.2	T0+12 months	Shipment-II
4	Engine No.3	T0+12 months	
5	Engine No.4	T0+15 months	Shipment-III
6	Engine No.5	T0+15 months	
7	Engine No.6	T0+15 months	

T0- Placement of Purchase Order by HAL and its acceptance by supplier.