INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
MATERIALS MANAGEMENT DIVISION
Powai, Mumbai - 400076

PR No. 1000027131 **Rfx No. 6100001170**

Specifications for Inflight earthquake actuator Shake Table with Servo Hydraulic Actuator (STASHA) with Accessories for IIT Bombay large-beam centrifuge facility

Short Description of item: - Procurement of **In-flight Earthquake Actuator** for triggering earthquakes at high gravities for studying the behavior of geotechnical structures during centrifuge tests at the National Geotechnical Centrifuge Facility (NGCF), IIT Bombay.

Objective:
Indian Institute of Technology Bombay (IIT Bombay) is seeking proposals for the development and installation of a new 1D shaker (uniaxial earthquake simulator) on the existing 4.5 m radius large beam centrifuge facility with fixed swing basket, 250 g-ton centrifuge at National Geotechnical Centrifuge Facility of Department of Civil Engineering

National Geotechnical Centrifuge Facility (NGCF) of Department of Civil Engineering, IIT Bombay has a 4.5 m radius large beam centrifuge facility commissioned in 2002 and is mainly used for modeling the response of materials and structures such as soil, dams and foundations to natural and manmade hazards such as earthquakes, floods and explosions. Centrifuge modeling technique is a physical modelling technique in which a small-scale model instrumented with various transducers (like Potentiometers/LVDTs/Load Cells/Pore Pressure Transducers/Accelerometers/Pressure sensors, etc.) is subjected to high gravities by rotating about a vertical axis in horizontal plane. Simulation of earthquake geotechnical problems in centrifuge has grown significantly in the past two decades and a variety of challenging problems are now tackled in various centrifuge establishments all over the world. Considerable experience has been gained in simulating successfully earthquake effects in the centrifuge facilities worldwide.

Accordingly, it is felt that there is a need of upgrading the existing centrifuge in IIT Bombay to enable us to carry out earthquake studies. This is in addition to modelling of geotechnical and geoenvironmental problems being executed at NGCF. Hence, NGCF requires the quotation for a shake table with a servo hydraulic actuator (**STASHA**) for the centrifuge to generate and control sinusoidal and seismic signal accurately for modelling earthquake at high gravities. The shake table with actuator should comply with or comply better than all the specifications mentioned in **Annexure-1.** Detailed technical background information for STASHA and other accessories is also given in Annexure-1, **Annexure -2 and Annexure-3**.

It is advised to visit to the NGCF Facility, Department of Civil Engineering, IIT Bombay, Mumbai – 400076, Maharashtra, INDIA to understand about the logistics and operational parameters of the **STASHA**, along with the physical inspection of large beam centrifuge facilities. In addition to the procurement of STASHA, it is also required to replace existing old slip ring stack with electrical-hydraulic slipring system for performing high-gravity experiments in a 4.5 m radius large beam centrifuge facility available at Indian Institute of Technology Bombay.

The Technical Bid should contain detailed technical specifications of the products being offered and should not mention any prices.

Terms and Conditions:

1. Maximum education institutional discount should be offered.
2. Quotation should carry proper certifications like agency certificate, proprietary certificate, manufacturing certificate, Bidder Authorization Certificate, etc.
3. Prospective bidders must have established in supplying, installing, and commissioning inflight earthquake actuators (1D/2D) at least in three large beam/balanced geotechnical centrifuge facilities having radius more than or equal to 3 m in the past Twenty years.

Annexure-1
INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
NATIONAL GEOTECHNICAL CENTRIFUGE FACILITY (SUDERSHAN)

Technical Specifications for Shake Table with Servo Hydraulic Actuator (STASHA)

S No.	Particulars	Technical Requirement	Cost (INR)
1	**Background for Shake Table with Servo Hydraulic Actuator (STASHA) along with existing centrifuge equipment details**	→To more closely model actual earthquake motions, IIT Bombay is planning to undertake the design, development, fabrication, and installation of a new 1D shaker (Uniaxial earthquake simulator) on the 4.5 m radius large beam centrifuge facility with fixed swing basket, 250 g-ton (Maximum payload of 2.5 t at 100 g) centrifuge at National Geotechnical Centrifuge Facility of Department of Civil Engineering. **Figure 1** shows cross-section of centrifuge equipment. **Figure 2a** shows the typical photograph of IIT Bombay centrifuge equipment along with junction box(s) placed on either side of the swing basket relating to data acquisition system. **Figure 2b** gives close view of the swing basket of the centrifuge equipment. **Figure 2c** gives another perspective view of a 4.5 m radius large beam centrifuge facility at IIT Bombay. **Table 1** gives details of the existing centrifuge equipment. This shaker will be used to apply base shaking to centrifuge models in one prototype direction by using the proposed 1D shaker. The new 1D shaker should be capable of producing a wide range of input motions, including suitably scaled reproductions of actual recorded earthquake ground motions. →While several approaches have been used in the past for creating simulated earthquake motions on centrifuges, previous experience indicates that servo-hydraulic actuation is the most versatile method for creating the varied input base motions required in the study of geotechnical problems. Therefore, the new IITB 1D shaker will be servo hydraulic. →The bidder is clearly informed that existing swing basket of a large beam centrifuge facility is fixed and cannot be removed, and major components of centrifuge equipment cannot be changed (like arm, basket, etc.). The new 1D shake table system shall have to be mounted on to the basket, whenever	

