ANNEXURE I

I. 6 DEGREE-OF-FREEDOM LIGHTWEIGHT COLLABORATIVE ROBOT (COBOT) WITH MANIPULATOR, CONTROLLER, TEACH PENDANT, AND NECESSARY ACCESSORIES.

TECHNICAL SPECIFICATION

The robot should meet all the following technical specifications and terms and conditions, unless otherwise stated.

1. MANIPULATOR AND CONTROLLER (COBOT)

Number of joint axes	Six rotating joints
Joint transmission	Harmonic Drive gears
Communication	Control frequency at least 500 Hz (Low level) Ports: USB, Ethernet.
Total Weight of the robot	Less than 25Kg
Payload	Minimum 2 Kg
Reach	750 mm or more
Operating Temperature range	25 to 50 degrees or wider range
Pose Repeatability	within ±0.1 mm
Programming Language	C++ and/or Python
Software Compatibility	1. Default API/GUI 2. Should have ROS compatibility
Operating system	Windows and Linux
Control and sensing	Position, Velocity, Force/Torque (for all the joints)
Force Range along X-Y-Z axis	Minimum 25 N
Torque Range about X-Y-Z axis	Minimum 7.5 Nm
Protection rating	Minimum IP33 standard

2. TEACH PENDANT

Programming Interface	Teach pendant with touch screen, emergency stop, etc.
Cable length	At least 2 meter
Weight	Maximum2 Kg

3. NECESSARY ACCESSORIES:

3.1. GRIPPER

Number of fingers	3
Finger joint type and mechanism	Rotary joints and Underactuated (adaptable)
Actuation	Only Electric
Joint sensor	Encoders (for each joint)
Gripping force	20 N or more

Grasping object diameter	Minimum: 5 mm or less , Maximum: 45 mm or more
Total weight	Less than 1.5 kg
Hardware interface compatibility	Should be modular and independently driven even in the absence of manipulator (standalone operational capability)
Programming Language	C++ and/or Python
Software Compatibility	1. Default API/GUI 2. Should have ROS compatibility

3.2 FORCE TORQUE SENSOR

Force range Fx, Fy, Fz	Minimum 25 N
Moment range Mx, My, Mz:	Minimum 10 N
Weight	Less than 400g
Hardware interface compatibility	Could be used independently, even in the absence of a manipulator (standalone operational capability). Compatible with the gripper
Programming Language	C++ and/or Python
Software Compatibility	1. Default API/GUI 2. Should have a ROS compatibility

System Requirements:

1. All the joint axes should contain sensors to provide signals for robot control (e.g., position control and impedance control) as a protective function.
2. The robot should be equipped with a force/torque sensor that is compatible with the Gripper to perform high-precision assembly tasks, and to precisely detect and measure the contacts.
3. Power and communication cables, compatible software, and couplings for Gripper (3.1) and Force/torque sensor (3.2) should be provided.
4. All software packages (ROS Packages, Matlab scripts (optional)) and sample software programs (ready to program tasks) should be supplied with the robot.
5. The structure of the robot should be rigid and free from vibrations.
6. The robot should be fitted with all electrical items to carryout work immediately.
7. The operation and maintenance manuals of the robot have to be supplied.
8. All necessary and suitable accessories such as base frame, clamps for tabletop fitting, etc., should be included.
9. Direct access to each actuator is preferred.
10. A portable casing is preferred for safe transportation.
11. All the actuators should operate at comparatively less noise.
12. Should provide at least 3 years warranty.

II. 7 DEGREE-OF-FREEDOM LIGHTWEIGHT COLLABORATIVE ROBOT (COBOT)WITH MANIPULATOR, CONTROLLER, TEACH PENDANT, AND NECESSARY ACCESSORIES.

TECHNICAL SPECIFICATION

The robot should meet all the following technical specifications and terms and conditions, unless otherwise stated.

