वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्
Council of Scientific & Industrial Research
राष्ट्रीय वांतरिक्ष प्रयोगशालाएं
National Aerospace Laboratories

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ISO 9001 : 2015
Certified Organization

INVITATION FOR BIDS/NIT

Tender No. NAL/PUR/STTD/531/19-Y **Dated: 24-Jan-2020**

CSIR- National Aerospace Laboratories (NAL), Bengaluru, India is one of the premier laboratories under Council of Scientific and Industrial Research (CSIR), an autonomous body under Department of Scientific and Industrial Research, Government of India, New Delhi. CSIR-NAL is a Science and Knowledge based Research, Development and Consulting Organization. It is internationally known for its excellence in Scientific Research in Aerospace Engineering.

The Director, CSIR-NAL invites online quotation for procurement of the following item(s) for day to day research work.

Sl.No.	Description of Items	Unit	Quantity
01	**Flight and Ground Control System for VTOL-UAV** **Please refer Annexure for detailed specification.**	No	01

Single / Double Bid	**Single Bid**
Bid Security (EMD) (in INR)	**Rs. 50000/-**
Performance Security	**10% of the purchase order value**

01. Tender Documents may be downloaded from Central Public Procurement Portal https://www.etenders.gov.in. Aspiring Bidders who have not enrolled/ registered in e- procurement should enroll/ register before participating through the website https://www.etenders.gov.in. The portal enrolment is free of cost. Bidders are advised to go through instructions provided at 'Instructions for online Bid Submission'.

02. Tenderers can access tender documents on the website (For searching in the NIC site https://www.etenders.gov.in, kindly go to Tender Search option, select tender type and select ' Council of Scientific and Industrial Research' in organization tab and select NAL-Bengaluru-CSIR in department type Thereafter, Click on "Search" button to view all CSIR-NAL, Bengaluru tenders). Select the appropriate tender and fill them with all relevant information and submit the completed tender document online on the website https://www/etenders.gov.in as per the schedule given in the next page.

03. Either the Indian Agent on behalf of the Foreign principal or the Foreign principal can bid directly in a tender but not both. However, the offer of the Indian Agent should also accompany the authorization letter from their principal. To maintain sanctity of tendering system, one Indian Agent cannot represent two different Foreign principals in one tender.

04. Unsolicited / conditional / unsigned tenders (Quotations) **shall not** be considered. Quotations received after the due date and time **shall be summarily rejected.**

05. The Bidder shall comply the terms and conditions of the tender, failing which, the offer shall be liable for rejection.

06. The Director, CSIR- National Aerospace Laboratories., Bengaluru reserves the right to accept any or all the tenders either in part or in full or to split the order without assigning any reasons there for.

Raman Kumar
(Section Officer S&P)

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SCHEDULE CUM CRITICIAL DATE SHEET

1	Name of Organization	CSIR-National Aerospace Laboratories, Bengaluru	
2	Tender Reference No	NAL/PUR/STTD/531/19-Y dated: 24-Jan-2020	
3	Tender Type (Open/Limited/EOI/Auction/Single)	Open Tender	
4	Type/Form of Contract (Work / Supply / Auction / Service / Buy / Empanelment / Sell)	Supply	
5	No of Covers (One/Two/Three/Four)	One	
6	Tender Category (Services/Good/Works)	Goods	
7	Allow Resubmission (Only in online mode within scheduled period)	Yes	
8	Allow Withdrawal (Only in online mode within scheduled period)	Yes	
9	Allow Offline Submission	No	
10	Work Item Title	Flight and Ground Control System for VTOL-UAV	
11	Work Description	Flight and Ground Control System for VTOL-UAV	
12	Delivery Schedule	60 days from the date of purchase order	
13	Product Category (Civil Works / Electrical Works / Fleet Management / Computer Systems)	R & D Equipment	
14	Is Multi Currency Allowed	Yes	
15	a) Tender Publishing Date -	27-Jan-2020	1800 Hrs
	b) Document Download Start Date-	27-Jan-2020	1800 Hrs
	c) Bid Submission Start Date-	27-Jan-2020	1800Hrs
	d) Bid Submission End Date-	17-Feb-2020	1000 Hrs
	e) Bid Opening Date-	18-Feb-2020	1100 Hrs
16	Bid Validity Days	90 days	
17	Address for communication	Stores and Purchase Officer CSIR-National Aerospace Laboratories, HAL Airport Road, Kodihalli, Bengaluru - 560017	
18	Inviting Officer	Director, CSIR-NAL	
19	Contact No	25086040, 25086041	
20	E-mail Address	purchasek@nal.res.in	
21	Detailed specification of item	Refer Invitation for bids / NIT	
22	Tender Terms & Conditions & Instruction for online bid submission	The prospective bidders are requested to refer to the Standard Tender Document available on NAL Internet **(www.nal.res.in)** under the icon Tender-Purchase before formulating and submitting their bids	

Technical Specification of Flight and Ground Control system (FGCS) for VTOL-UAV

1. INTRODUCTION

FLIGHT and GROUND CONTROL SYSTEM (FGCS) is required for the implementation of closed-loop flight trajectory control of VTOL Winged UAV during flight, guidance and monitoring real-time from the ground station. FGCS comprises of 2 segments i.e. Airborne Segment (FCS) and Ground Segment (GCS) interconnected by RF communication link. Using the FLIGHT CONTROL SYSTEM, the VTOL Winged UAV will be made to travel through the predefined path in autonomous mode. This document details the technical requirements of the proposed system (including design and development if required). To test the functionality of the supplied system there should be integrated Hardware In Loop (HIL) should be carried out in NAL premises.