		dynamic centrifuge model tests are planned such that the mounting of shake table system is requiring a simple procedure requiring only a few hours (within two hours). As it is being used now, whenever dynamic centrifuge tests are not being planned and the centrifuge facility shall be used for performing static centrifuge tests. In the case of any earthquake actuating accessories, like accumulators and other systems, they shall be placed on the arm of the centrifuge, and they should be fixed such that they can withstand gravity levels of the order of 100. →An important point relative to this project is that during the original design of the centrifuge, particular attention was paid to size mechanical parts in order to accommodate an in-flight earthquake simulator. However, the bidder should evaluate any possible risk associated with the proposed design and implementation of the 1D shaker STASHA on IIT Bombay's existing beam centrifuge facility and its compatibility to operate in such new environment with STASHA. →The bidder should review the IIT Bombay's large beam centrifuge design (if required the necessary centrifuge mechanical drawings will be provided by IIT Bombay and the agency may contact Prof. B.V.S. Viswanadham, Department of Civil Engineering, IIT Bombay (indenter) as part of the bidder's design of the 1D shaker. If the bidder concludes that some elements of the IIT Bombay large beam centrifuge must be modified/strengthened (This has to be supported by technical design and this will be reviewed by IIT Bombay) or replaced to insure a safe and successful operation of the 1D shaker, such modifications should be clearly listed (like any structural changes of the centrifuge equipment, placement of accumulators, electrical and hydraulic slip ring stack units, suitable hydraulic power pack with chiller unit, etc) and included as part of the proposed design, and the associated costs of these modifications should be included as part of the project total cost. Based on previous experiences, the shaking axis is perpendicular to the plane of rotation of large beam centrifuge facility. →In order to verify a safe operation of the new 1D shaker and the existing centrifuge, the bidder must provide a detailed monitoring plan for the centrifuge	

		machine to evaluate its dynamic response and the development of additional stresses after the implementation of the 1D shaker system. →The onsite acceptance tests should proceed in increasing stages so as to insure the safety of both the centrifuge and the 1D shaker and its accessories. The successful bidder will be responsible for the safety aspects of the existing IIT Bombay centrifuge machine associated with the operation of the new in-flight 1D shaker; this responsibility will be limited to operation conditions consistent with those of the acceptance tests. →STASHA system will have to operate during centrifuge rotation from 46 RPM (10 gravities) to 145 RPM (100 gravities) of 4.5 m radius beam centrifuge equipment available at NGCF. The Power Supplies for the System shall have to be mounted on the rotating arm in line with slip ring stack unit on the first-floor level of the NGCF. STASHA system includes suitable hydraulic power pack (along with Chiller unit) for activating accumulators placed on the arm of the centrifuge towards the swing basket side, electric and hydraulic sliprings, one number of rectangular laminar container, software interface (for firing earthquakes) and suitable rugged Personal Computer(s) and the necessary spares. The Layout of the STASHA along with all connectors will require Approval from IIT Bombay before Fabrication and installation. →The required enclosures, wiring and cabling from slip ring to the control room, along with installation and integration of slipring stack to suit the STASHA shall have to be included in the scope of the supply of STASHA and they shall be industry rugged to withstand high gravity environment during centrifuge tests. The Centrifuge System at IIT Bombay comprises of Swing Basket, Arm, and Central Axis. The Slip Rings are in line with central axis and are located at the first-floor level. Vertical distance between the surface of the arm to the bottom of the centrifuge chamber slab is 1.06 m. From the centre of the shaft to about 2.4 m length, there is a moving imbalance plate assembly. So, any placement of accumulators housing on the arm of centrifuge must be above 450 mm vertically (See Figures 1-2). The distance from the slip ring stack located on the first floor to the instrumentation room on the ground floor is about 60 m.	

		→Uninterrupted Power (220VAC or 24V DC) can be accessed on the Central Axis for the STASHA as per specifications listed in Item No. 7.	
2	**Shake Table with Structural frame and Servo-Hydraulic Actuator (STASHA) Shaker assembly**	→**Table 2** gives targeted performance specifications for the requested 1D shake table STASHA. →The shaker assembly should be fully integrated into a single unit. The base plate of the structural frame of the shake table assembly should be rigidly fixed to the centrifuge swing basket with bolts (plan dimensions of swing basket and existing holes layout will be provided by IIT Bombay) such that no relative movement takes place between the two components (i.e. shake table structural frame and centrifuge swing basket)**.** Installation of the shaker assembly onto the swing basket and removal of the same should be possible within 2 hours using an overhead crane or a suitable system custom built for STASHA. →The shake slip table plan dimensions (Approx. 800 mm x 700 mm) must be large enough to accommodate at least **Two** different types of laminar containers (one rectangular and other one octagonal type) and be optimized for maximum structural stiffness with minimal weight. The shaker table should have female threads of adequate numbers to accommodate bolts used for fixing model containers on the shaker slip table (i.e., must provide threaded stainless-steel inserts for attachment of model containers). The bolts used for fixing should be provided by the vendor including two spare sets. →There should not be any relative displacement between shake table top surface and the base plate of model container with a maximum pay load of 400 kg (including container, soil and other components) at 100 g. →Must provide sufficient constraint to prevent off-axis accelerations over the specified operating frequency range (0-250Hz). →Maximum allowable acceleration in the off-axis direction (direction other than the direction of shaking) should be less than 2% of acceleration of earthquake simulation.	