1. MANIPULATOR AND CONTROLLER

Number of joint axes	Seven rotating joints
Joint transmission	Harmonic Drive gears
Total Weight of the robot	Less than 30Kg
Payload	Minimum 2Kg
Reach	700mm or more
Operating temperature range	25 to 50 degrees or wider range
Repeatability	Within ±0.2 mm
Programming Language	C++ and/or Python
Software Compatibility	1. Default API 2. Should have ROS compatibility
Operating system	Windows and Linux
Low-level controller	Position, velocity, current, torque (for all the joints)
Noise	Comparatively noiseless
Protection rating	Minimum IP33 standard

2. TEACH PENDANT

Interface	Teach pendant with touch screen, emergency stop, etc.
Cable length	At least 2 meter
Weight	Maximum 2 Kg

3. NECESSARY ACCESSORIES:

3.1. GRIPPER

Number of fingers	3
Finger joint type and mechanism	Rotary joints and Underactuated (adaptable)
Actuation	Only Electric
Joint sensor	Encoders (for each joint)
Gripping force	20 N or more
Grasping object diameter	Minimum: 5 mm or less, Maximum: 45 mm or more
Total weight	Less than 1.5 kg
Hardware interface compatibility	Should be modular and independently driven even in the absence of manipulator

Programming Language	C++ and/or Python
Software Compatibility	1. Default API/GUI 2. Should have a ROS compatibility

3.2 FORCE TORQUE SENSOR

Force range Fx, Fy, Fz	Minimum 25 N
Moment range Mx, My, Mz:	Minimum 10 N
Weight	Less than 400g
Hardware interface compatibility	Could be used independently, even in the absence of a manipulator (standalone operational capability). Compatible with the gripper
Programming Language	C++ and/or Python
Software Compatibility	1. Default API/GUI 2. Should have a ROS compatibility

System Requirements:

1. All the joint axes should contain sensors to provide signals for robot control (e.g., position control and impedance control) as a protective function.
2. The robot should be equipped with a force/torque sensor that is compatible with the Gripper to perform high-precision assembly tasks, and to precisely detect and measure the contacts.
3. Power and communication cables, compatible software, and couplings for Gripper (3.1) and Force/torque sensor (3.2) should be provided.
4. All software packages (ROS Packages, Matlab scripts) and sample software programs (ready to program tasks) should be supplied with the robot.
5. The structure of the robot should be rigid and free from vibrations.
6. The robot should be fitted with all electrical items to carryout work immediately.
7. The operation and maintenance manuals of the robot have to be supplied.
8. Supply of necessary and suitable accessories such as base frame, clamps for tabletop fitting, etc., should be included.
9. Direct access to each actuator is preferred.
10. A portable casing is preferred for safe transportation.
11. All the actuators should operate at comparatively less noise.
12. Should provide at least 3 years warranty.

III. TWO WHEELED MOBILE ROBOT WITH CONTROLLER AND NECESSARY ACCESSORIES.

TECHNICAL SPECIFICATION

The robot should meet all the mentioned specifications, terms and conditions, unless otherwise mentioned.

1. **Two-wheeled mobile Robot and Controller:**

Size Length Width Height	 Maximum 0.3 m Maximum 0.35 m Maximum 0.2 m
Payload	Minimum 10 kg
Translational Velocity	Minimum 0.20 m/s
Rotational Velocity	Minimum 100 deg/s
Weight including sensors and actuators	Less than 2.5 kg
Embedded board	OpenCR (Open-source Control module for ROS)
SBC (Single Board Computers)	Raspberry Pi 3 Model B or B+
MCU	32-bit ARM Cortex®
Remote Controller	Bluetooth communication (optional)

2. **Necessary accessories:**

a. **Sensors and Actuators:**

1. LiDAR	
Detection distance	Minimum 2000mm
Angular range	360^{o}
Angular resolution	1^{o}
2. IMU	
Gyroscope	3 axis
Accelerometer	3 axis
Magnetometer	3 axis
3. Actuators	
Operating modes	Velocity control, Position control, PWM control mode
Sensor and feedback	Wheel encoder, wheel velocity, Real-time tick etc.

b. Power supply and ports:

Battery Type	Lithium ion polymer
Operating time	Minimum 2 hours
Charging Time	Maximum 2.30 hours (for full charge)
Power connectors	3.3V / 800mA 5V / 4A 12V / 1A
Peripheral	UART, CAN, SPI, I2C, ADC
Programmable indicators	LEDs
Status indicators	Board status and Power status
PC connection	USB
Firmware upgrade	via USB / via JTAG
Power adapter (SMPS)	Input : 100-240V, AC 50/60Hz, 1.5A @max Output : 12V DC, 5A