2. FCS REQUIREMENTS: HARDWARE

2.1. Flight Control System (Air Borne Segment)

Airborne segment shall consist of the following components:

a. ARM series microcontroller based Single Board Computers
b. Sensors (IMU, Pressure sensor, GPS, magnetometer)
c. Spread Spectrum Modem
d. Custom fabricated Cable Loom
e. Power Converters, Data recorder, antenna connection
f. Datalink antenna
g. Digital and Analog I/Os

2.2. Ground Control Station (Ground Segment)

Ground segment shall consist of the following components:

a. Spread Spectrum Modem
b. DGPS
c. Ground Control Software
d. Power, data interfaces, indicators, antenna connection

2.3. Hardware in Loop Simulation

a. Real-Time Flight model development of VTOL-UAV
b. Communication interface with FCS and computer with real-time flight model running at 50 Hz and I/O's
c. Telemetry record for data analysis
d. Visuals display of Simulation

3. SPECIFICATIONS OF FLIGHT CONTROL SYSTEM (AIRBORNE SEGMENT)

The flight control system includes ARM microcontrollers with independently developed software for Flight Control by NAL. Software is coded in code composer studio and Simulink using floating-point arithmetic. The basic update rate should be 100 Hz, which corresponds to a frame time of 10 ms. The supplier should integrate flight control software (firmware) developed by NAL in the flight control system.

A schematic of the flight control system is shown in Fig-1. The flight-critical sensors (rate gyros and normal accelerometers), and the air data sensors are to be provided for flight data redundancy. Fail-safe operational capabilities are also provided for the flight control system using Hardware redundancy for I/O's. The primary control law computations and Navigation are performed by FCS computer.