		→The shake table with high performance servo-hydraulic actuator system (with two actuators on either side or one actuator as per **Table 2**) to be mounted on the existing centrifuge swing basket having plan dimensions of 1000 mm x 1200 mm with a clear height of 660 mm or with plan dimensions of 760 mm x 1200 mm with a clear height of 1200 mm. →The maximum force exerted by STASHA system on the swing basket should be less than 100 kN. (As mentioned in Table 2, the parameters were listed based on the information available with IIT Bombay. However, the bidder is requested to carry-out design and arrive at suitable parameters for the STASHA).	
3	**Ultra-high frequency servo actuators**	→The servo actuator(s) should have at least the following specifications or better while performing under centrifugal acceleration of 1g to 100g: i) Peak shaking force = 90 kN ii) Peak shaking velocity = ±1.25 m/s. iii) Peak displacement = ± 10 mm iv) Range of operating frequency = 0-250 Hz **Note:** Shaker performance will be limited by either maximum shaking force, peak velocity or peak displacement depending on the shake frequency. →Should be high-force, high frequency units designed specifically for use on centrifuge shakers. →Must be proven to operate reliably at up to 100g centrifugal acceleration. →Must be capable of providing high-fidelity reproduction of single-axis target model accelerations over the specified operating frequency range (0-250Hz). →The servo-hydraulic actuator shall have to be rugged enough for use on centrifuge shakers and shall have good frequency response in the range of	

		0 - 250 Hz while operating in the high-gravity environment of a geotechnical centrifuge. It shall have an ability to simulate any given acceleration-time history subjected to stated performance limits. →The full system comprises of actuator, shake table, hydraulic power pack, accumulators to be mounted on the arm of the centrifuge, High-end PC based control system, application software, suitable hardware and consumables to be provided by a single agency. Details of the same along with technical specifications and shake table performance curves with and without load to be provided for IIT Bombay's review. (The parameters listed above are based on the information available with IIT Bombay. However, the bidder is requested to carry-out design and arrive at suitable parameters for Ultra-high frequency servo actuators).	
4	**Hydraulic Supply system (Power Pack with Chiller unit) and Accumulators)** Note: This item has two sub-items; As these are relevant to hydraulic system, they are placed combinedly.	→This item consists of hydraulic Supply system, Hydraulic power pack along with Chiller unit for cooling oil during shaking and accumulators. →Due to the required large piston area of the actuator(s) coupled with the high specified peak velocity of shaking, very large flow rates of hydraulic oil will be required. Because of the limited flow capacity of the external hydraulic power unit (HPU) and the hydraulic rotary union, the hydraulic supply system will be augmented with an on-arm hydraulic supply system providing high-pressure accumulators to permit on-arm storage of supply and return oil for shaking. **Requirements of hydraulic supply system:** i) Must permit automatic sequencing of the hydraulic control system to pressurize the shaker without 'thumping' the sensitive centrifuge model, then apply the shaking signals, and to de-pressurize the shaker in a smooth and controlled fashion. ii) Must provide sufficient oil capacity to permit shaking at the peak specified velocity for a duration not less than 1 second (or as per the design for better performance). iii) Should provide suitable solenoid-operated valves and manually adjustable	

		pressure and flow regulators to implement the following functions while the centrifuge is rotating: iv)Activation of bypass hydraulic circuit with adjustable needle valve to provide low-flow circulation of oil through shaker for warm-up of servo-actuators prior to shaking v)Activation of high-flow hydraulic circuit to provide oil for shaking at minimal pressure drop. Soft-shift valves should be utilized as required to minimize disturbance to the model caused by switching transients. vi) Should be located as close to the centrifuge axis or rotation as practical. vii) A means for providing sufficient counter-balancing mass to offset the fixed mass of the on-arm hydraulic supply system should be provided if required. →Towards the swing basket side required number of accumulators have to be fixed on to the arm of centrifuge. These accumulators shall be connected one side to hydraulic power pack placed on the first-floor slab via new suitable hydraulic slip rings. Other side of accumulators shall be provided with appropriate and industry grade hoses for enabling to connect to shake table mounted on the swing basket with appropriate leak proof connectors. As placement of accumulators and housing arrangement causes imbalance on the arm of centrifuge and it is required to be counter balanced with the help of fixed strap weights. →All hydraulic connectors which will be subjected to centrifugal acceleration or high pressure must be industry-standard hydraulic quick disconnect fittings. →The position of the on-arm hydraulic supply system (i.e. accumulators) should be located on the centrifuge arms towards the swing basket side, as close to the centrifuge axis as possible. Connection of hoses with suitable manifold on arm to be designed appropriately and verified. →The hydraulic oil temperature to be maintained with the help of a suitable	

		chiller unit attached to hydraulic power pack. Procurement and installation of the same will remain under scope of the bidder. The chiller unit must be effective in the Mumbai climatic environment having temperature varying between 25°C and 45°C with relative humidity in the range 60% to 90%. →Appropriate number of accumulators to be used to store the energy and used when required for smoothening the sharp pulsation during switching of pump. Procurement and installation of the same will remain under scope of bidder. →The method used to fix the on-arm hydraulic supply system is well designed and verified without any oil leakages. →The total weight of the on-arm hydraulic supply system (accumulator cylinders should be less than 350 kg. <u>Hydraulic power pack with Chiller unit</u> →The energy required to shake the centrifuge model is stored in hydraulic fluid which is compressed to a high pressure in the power pack. For this appropriately selected hydraulic power pack chiller unit is required. This power pack along with the chiller unit will be located on the first floor and above the centrifuge chamber slab in a room having carpet area of 2.5 m x 3.5 m with a ceiling height of 3.2 m. Two functions of the hydraulic power pack are stated as follows: a)While the centrifuge is rotating, the servo-valve and actuator need a certain amount of flow of hydraulic oil at relatively low pressure and low flow rate to keep the hydrostatic bearings afloat. If this flow stops the servo valve and actuator can be damaged. b)When the earthquake is fired, a large amount of hydraulic oil needs to flow through the servo-valve at high pressure and high flow rate to provide the shake.	