Number of robots required: FOUR

System Requirements:

1. All software packages (ROS Packages) and sample software programs (ready to program tasks) should be supplied with the robot.
2. The robot should be provided with SLAM (simultaneous localization and mapping) algorithms to build a map and can drive around your room.
3. The robot should have the provisions to mount other systems like manipulator, Kinect sensor
4. The structure of the robot should be rigid and free from vibrations.
5. The robot should be fitted with all electrical items to carryout work immediately.
6. The operation and maintenance manuals of the robot have to be supplied.
7. All necessary and suitable accessories such as brackets, plates, wheels, cables, fasteners, casters, batteries, motors, boards etc., should be included.
8. Direct access to each actuator is preferred.
9. A portable casing is preferred for safe transportation.
10. Should provide at least 3 years warranty.

IV. TELEOPERATION TRAINER

In view of getting the students acquainted with teleoperation systems, two kinematically and dynamically similar haptic devices are necessary at a training phase. The two haptic devices can be then programmed to function as master and slave robots. To achieve this end at the laboratory level, each of the haptic devices are expected to have the following features and specifications:

Features:

- Portability
- Serial arms
- Rigid structure
- 6 Degree of Freedom (DOF) motion capability
- Backlash free design and fabrication
- Low inertia
- A stylus or a grasper with good grip attached as the end-effector
- Position sensing in all 6 DOF
- Force feedback ability in at least 3DOF
- A user friendly software interface tool
- Preferably with lab curriculum

Specifications (approx.):

Weight	-	< 2 Kg
Workspace (l× $b \times h$)	-	at least $15 \times 10 \times 5$ cm
Position sensing	-	All 6 DOF
Position resolution	-	< 0.1mm
Force feedback ability	-	At least 3 DOF
Back drivability	-	Yes
Permissible exertable force	-	> 3N
Hardware interface	-	USB preferred
Software compatibility	-	Windows and Linuxwith device drivers
Warranty	-	3 Years

Number of devices necessary for teleoperation training: **TWO**

V. 6-AXIS FORCE TORQUE SENSOR

TECHNICAL SPECIFICATION

S.No.	Specification	Value
1	Sensor diameter	<45 mm
2	Sensor height	< 15mm
3	Weight	<=60 grams
4	Sensing Force range (Fx,Fy,Fz)	40N (minimum)
5	Sensing Torque range (Tx,Ty,Tz)	1Nm (minimum)
6	Sensing Force resolution (Fx,Fy,Fz)	Less than 0.05N
7	Sensing Torque resolution (Tx,Ty,Tz)	Less than 0.0005Nm
8	Overload factor for force and torque	5 (minimum)

System Requirements

1. Sensor to be supplied with signal conditioning and amplification
2. Communication through USB preferred
3. Capability to interface with LabView software preferable
4. Software support for windows 10 and data acquisition
5. Preferably with lab curriculum
6. Calibration certificate
7. Sensor to be supplied with necessary mounting accessories

VI. INDOOR NAVIGATION POSITIONING SYSTEM

The navigation system is based on stationary ultrasonic beacons that are united by radio interface in a license-free band (433 MHz or 915/868 MHz). It should provide 3D (X, Y, Z) tracking and precise (±2cm) location data to autonomous robots, vehicles (AGV), and copters.
The system should contain Stationary beacons, Mobile beacon and Modem/Router.

TECHNICAL SPECIFICATION

Distance between beacons	Up to 50 meters in lab conditions
Location precision	Within ±2 cm
Location update rate	0.5-45Hz
Power supply	Lithium-ion based battery (1000mAh) Stationary beacon with 16Hz update rate - up to 72h Mobile beacon with 8Hz update rate – 12h External port: MicroUSB
Weight	Mobile beacon from Starter set: -Less than 65 grams (including battery 1000mAh and housing and antenna 50mm) -Less than 35 grams (bare board w/o battery)
Software Compatibility	1. Default API/GUI 2. Should have a ROS compatibility
Beacon size	55x55x33 mm (with 50mm antenna: 55x55x65 mm)

System Requirements:

1. A system should contain 4 Stationary Super-Beacons, 4 Mobile Super-Beacon, 1 Modem
2. All beacons (stationary and mobile) should be equipped with 6D IMU (3D accelerometer + 3D gyroscope) and standard 50mm antennas.
3. All software packages (ROS Packages, Matlab scripts) and sample software programs (ready to program tasks) should be supplied.
4. Should provide 3 years warranty.