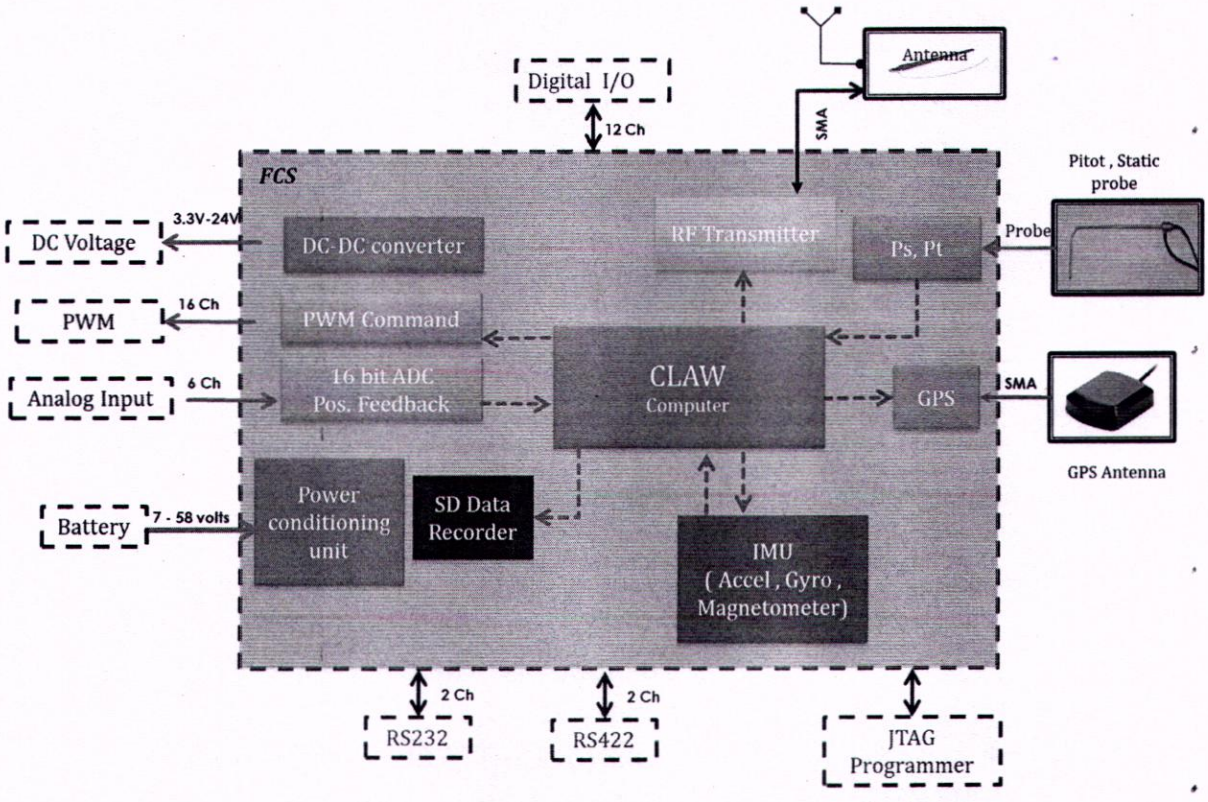

Figure 1: Functional block Diagram of FCS

3.1 The Flight Control System (FCS) should have the following major ICs integrated over the single PCB:

- ARM Series microcontroller should be used. (Part: No: Hercules RM57L843 or Equivalent)
- GPS (Part No: u-Blox M8 engine or Equivalent)
- *Inertial Measurement Unit* (Part No.: Analog Devices, ADIS16448 or Equivalent)
- Modem (RF transceiver): (Part No: Microhard: P400 or Equivalent)
- Digital Barometric Pressure Sensor: (Part No: Freescale: MPL3115A2 or Equivalent)
- Flash memory: (Part No: TI: SM28VLT32-HT or Equivalent)
- Antenna: 410 - 480 MHz Magnetic Base Omni Antenna, with 2 dBi Gain

3.2 FCC should have following major I/O configurations

- Should have onboard µController along with clock circuit for carrying out arithmetic and logical computation. If µProcessor is employed for this purpose then other suitable ICs like RAM, ROM and Flash memories should also be there onboard itself for the faithful execution of the Flight Control Software.
- The supporting IDE should have programming capability in C language or GUI based configuration utility
- FCS should have at least 4 nos. of serial ports (RS232 & RS422).
- FCS should have at least 12 configurable general-purpose Digital I/Os channels
- FCS should have at least 6 nos. of 16-bit Analog Input channels with an input range of -10V to +10V or better. These channels should have a simultaneous sampling rate of at least 1000 Hz.
- FCS should have at least 04 analogue output channels with a resolution of 16 bit or better with an output range of -10V to +10V or better
- It should have at least 16 PWM channels configurable as input capture & output between 50 Hz to 1000 Hz. The ON period of these channels should be configurable in the steps of 1 microsecond at least.
- Should have onboard variable output DC to DC converter for generating 3.3V-24V for external servos and other subsystems.
- Should have an interface for connecting external RF Datalink, should also support from flight control software side too.
- Should have at least 8GB onboard data recording facility using SD card excluding external memory. The supplier should supply the SD/ external memory cards.

- JTAG interface for programming the microcontroller should be available on the FCS.
- GPS & Transceiver antenna interface should be there on the enclosure and of SMA type.
- The FCS should have separate connectors for power & data connectivity on the enclosure. The power connector should be 2 pin type & data connector should be with locking and should be at least of industrial grade.

3.3 Physical Parameters:

- Flight Control System weight should not be <= 500 gm and of dimensions of (L X W X H) => 100x 80 x 50 mm.
- Mounting using suitable external screws with lock nuts

3.4 Electrical requirements:

- The system should operate on input voltage from 12 to 58 V DC. Internally power must distribute to all modules and sensors as per requirements. The total power requirements should not be more than 6 watts including the operational RF transceiver.
- Heat dissipation- FCS should perform with the natural air cooling
- All component used in FCC should have temperature rating -40°C to 85°C at least (at least).

3.5 µController/ µProcessor specifications:

- Should be of ARM Architecture based
- Should be able to support at least 32-bit instruction set
- The operation clocks of µP or µC should be at least 330 MHz

3.6 Memories Specifications:

- SRAM: at least 512KB
- Program Storage Memory: at least 4 MB
- Data Flash/EEPROM: at least 128 KB
- Onboard Data Recording: yes
- Data Recording memory: Flash type, SD/ uSD Card with sturdy fitting (at least Class -6)
- Data Recording Memory Size: at least 8 GB

3.7 ADC and DAC Specifications:

- Analog input should be able to handle at least -10V to +10V volt signal level
- Should have 16-bit resolution

3.8 PWM Specifications:

- Number of PWM channels: At least 16
- Should be configurable from 40 Hz to 500 Hz along with 5% to 95% ON cycle
- All PWM channels should be separately configurable

3.9 Serial Port Specifications:

- Should support configurable baud rate at least up to 115200 bps
- should have at least 3 serial ports (RS232/ RS422) and at least one among them should support RS232 protocol

3.10 On-board RF Data Telemetry Specifications (Microhard: P400 or Equivalent):

- Should have at least 60 km line of sight communication range with at least (RF) transmission power capability
- Should be able to make operation at Frequency 410 to 480 MHz or Frequency 902 to 928 MHz band
- Should have Frequency Hopping Feature