		→A hydraulic system able to deliver both the low pressure (150 bar)-low flow and the high pressure (280 bar)-high flow conditions is required to be considered. Flow from hydraulic power pack to accumulators is estimated as 5 litres/minute and the accumulators to actuators the adequate flow rate need to be estimated by the supplying agency. →During the earthquake loading, as the hydraulic power pack cannot supply oil through the centrifuge slip rings at a high enough flow rate to power the actuator directly. The hydraulic oil is therefore compressed slowly into accumulators placed on the arm or at an appropriate location. During the earthquake shaking this high-pressure oil flows from the accumulators into the servo-valve and then is collected in an accumulator that is maintained with a preferred minimum pressure of 10 bar for return accumulators for a 275 bar supply such that cavitation is not caused. →The hydraulic oil must also be maintained within a tight temperature range between 20°C and 35°C to keep the hydraulic oil's viscosity at a suitable level for the actuator. To do this, a chiller unit is required (suiting Mumbai, India climatic conditions). The control of these temperatures and pressures in a safe manner became a concern and hence a human-machine interfaced control system need to be provided. Specifications of Hydraulic power pack unit/Chiller unit/Human-machine control unit: i)Plan dimensions of hydraulic power pack be approx. 1000 mm x 750 mm and height of 1800 mm. ii)Chiller unit can be placed at a suitable location and level on an appropriate frame along with a collection tank iii)System working pressure of hydraulic power pack: 280 bar iv) Directional control valve, pressure relief valve and check valve with other necessary hydraulic hose (suitable sizes need to be adopted as per the design for	

		better performance). v) Suitable heat exchanger for cooling of power pack vi) Electric motor three phase 440 Volt (Preferably) 50 Hz vii) Electric panel for motor control and cylinder movement. ON/OFF and Emergency push button and Suitable cable length of not less than 60 m. viii) Tank capacity: 100 litres ix) Power pack flow: 10 litres/minute x)Spares required: Directional control valve; Pressure relief valves; Check valve used in power pack, each in 3 no's. xi)Digital indicator of pressure gauge in pressure line (Wherever required) xii) One barrel (about 200 litres) of suitable oil and this oil having suitable grade can be outsourced locally **Chiller unit suiting the above requirement is required to be specified by the bidder.** **Human-machine interface controller unit** for operating hydraulic power pack, maintaining pressures, supplying oil to accumulators and operation of chiller unit to maintain specified temperature range need to be specified by the bidder. Note: 1. Technical datasheet / product catalogue with complete drawings including mounting details shall be sent along with the offer for the component of power pack. 2. The bidder may visit the centrifuge facility before quoting for getting acquaintance about the application.	

		(The parameters listed above are based on the information available with IIT Bombay. However, the bidder is requested to carry-out design and arrive at suitable parameters for On-arm hydraulic Supply system (Power Pack with Chiller unit) and on arm Accumulators).	
5	**Shaker electric control Unit, Software, CPU units, Display monitors**	**Shaker Electrical Controls and Software** →Provides the operator interface and support functionality needed to efficiently operate the shaker system and provides the low-level closed-loop control required for stable and accurate high-bandwidth control of the shaker. **Requirements for Shaker Electrical Controls and Software** a) Must provide basic closed-loop displacement control of the shaker table, and closed loop displacement control of slave valves (if two-stage valves are utilized for the servo-actuators) b) Must provide logic and control signals needed to implement automatic sequencing of the on-arm hydraulic control system as described above. c) Must provide feedback transducers for monitoring of the pressures within the hydraulic supply. d) Must provide required power amplification and feedback transducers for implementing the actuator servo control loop(s). e) Must provide adjustable dither signal to reduce stiction on the servo-actuator(s). f) Must provide a dedicated data acquisition and shaker control computer and software interface to permit full and simple control of the shaker. g) In case multiple (redundant) actuators are used in parallel, suitable cancellation of off-axis and/or rotational force components must be provided.	

		→In order to produce a wide range of input motions using the 1D shaker, including suitably scaled reproductions of actual recorded earthquake ground motions, maintaining the proper phase between all actuators (two actuators/one actuator) of the shaking table is very important. Any out of phase movement will produce a distorted shaking signal and would reduce the available force. →A 1D shaker control system capable of maintaining in phase operation for all actuators and throughout the frequency range is critical for a successful shaker. →It is very important that the 1D Shaker Control System be capable of communicating with the other elements of the IIT Bombay Centrifuge Data Acquisition Network (WCDAS). →This includes shaker electric control system, application software with possibility of upgrades, high end rugged Personal Computer with monitor and CPU unit. →All electric connectors which will be subjected to centrifugal acceleration must be Mil-spec connectors with proper grounding to get noise free data. →Suitable application software for data acquisition must also contain multiple graphs displayed in real-time data with time and FFT domain, allowing the user to segregate and view data information in an orderly fashion. The software should be capable of converting acceleration waveform to velocity and displacement through single and double integration respectively. →The connectivity through slip rings or wireless system shall be properly designed for uninterrupted shaking, control and acquisition activity. →The software will also possess a user Login and modification functions. →The information will be automatically stored on the system to ensure, that repetitive data input is not required in successive runs. →The user can also be able to select the type/scale of the chart/graph he/she	