VII. COMPACT SMART ROTARY ACTUATOR.

TECHNICAL SPECIFICATION

The actuator should meet all the mentioned specifications, terms, and conditions unless otherwise mentioned.

Weight	300 – 1000 gram
Dimensions (L, W, H)	Not exceeding (140 mm, 120 mm, 80 mm)
Nominal torque	8 to16 Nm
Maximum speed	10 RPM or more
Voltage	12V to 48V DC
Angular Resolution	0.005° Or less
Torque Resolution	0.01 Nm or less
Sensing	Position, Velocity, Torque, Current, Temperature, 3Axis - Accelerometer and 3 Axis - gyro
Software support	Should have ROS (Linux) compatibility Other preferences are as follows: Matlab (Windows and Linux) C/C++ (Windows and Linux) Python (Windows and Linux)

System Requirements:

1. All software packages (ROS Packages) and sample software programs (ready to program tasks) should be supplied.
2. All the electrical accessories (I/O boards, power cables, network cables, power supplies) should be provided with the motor to carry out work immediately.
3. The operation and maintenance manuals of the actuator have to be supplied.
4. All necessary and suitable mechanical accessories such as brackets, plates, fasteners, etc., should be included.
5. Desktop and mobile applications are preferred.
6. Should provide at least 3 years warranty.

VIII Propeller Analysis Test Bench:

Aim: To have an instrumented test bench to characterise the existing propulsion systems paving path to analyse and evaluate conceptual propulsion systems.The aim is to get a test bench where one can install a UAV propulsion system and characterise it by collecting its main electrical and mechanical parameters during the testing operation, i.e., Rotational Speed,Torque,Engine Temperature,Static Thrust,Fuel Consumption and Vibration.

Test Rig Specifications :

Parameters	Desired Range
Length	50- 100 cm
Breadth	50-100 cm
Height	50-100cm
Range of RPM	1000- 1500000
Sensors	Biaxial Thrust sensor for measurement of Thrust,Torque sensors to measure the torque provided by the motor, Temperature sensor to measure the heating of the components, Fuel Consumption and battery discharge sensor, mounted laser tachometer to measure RPM, Vibration sensors for measuring dynamic loading.
Data Acquisition Module	Preferably using Arduino or Raspberry Pi to log data for further analysis

Desirables : Emergency Stop during malfunction, Protection Safety cage around the experimental test bed, Spare mountings and sensors in case of malfunction.

Operating System / Programming Language : Arduino, Python or LabView

IX. Unmanned Underwater Vehicle (UUV)

Aim: To expose students to an affordable, modular and expandable UUV with 4 - 8 thrusters. The design should be robust to accommodate preexisting manipulators and sensors as scientific payloads, modular to make modifications in the future and expandable to work with the current state of the art software ikeROS(Gazebo) and Matlab to run real time simulations and validate it with the UUV so that students get to apply the knowledge learnt from Robotics in real life.

Specification:

Parameters	**Desired Range**
Length	Minimum: 35 cm Max: 100 cm
Breadth	Minimum: 25cm Max. : 50 cm
Height	Minimum: 20cm Max. : 45 cm
Weight in air	less than 12 kg
Forward Speed	1 m/s or more
Minimum rated Depth	50m
Endurance	2 - 3 hrs under normal continuous operation
Range of Communication	50m - 300m
Thrusters	6 thrusters (4 vectored,2 vertical)
Sensors	Leak Detection Sensor for leak detection, Accelerometers, Gyros, magnetometerand Barometer, Sonar or Ultrasonic Sensors for Obstacle Avoidance, High Resolution Camera optimised for low light conditions and pan tilt mechanism.
Communication	Tether upto the length of 50m or wireless communication with the ROV
Breaking strength of tether	More than 1200N
Lights and camera	2 x 1500 lumens LED lights with large field of view 1080p camera enabling real time video transmission