Sl.No	*PARAMETER*	*SPECIFICATIONS/ RANGE*
1.	Frequency range	Software Selectable 400 MHz & 900 MHz Bands.
2.	Serial Baud Rate	300 bps to 230 kbps
3.	Range	>60km
4.	Rejection	Alternate Channel @ 400 MHz: 70 dB Alternate Channel @ 900 MHz: 65 dB
5.	Input Impedance	50 Ohm
6.	Input VSWR	1.5:1
7.	Image/spurious rejection	60 dB min
8.	Dynamic range	80 dB
9.	Transmission Power	2W for Frequency 410 to 480 MHz 1W for Frequency 902 to 928 MHz

10.	De-modulation type	Frequency Hopping, GMSK, 2GFSK, 4GFSK, QPSK
11.	Sensitivity	-115dBm at 9.6kbps
12.	Power supply, Voltage (Internal Power Supply)	3.3VAC, 2 A max
13.	Connector details RF input, Power Supply Connector, RS232 / RS422 output	Antenna: RP-SMA Female Bulkhead Data: DB9-F
14.	Environmental	-55°C - +85°C , 5-95 % humidity, non-condensing
15.	Qualification levels for airborne	FCC Part 15.247, IC RSS210, FCC Part 15.90 IC RSS119, RoHS Compliant

3.11 On-board Navigation Sensor Specifications (Analog Devices, ADIS16448 or Equivalent):

- Should have 03 axis gyro with following specifications or better
- Should have 03 axis accelerometer with following specifications or better
- Should have 03 axis magnetometer with following specifications or better
- Should have Barometer with following specifications or better
- The data conversion rate of 10 DOF sensor: At least 2 KSPS (Internal)
- Temperature Range: −55°C to +105°C
- Start-up time: better than 1 second (~500 ms)
- Should have INS/GPS based navigation software for state estimation and noise filter.
- All vehicle states should be measures, velocities, attitudes, position, acceleration, rates, body frame translation and rotational velocities, ground speed, heading, airspeed etc.

NAME	PARAMETER	SPECIFICATIONS/ RANGE
GYROSCOPES	Dynamic Range	±500 °/sec
	Bias Temperature Coefficient	± 0.005 °/sec/°C
	Misalignment Error	±0.05 Degrees
	Nonlinearity	0.1 % FS
	Repeatability	0.7°/sec at −40°C ≤ TC ≤ +85°C, 1 σ
	In-Run Bias Stability	14.5 °/hr
	Error over Temperature	±0.2 °/sec at −40°C ≤ TC ≤ +85°C, 1 σ
	Output Noise	0.27 °/sec rms

	Linear Acceleration Effect on Bias	0.015 °/sec/g
ACCELEROMETERS	Dynamic Range	±18 g
	Sensitivity Temperature Coefficient	±40 ppm/°C
	Misalignment Error	±0.2 Degrees
	Nonlinearity	0.2 % FS
	In-Run Bias Stability	0.25 mg
	Bias Temperature Coefficient	±0.15 mg/°C at −40°C ≤ TC ≤ +85°C, 1 σ
	Output Noise	5.1mg rms
MAGNETOMETER	Dynamic Range	±1.9 gauss
	Resolution	145 micro-gauss
	Alignment Error	±.25 Degrees
	Repeatability Error	0.1 %FS
	Initial Bias Error	±4 mgauss
	Total RMS Noise	2.4 mili-gauss
	Temperature Effect	0.11 mgauss/°C
INS WITH GPS	Pitch & Roll Accuracy	0.25 Degrees
	Heading Range	0 to 360°
	Heading Accuracy	1 Degrees
	Heading Resolution	0.1 Degrees
	Heading Repeatability	±0.5 Degrees
	Position accuracy (latitude , longitude)	<2.5m
AIR DATA PROB	Airspeed range	>90m/s
	Airspeed accuracy	< 0.5 m/sec @ 30m/sec <1.5 m/s above 5m/s
	Altitude range	0-9.4km
	Digital barometer calibrated range	300 ar to 1100 mbar

3.12 On-board GPS receiver Specifications (u-Blox M8 engine):

- Should be able to lock within 27 seconds under cold start with an active antenna connected.
- Should have at least 10 Hz update rate.
- Update rate should be user-configurable.
- Should work in DGPS configuration along with ground control station
- Should have the capability to support various GNSS systems i.e. GPS, GLONASS, BeiDou, Galileo etc.