		would like to see the sensor readings on. The user can select the Y-Scale number, X-Scale number and the Scale of the minimum range required as per where they have set their sensors to be displayed. →In addition to the above functions, the software will also possess details of storage, system watch dogs to ensure the proper functioning of all Hardware, etc. →The Software must be based on LabVIEW Application Development Environment which should be compatible to suitable NI hardware and should be compatible with existing recently procured NI based data acquisition system. →Bidder must get the Software Requirement Specifications (SRS) approved by IIT Bombay before Providing the Software Solution. →The data will be connected and displayed on a set of two PC systems. There should be possibility of data transfer from one PC to other PC at the same instant for the display of generated data and response data duly processed without the loss of any data. All systems will be i7 or higher and with a minimum of 500 TB HDD. The systems should be running licensed version of the Windows Operating System. Considering the possibility of upgrade in Windows operating system, suitable compatibility shall have to be considered for the SRS. →One computer system with a screen, upwards of 27 inches, with Processing Unit will be used to control, display and store the input data to the STASHA. The suitable computing system required for the purpose will be provided in the scope of the project. →Another display, also upwards of 27 inches, with the Processing Unit, will be used to display process, and store the output signal data from the feedback transducers of STASHA system. →The units will be placed in a control panel in the Instrumentation room at the Facility.	

		→Third screen with a display switch will be provided to broadcast the view from either of the two Computer Systems. This screen will be wall mounted and will be of a size upwards of 42 inches. **(The parameters listed above are based on the information available with IIT Bombay. However, the bidder is requested to carry-out design and arrive at suitable parameters for Shaker electric control Unit, Software, CPU units, Display monitors).**	
6	**Feedback transducers and signal conditioning**	Transducers and signal conditioning for measurement of displacement, acceleration and hydraulic pressure as required for monitoring and control of the shaker. →The bidder shall include suitable number of transducers and signal conditioner required for monitoring the feedback and acquisition during triggering earthquake; The response measurement of transducers embedded in the soil shall be compatible with data acquisition system details mentioned in Annexure-3. (Based on the requirement, the bidder is requested to suggest and consider including appropriate and suitable number of feedback transducers and signal conditioner)	
7	**Rotary union along with Electric slip rings - Supply, installation, and integration of hydraulic and electrical slipring Stack for the existing centrifuge facility**	→**Annexure -2** gives existing details of electrical and hydraulic slip rings. →The existing electrical and hydraulic slip rings are about 20 years old and needs replacement for be able to accommodate hydraulic requirements of STASHA and other requirements of non-earthquake type experiments. Existing details of Electric and hydraulic slip rings are given in Table 4. The proposed requirements of electric and hydraulic slip rings are as follows: • Port(s) passing Hydraulic oil (250 bar) One (1) No. • Ports for passing Air Three (3 No.), Oil Two (2 No.), Water (3 No.). Maximum pressure of 20 bar	

		• Ports for Power voltage (Five No.) Phase R+G+B+N+Earth (600V AC; 20 A; 60 Hz) • Ports for Power voltage (Six No.) Phase + Neutral+Earth (Two sets) (600 V AC; 20 A; 60 Hz) • Ports (16 No's) for various signals (24 V DC, 5A) • Ports (6 No's) for Power for camera (+) & (-) (3 Sets) (24V DC, 10A) • Ports for general purpose (32 No's) for Signal or Power (220V AC/DC, 20A, 60Hz for AC) • Ports for Camera Signal with Shield Signal (14 No's) - PAL /NTSC 1280 x 960, 60 frames/s NTSC & 50 frames/s PAL 1.OPV-P 75 V (BNC) (existing cam has BNC Co-axial connector) (24V DC, 5A, Signal to Noise Ratio ≥48 db) • Ports for Ethernet (2 Sets) (1000mbps, CAT6 or better quality) • Optical slip ring (1 no of set) Note: Connection type: Stator (Housing): Flying leads: 60 meters long Connection Type: Rotor (shaft) connection: Flying leads: 6 meters long The above shall be procured from GAT Germany or equivalent. →In order to provide hydraulic oil for the shaker having adequate pressure, flow, filtration, and temperature control, a new hydraulic rotary union is required to be consider by the bidder (along with Electric slip rings) completely separate the hydraulic oil supply for the shaker from other hydraulic equipment that may be mounted on the centrifuge. (Based on the requirement, the bidder is requested to suggest and consider including the above Rotary union along with Electric slip rings -Supply, installation, and integration of hydraulic and electrical slipring Stack for the existing centrifuge facility)	
8	**Waveform replication controller and software**	→ An iterative time-domain waveform replication system is to be provided for defining the input signal required for closely approximating a target acceleration waveform with the shaker. Iterative adjustment of the input signals	

		applied to the shaker is performed, resulting in an optimized input waveform providing excellent agreement between the 'target' model acceleration and the acceleration applied to the shaker payload. Requirements for waveform Replication System i)A dedicated shaker control server computer with software to provide a convenient graphical user interface for implementing waveform replication functionality. ii)Provide a two-channel analyzer function to measure the dynamic (frequency-domain) transfer characteristic (FRF) of the shaker and model and permit FRFs to be saved in a library for subsequent use. →The wave form replication controller should be capable of replicating different input signals (ramp, sine, haversine, square, triangle, random, earthquake time history development and generation through iteration method in acceleration, velocity, and displacement mode, etc. required for closely replicating target waveform to the shaker. The minimum sampling rate of the signal should be 5000 samples per second. →Performance curve of actuator, servo valve with power pack and controller at various frequencies (say 20 Hz - 250 Hz) and at various "g" level should be established with bare slip table and 80% loaded slip table for reference. This can be used as calibration of system for periodic check of performance of shaking system. (Based on the requirement, the bidder is requested to suggest and consider including the appropriate Waveform replication controller and software)	
9	**Design, fabrication, and supply of one number of laminar container**	→Internal dimensions of rectangular laminar container shall be close to 640 mm in length, 400 mm in breadth and 410 mm in depth (subjected to change depending upon STASHA height and hinges of swing basket); Shall simulate flexible shear beam boundary conditions; Capable of withstanding 100 g and made up of high strength Aluminum or its alloy or equivalent.	