Accessories : Battery , Battery Charger , Tether spool, Spare kit(including penetrators, connectors and battery),Electronics to be replaced in case of accidental leakage.
Desirables : Experimental Compact Test Bed for small experimental setup, Controller interface laptop or joystick.
Operating System / Programming Language: ROS, MATLAB, PYTHON

X. Unmanned Aerial Vehicles:

To expose students for modelling and analysis of aerial vehicles, how the change of various parameters will affect the response of the system. The product should be compatible with the present state of the art modelling and simulation environments like Matlab, ROS,versatile to mount multiple sensors and compact enough to simulate swarm situations in an indoor environment.

Specification :

Parameters	Desired Range
Overall Vehicle dimension	Less than 1m x 1m x 1m
Endurance	20 - 45 minutes
Overall Takeoff Weight	< 6kg
Sensors	GPS, Accelerometers,gyroscope,barometer and magnetometer for localization Vertical camera and ultrasound sensor for object detection using ROS or MATLAB High Resolution Camera (15-21 MPix) to aid localization by optical flow and continuous stream of data for processing. Should be versatile enough able to mount available sensors as payload and process the data.
Communication	Wireless Communication using radio frequency
Maximum range	1 - 7 kms

Accessories : Built in Ground Control Station including transmitter, extra battery, spare electronics and mountings and markers which can aid in indoor navigation.

Desirables :1) Ability to have standard set of sensors with the access to the data recorded so that students can perceive the use of sensors like LIDAR for localisation in indoor and outdoor environment, Multispectral camera for application in agricultural purposes, Thermal and RGB camera for mapping and aerial survey. 2) Ability to carry a scientific payload of around 800 grams which can include a camera, gripper or customised payload for various applications 3) Software compatibility: MATLAB/ROS/PYTHON. The students should be able to use it as an educational platform modifying the various parameters affecting the modelling of the vehicle and see their effect in real time.

XI. Multispectral Image Analyser:

Aim:Multispectral camera used to capture the remote sensing images. This multispectral camera is attached with small unmanned aerial vehicles or ground field robots.Multispectral Images are a very effective tool for evaluating soil productivity and analyzing plant health.

Specification:

Specifications	Value
Spectral Bands	Green, Red, RedEdge, Near-Infrared
Ground Sample Distance	6 to12 cm/pixel-per band at 120 m or higher
Capture Speed (minimum)	1 or more(capture per second)
Interface	Serial, Ethernet, Wi-Fi
Field of View	45 º to 70 º HFOV
Power source	Less than 5.0 V, Less than 10 watts
Weight	Less than 250 grams
Dimensions (L x W x H)	Less than 10 x 10 x 10 cm

Desirables : To be able to access the video or image transmission from the multispectral camera and process it for utility in farming and health monitoring.The data provided from the camera should be available in form of video or stitched images so that further image processing and other complex algorithms could be applied. Effective stabilization using gimbal is preferred.

Software Compatibility: The data from the multispectral camera is analyzed by the remote sensing or GIS software

XII Industrial Camera

An Industrial camera that can be mounted on the robotic platforms to perform various computer vision applications. The camera should be suitable for applications that include Machine Vision, Metrology, Medical engineering applications, etc.

Specifications

Sensor type	CMOS (Color)
Color depth (Camera)	Minimum 12 bit
Interface	USB
Frame rate	90-150 fps
Resolution	Minimum 1Mpix@90fps
Shutter	Global
Resolution	Minimum 2MPix
Dimension (H/W/L)	Less than 50mm
Weight	Less than 200 g

The camera should be supplied with the following

1. Connectors:
    1. Interface connectors
    2. I/O Connector
    3. Power supply
2. Camera Casing
3. Lenses
    Working Distance: Approximately 1000 mm
    Height: Approximately 1000 mm
4. Lens Mount
5. Tripod Adapters
6. Software suite (for calibration and changing the parameters)
7. Status LED
8. At least 3 years warranty.

Quantity: **THREE**