- Should have the capability to support Augmented GNSS technologies i.e. WAAS, GAGN, MSAS etc.
- Should have separate GPS antenna interface for connecting Active as well as Passive GPS antenna.
- Should have inbuilt spoofing detection mechanism and anti-jamming techniques.
- Horizontal position accuracy: Standalone <2.5m
- Real-Time Kinematics: <0.025 m + 1 ppm CEP
- Operational limits: >3g
- Velocity accuracy:0.05m/s
- Dynamic heading accuracy: 0.3°
- Sensitivity: –160 dBm

3.13 Functional for configuration of I/O's and telemetry-

- Should be able to send the necessary commands for control surface movement, thrust vectoring and thrust power based on flight control software output.
- Should be able to deliver I/O, PWM, analogue commands to relevant Power plant or actuation system in order to complete the vehicle flight from takeoff till touchdown.
- Should be capable of storing up to minimum 500 waypoints in memory for guidance algorithms.
- Shall have a Built-In Test (BIT) module to test all the hardware (sensors and controller and IO lines) and activates audio and visual command for the fail-safe go-ahead for each flight. The same will be communicated to the ground station
- Must have a module to detect other hardware failures e.g. memory, stack overflow etc. and take corrective actions, In case of any sensor failure FCF must initiate the corresponding flag to ground station for monitoring and remedial action an provision for uninterrupted control surface movement commands to be taken to complete the vehicle flight from takeoff till touchdown.

- Should detect that the roll/pitch/yaw control function is close to saturation utilizing the limiting values of relevant subsystems.
- On the ground during flight control checks and initiation of HMI should implement a specific operational mode allowing the operator to check the end to end functionality with respect to full deflection of control surfaces vis-à-vis the command control.
- Should provide all the necessary information to the ground operator so that this could be represented at the ground in the form of textual or graphical output.
- Should have the capability to accept waypoints during flight itself
- FCF should be developed in C++/C/Assembly and the source code should be supplied to CSIR-NAL, Bangalore along with any necessary compiler, if required, so that minor tweaking can be executed in-house.
- Compiled firmware along with NAL flight control law should be able to directly fused with FCS

4. SPECIFICATION OF GROUND CONTROL STATION (GCS)

Ground Station allows remote control of UAV, receives and processes navigation data from UAV via the data-link, supports flight planning and communicates with the Ground Navigation and Control (GN & C) onboard on the ground via RS232 interface (flight plan upload, system configuration and control laws adjustment). Conventional Joystick is to be provided by the supplier for GN&C engagement and disengagement as well as allows manual/remote controlled flight operations during visual range with UAV. A pictorial representation of GCS is shown in Fig-2.

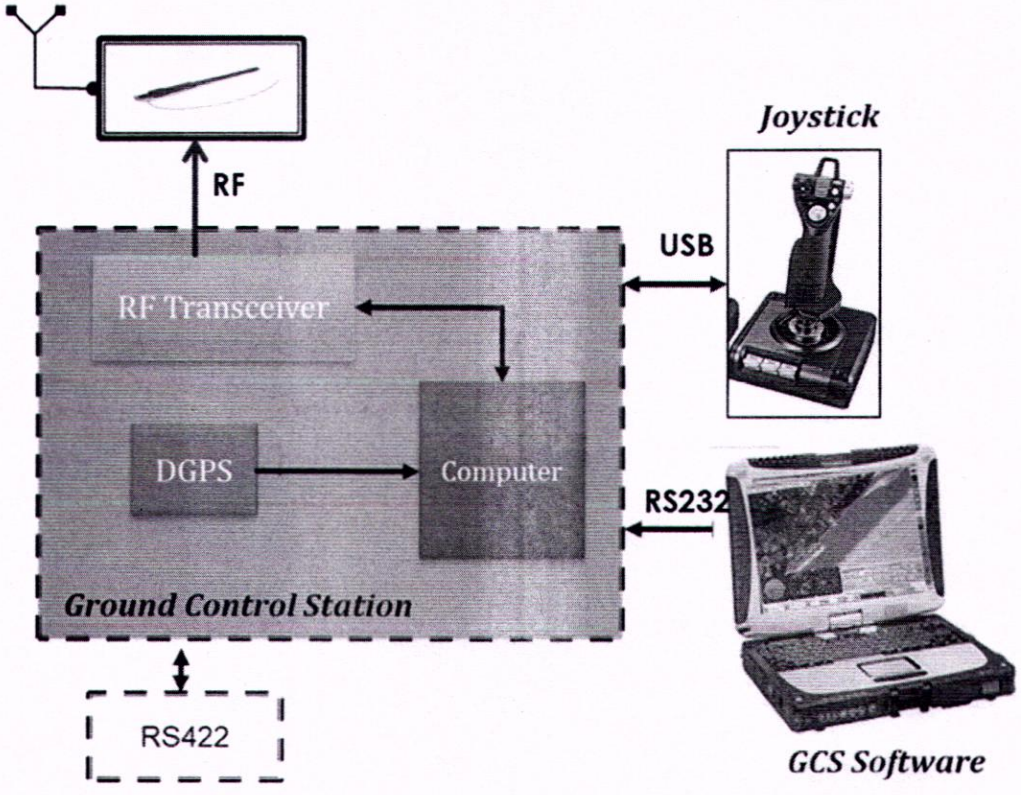

Figure 2: Ground Control Unit Schematic

4.1 The requirement of Ground Control System (GCS)

- Should be compatible with the transceiver of FCS and having the same technical specifications
- Should be capable to transmit commands through joystick to FCS or receive mission-critical data from FCS
- It should be able to log Data and display airborne parameters, received through RF communication via RS232 port
- It should have inbuilt GPS for DGPS operation
- It should be capable of downloading maps (if internet connection is provided) and displaying UAV over maps.
- GPS Data overlay over maps.
- It should also be able to generate commands and transmit through RF modem via RS232 port for Auto/Manual mode of control
- The interface between the enclosure of modem & battery and laptop will be RS 232 port