		→Each laminate is separated from the upper and lower adjacent laminae by roller bearings or a better alternative to permit relative movement in the long direction with minimal friction →Both along length and breadth of the laminar container, there shall be adequately designed stopper supports shall be provided. →For doing tests with model pore fluid or with water, a rectangular shape rubber membrane bags (Three no's) or a better alternative of adequate dimensions shall be provided for placement on the inner side to prevent particles to enter gaps between the laminae or to retain water or pore fluid during shaking at high gravities. →A relative displacement equivalent of 20% overall shear strain between adjacent laminae shall be possible. →The laminar container should have provision for loading on to STASHA using overhead crane available near the centrifuge chamber. →**Figure 3** gives the schematic details of proposed laminar container	
10	**Supply, Installation and Commissioning of equipment**	→The bidder should take full responsibility for supply, installation, and commissioning of STASHA at NGCF of Civil Engineering Department, IIT Bombay and performance of the system demonstrated to the satisfaction of the users. Necessary fittings and fixtures required for the installation and commissioning of STASHA will be in the scope of the bidder. This shall include travel to IIT Bombay and stay at IIT Bombay.	
11	**Maintenance and service support of system during the warranty period**	• The vendor should have competent and reliable service network in India for quick and necessary repair and maintenance of the equipment. • The vendor should provide the list of users of STASHA for high-gravity large beam geotechnical centrifuge testing facilities or similar equipment (viz. Universities/Institutes in USA, UK, EUROPE, CANADA, JAPAN, HONG KONG, SOUTH KOREA, IITs, NITs, Research and Development laboratories under Government of India, etc.) along with their contact details. • Bidder must provide Training on the System for 15 working days Post System	

		Prove out. • Provide Maintenance tool kit and schedule for routine maintenance. • Details of the nature of service support the vendor can provide should be given along with the proposal. • Warranty should be for at least three years (3 years) after System Acceptance by IIT Bombay with the followings tasks: a) Breakdown maintenance (as required) – 1 visit per year. b) Calibration visits for STASHA and sensors. – 1 visit per year (for initial period of three years after successful commissioning only) c) Any maintenance visit during warranty period of 3 years not performed in the current year to be carried forward in the next year which is to be performed in addition to the existing visits. • The successful bidder should submit plan for list of vendors, maintenance duration so that teething problems post installation and during the initial period of 3 years are met adequately. • List of necessary Spares to be provided along with the proposal. • After completion of warrantee of 3 years, the successful bidder shall have to specify requirements for selecting AMC agency locally and guide AMC agency to maintain STASHA initially.	
	GRAND TOTAL		
12	**Other terms and conditions**	**a)** The working model of a system similar to STASHA should be demonstrated at any one of other user's place so as to get the firsthand information on working and usages. **b)** Prospective bidders must have established in supplying, installing, and commissioning inflight earthquake actuators (1D/2D) at least in three large beam/balanced beam geotechnical centrifuge facilities elsewhere having radius more than 3 m (Three) in the last Twenty (20) years. It is also required to include performance certificates in original and references from any of two large beam centrifuge facilities, where the supplying, commissioning and testing of inflight earthquake actuators (1D/2D) was carried-out need to be enclosed in the technical bid.	

		c) It is to be noted that proper design aspects to be taken care so that the existing centrifuge system should not go into resonance when actuator **(STASHA)** is excited with any frequency within its working range. **d)** If there is a need for modifying or replacement the existing components (electrical peripheral, slip ring, rotary joints, etc.) of centrifuge to accommodate **STASHA,** procurement and installation of the same will remain under the scope of bidder. In that case integration of the existing systems with modified or replaced components will also remain under the scope of bidder. This will be reviewed by IIT Bombay. **e) STASHA** to be designed on the basis of specifications and availability of components satisfying centrifuge requirements. **f)** All signal and electrical cables selected shall have to be such that they minimize noise during transmission of signal and data being acquired. **g)** The bidder must provide an Authorization Certificate for the bought-out items supporting their bid and their support to the bidder for the deliverable items, with reference to the Tender enquiry Number. **h)** All items required for STASHA are to be COTS (Commercially off the Shelf) and no development will be allowed. Certificate of Conformance from the bidder should be provided along with the hardware being delivered. **i)** Since Software is an important component of the systems, the company should have certified developers on the application development environment used for the development of the application. Certificate from bidder is needed with this regard - mentioning the Tender Enquiry Number directed to the Tendering Authority/ Director. Bids, unaccompanied by the Authorization Certificate are liable to be rejected in the technical stage itself. **j)** All application softwares compatible with the provided actuator should remain in scope of vendor. It should be possible to install the single license at multiple computers but only one computer will run at a time. Any updates to	

		application software shall have to be updated from time to time up to 3 years. **k)** Since the systems are to be used and deployed in India, the bidder quoting must facilitate for smooth operation of the equipment. **l)** The bidder must be Certified by the competent agency to ensure Quality of the System provided and should have technical expertise in the area of centrifuge shaker components and accessories. **m)** Since all the items are interconnected and required to communicate to the Software and controller unit all the items need to be ordered on a single bidder only, and part order will not be placed. **n)** Two sets of operation and maintenance manuals (in original colour hard copy and soft copy) along with all necessary drawings should be supplied along with the STASHA system. **p)** The bidder should enclose all the relevant technical documents and catalogues for all the components included in the proposal. Bids without proper technical documents and catalogues will be rejected. **q)** The vendor should take full responsibility for supply, installation, demonstration, proof testing and commissioning of the entire system of **STASHA** on the large beam centrifuge at NGCF of Civil Engineering Department on a turnkey basis and to the satisfaction of the users. Necessary fittings and fixtures required for the installation of **STASHA** will be in the scope of the bidder. **r)** The vendor should impart training to the user viz. faculty, staff, research students and any other personnel nominated by NGCF, IIT Bombay, India **s)** The parties may visit NGCF of Civil Engineering Department to understand the test set-up (for estimating length of hoses, cables, additional fixtures for mounting of STASHA, etc.)	

		t) Necessary consumables like connecting cables, connectors, etc. will be in the bidder's scope. **u)** Suitable and higher end PCs with compatible operating system, etc. will be in the bidder's scope. The compatibility of operating system with hardware and updates of the software with respect to change in operating system or change of PC / hardware should be supported and installed for free of cost to IIT Bombay for a period of Three(3) years from the date of system acceptance. **v)** The bidder is requested to quote combined for all Items No's (1) to (11). For those bidders qualifying in technical bid evaluation will be requested for breakdown of financial costs Item wise by email after opening of commercial bid. **DO NOT ATTACH COMMERCIAL DETAIL'S SOFT COPY IN TECHNICAL BID** Item No. 1 is primarily to review the existing centrifuge system at IIT Bombay. However, the design fabrication drawings along with the specifications will have to be provided by the bidder. One the overall cost, the bidder is required to mention schedule of delivery and payment, like i) contract initiation, ii) acceptance of design drawings, iii) successful completion of factory acceptance tests on components of STASHA, iv) shipping of components of STASHA at Mumbai, and v) successful installation at IIT Bombay **w)** The bidder may bring out any clarifications required in the technical prebid meeting, which will be conducted online at IIT Bombay. The prebid meeting in person will be scheduled on **October 14, 2022 (Thursday) by 10.00 AM (Indian Standard Time)** at the Conference Room of Department of Civil Engineering, Indian Institute of Technology Bombay, Powai, Mumbai – 400076, Maharashtra, INDIA. **The link for the meeting is: https://meet.google.com/bfm-ovwr-kia** **x)** IIT Bombay may provide the following: • Electrical power required for the installation of STASHA. • Extend the existing limited workshop facility (without manpower), if required for mechanical works like cutting, welding, drilling, etc. during the installation and commissioning of structural testing system.	

		• All the field wiring, hydraulic and electrical modules and different parts of the shake table should be labelled and documented. • Retention accessories to be provided along with individual modules. • All the components to be supplied should be with equivalent or better specifications than mentioned above. • The bidder shall provide schedule of consignment part by part after approval of designs and shop drawings by IIT Bombay. • The unloading of the components of the consignment will be done by IIT Bombay • The Collection of component(s) of inflight earthquake actuator from the Mumbai and bring to the National Geotechnical Centrifuge Facility (NGCF), Department of Civil Engineering, IIT Bombay will be done by IIT Bombay. • However, opening of trunk boxes and ensuring their correctness will have to be done by the supplying agency.	

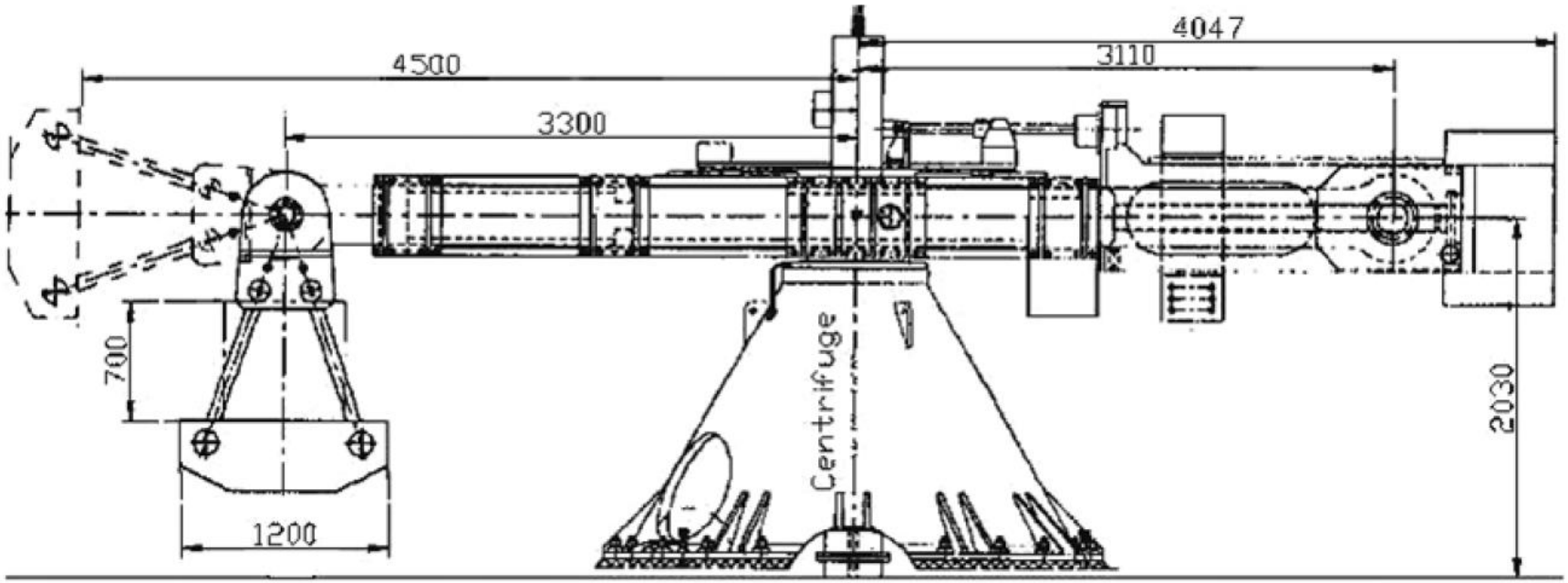

Figure 1 Cross-sectional view of the large beam centrifuge (NGCF) at Indian Institute of Technology, Bombay, India (All dimensions are in mm)