- Interface with Data Link/Communication box Communication between UAV and ground station is performed via wireless data link which operates at 433-480MHz or 900MHz.Commands can be sent to UAV onboard computer and telemetry data can be received at the ground station computer. The communication modules also can be used to control some logical states and controller settings from the ground.

4.2 The requirement of Ground Control system - Software (GCS)

- The functionality of the GCS is to receive the data from ECS, do data logging and data display for monitoring of mission-critical parameters and status. The software must implement all these features.
- GCS display must have a cockpit view of all mission-critical data i.e. vehicle attitude, tri-axial velocity, g levels, heading, altitude, power status, command status, system errors etc.
- GCS should support waypoint generation and onward transmission to the FCS.
- GCS should be able to display vehicle location in 2D along with the predefined waypoints and background stored maps.
- Ground Control station shall have Real-time Terrain and elevation information for presenting vehicle position, flexible mission design along with pre-determined mission loading capabilities, vehicle control, audio-visual warning and system monitoring, and a parameter estimation tool.
- The user interfaces for GCS for data display, flight data storage on PC, and top-level command handling from operator must be supplied by the firm. The GCS software should be compatible with Windows environments 7 or onward.
- The GCS software must be developed using C# language.
- User-friendly GUI to be developed to display airborne parameters to implement minimum functionality indicated as below
    a. Waypoint navigation

b. Vehicle Location
c. Mission planning and adaptations in fight
d. Data Analysis
e. Warnings (Aural and Visual)
f. System Health Monitoring
g. Telemetry measurement list
h. Upgradeable maps
i. Terrain and elevation information

- Basic displays like Artificial Horizon, Turn coordinator, Airspeed display, Compass, altimeter
- A typical layout is shown in the Fig-3 for reference

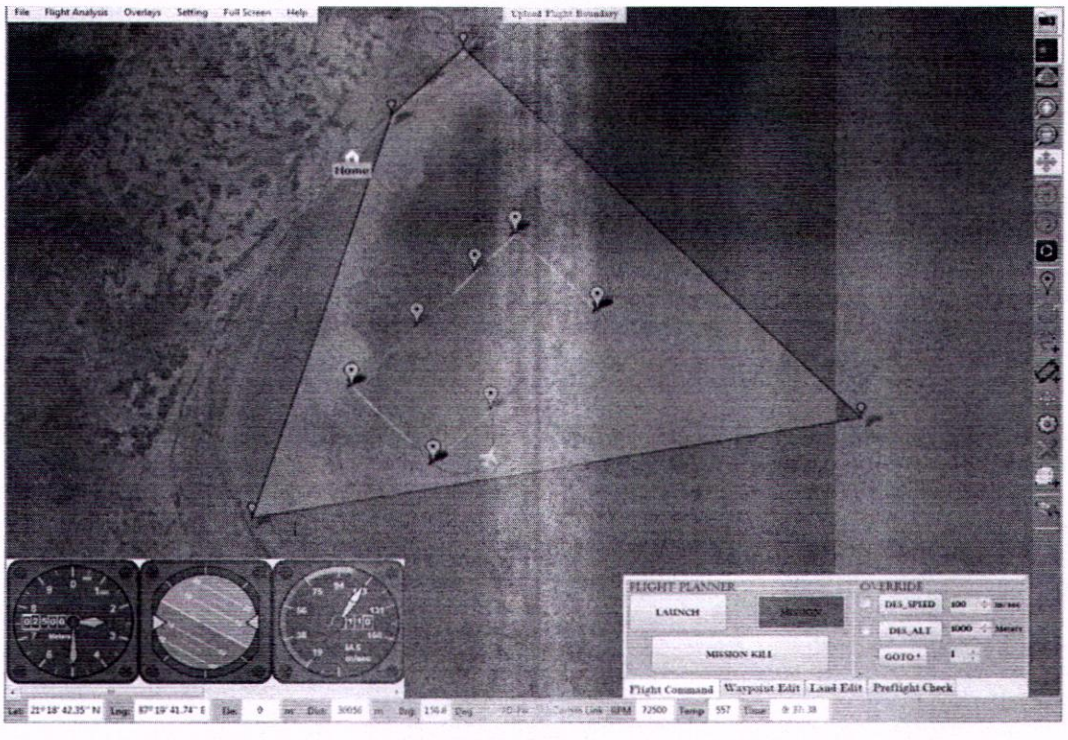

Figure 3: Typical layout of GCS

5. HARDWARE IN LOOP SIMULATION (HILS)

The vendor should create Hardware In loop simulation setup for VTOL-NAL flight control system to test algorithm and hardware interface of FCS. The flight control algorithm will be running on the actual FCS hardware during the test.

The vendor should create simulation environment to test flight control System for its functionality.

Work will involve the following activity.

- Real-time 6-DOF vehicle model running on workstation PC with required interfaces for simulation
- Develop Communication interface of FCS with 6-DOF Workstation PC, including an actuator, engine, Sensor interface to carry out integrated run, also carry out required modification in ground control station to conduct test.
- Ground command control to execute the mission
- Develop Interface required for flight control computer to integrate with Hardware I loop Simulation (HILS).
- Telemetry recorded for data analysis
- Visuals display
- Develop test cases for hardware test and Control law verification and validation
- Demonstrate and Validate the Flight Performance of flight Control Computer through HILS against required performance through the closed-loop integrated run.
- Undertake upgrading of Control and Guidance software based on results of flight trials

5.1 The HILS System Architecture

HIL simulator will Include VTOL-NAL avionics package (flight control system) as per specification mentioned in Section-2 for the implementation of the control algorithms and for real-time running dynamic flight model on PC workstation and for flight visualization commercially available software packages including FlightGear. Actuator systems of VTOL-NAL will be connected to the Flight control computer for physical calibrated movement of actuator via signal cable, and feedback from actuator will be connected Flight model Workstation PC which in turn goes as input for flight dynamic model. The mission management computer (VTOL-NAL GCS) is connected to the ground-based transceiver to load mission, Mission control, Vehicle situation /location and visualization. The

vendor should ensure that HIL simulation setup will provide Complete means for designers to construct mission and test navigation guidance and control algorithms, and test the avionics hardware and software systems in real-time, by simulating full missions, with realistic visual feedback of the vehicle response.

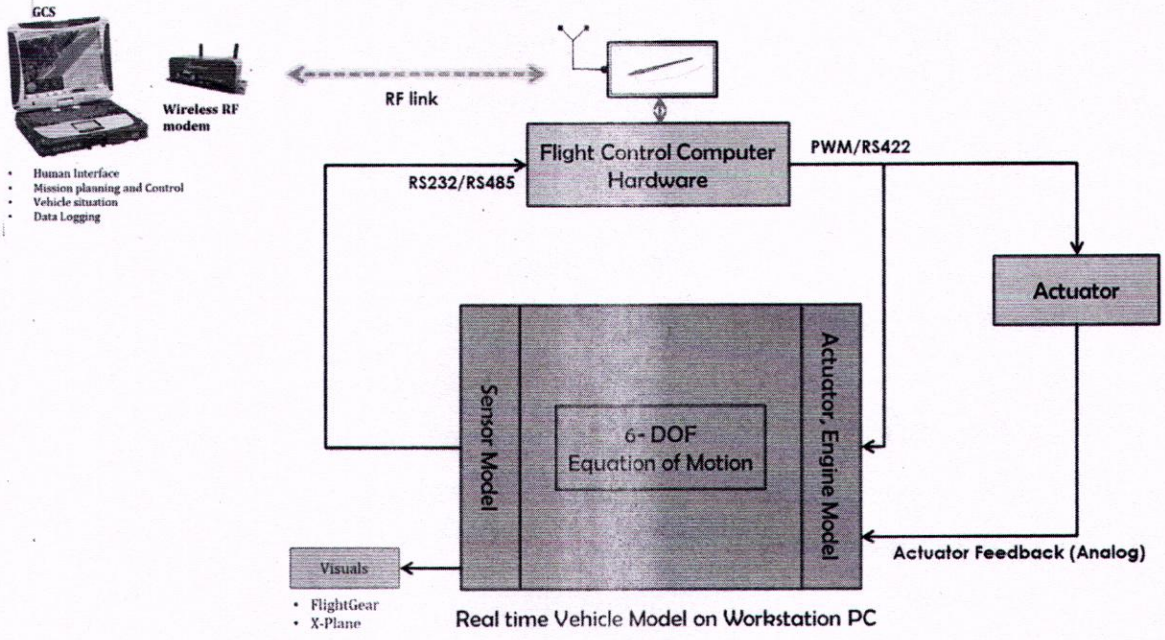

Figure 3: Hardware Setup for HIL simulation

5.2 Data communication and synchronization between FCS and flight dynamic model

A full 6-DOF nonlinear model for the VTOL-NAL should be built runs in real-time. The output states from the 6-DOF should be processed to emulate real sensors accounting for sensor latency, random walk bias, and measurement noise. After being digitized according to the word size of the micro-controller (32 bit, 4096 steps), the sensor values are transmitted to the autopilot via means of RS232/RS485 communication. In a similar manner, the navigation states are processed for data latency and measurement noise and encapsulated in a binary GPS packet identical to the actual GPS data output. This packet is also transmitted to the FCS at low update rate (5 Hz) via the

RS232/RS485 communication on same channel. In the HIL environment, the FCS functions identically as in a real flight test, computing control commands to each control actuator. These commands are then sent back to the 6-DOF simulator via measuring analogue feedback at servo in order to drive the flight dynamic model of VTOL-NAL vehicle. Each control surface is calibrated after installing on vehicle including fixing the saturation angle. Consequently, a simulation loop is formed between the 6-DOF simulator and the autopilot and actuator exchanging the simulated data back and forth. In order to visualize the simulation, open-source flight simulator visualization tool can be adopted (FlightGear /X-plane).

5.3 HILS Test and Performance Evaluation

1. The vendor should give a comprehensive document that lists down all the test cases of HILS that need to be performed with the FCS.
2. map the FCS functional requirements to these test cases for ensuring a full coverage on all possible functionalities requested of FCS.
3. Test cases should cover
    a. overall Functional requirement coverage
    b. Impact analysis & regression test
    c. failure cases derived from FMEA
4. Hardware Test cases should Include
    - FCS Input Power Check against specification
    - Test Cases for Actuators Health Status (Actuator Powers, Actuator Demands etc.)
    - Test Cases for Engine
    - GPS Check
    - Telemetry
    - Pressure Probes
5. Software Test Cases in HILS
    - Pre - Launch Checks (Self-test for Actuators (Servo Test), Waypoint upload and validation, Self-test for INS/GPS, telemetry)
    - Open Loop Checks:

- Longitudinal control
- Lateral control

- Closed-Loop Control Checks
  - Takeoff and landing Functions
  - Climb Phase Functions
  - Cruise Phase Functions
  - Waypoint Navigation
  - failure logic

6. PREVIOUS SUPPLY/EXPERIENCE OF THE VENDOR IN SIMILAR PRODUCTS

- **Vendor /supplier should have experience in developing custom based flight control system and supplied similar flight control system to organisations in India**

7. DELIVERABLES

A. Flight Control System (Air Borne Segment)

a. One No of Flight Controller Unit hardware on-board
b. One No. of Ground Control Station
c. One. Nos of Cable loom at the time of integration on one VTOL-UAV
d. The complete source code of Flight Firmware (not just APIs) has to be provided for FCS
e. BOM to be provided to NAL.
f. Detailed datasheets of all the sensors, controller & other hardware must be supplied to CSIR-NAL, Bangalore with required accessories i.e. IDE, programming hardware etc.
g. A detailed user guide for the Flight Control System should be provided by the supplier to CSIR-NAL, Bangalore

B. Ground Control Station (Ground Segment)

a. One unit of Ground control system software

b. The complete source code (not just APIs) has to be provided for GCS
c. Source Code of GCS Software and Utilities/Executables (both for FCS and ground station) must be provided to CSIR-NAL, Bangalore
d. A detailed user guide for the Ground Control Station should be provided by the supplier to CSIR-NAL, Bangalore

C. Hardware in Loop Simulation

a. Source Code of Real-time Flight model with interface
b. A detailed user guide for the Hardware in the Loop simulation
c. Report on Test Cases in Hardware in the loop simulation

8. SCOPE OF WORK FOR VENDOR

- The supplier should quote the price for FCS, GCS and HIL separately. The total supply cost for whole system will be considered as the price comparison. In future FCS only can purchased as per need basis.
- Flight Control System (FCS) of mentioned specifications should be supplied to NAL within 6 (Six) weeks of the release date of supply order for inspection and evaluation process.
- The supplier should integrate Flight control software developed by NAL on FCS hardware
- After integration of the control software, the supplier should carry out the integration of supplied items on VTOL UAV at NAL premises. The supplier should provide looming support at the time of the integration based on the sensors/ motors/ servos etc.,
- After the successful integration of FCS, the supplier will make compatible mating interfaces for the servos and motors (CSIR-NAL, VTOL UAV hardware).
- Test cases, fail/ pass criteria and acceptable errors wherever is not mentioned would be solved by the supplier.
- The supplier would assist CSIR-NAL team to conduct the flight trials of VTOL-UAV at Bangalore or nearby region.

- Flight data generated would be analyzed by CSIR-NAL team and supplier should assist in this process.

9. ACCEPTANCE TEST PROCEDURE FOR FLIGHT CONTROL SYSTEM FOR VTOL-UAV

- There will be no physical damage in any part of the deliverables.
- All the deliverables will be checked and verified as per the parameters mentioned in the specification and scope of work.
- The flight control system will be integrated on VTOL-UAV with the electronics hardware supplied by CSIR-NAL i.e. servos, motors and power unit with the help of supplier representatives. There must be no compatibility issues during the integration. If any compatibility issue arises then the supplier has to take care and solve it.