Figure 2a Perspective view of 4.5 m radius large beam centrifuge facility at IIT Bombay

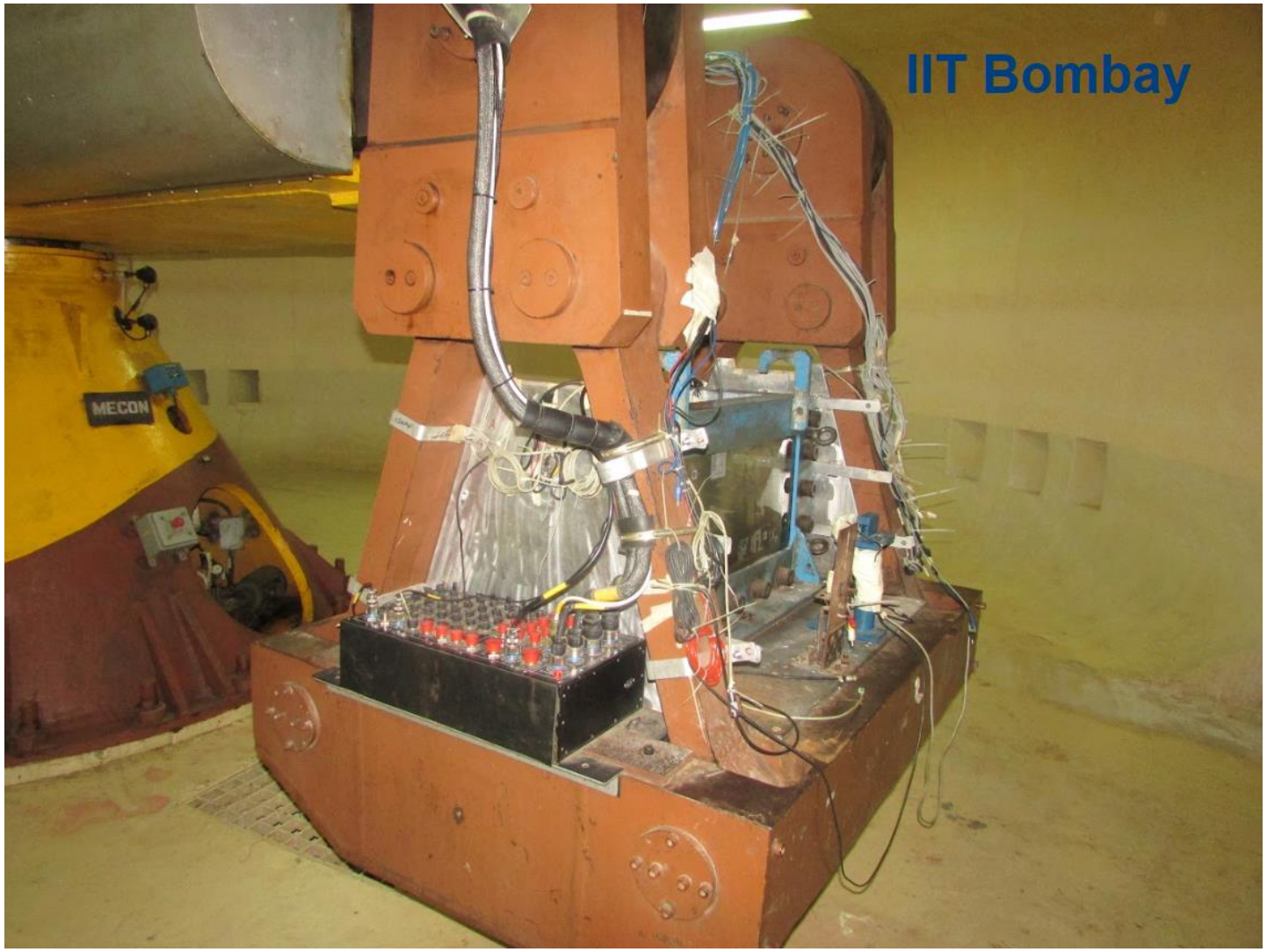

Figure 2b Close view of fixed swing basket of Centrifuge

Figure 2c View of the 4.5 m radius large beam centrifuge facility

Table 1 Technical details of a large beam centrifuge facility		
Sr. No.	**Parameters**	**Details**
1	Configuration type	Beam centrifuge with swing basket and adjustable counter weight
2	Radius	4.5 m [Measured upto top surface of the basket from center of the shaft.]
3	Radial acceleration range	10 g - 200 g
4	Rotational speed of centrifuge arm	46 - 205 RPM
5	Maximum pay load (includes mass of strong box, shake table, model and accessories; excludes mass of basket)	2.5 tons @ 100 g; 0.625 tons @ 200 g
6	Capacity	250 g-tons
7	Run-up time from 1 g to 200 g	6 minutes
8	Run-up time from 200 g to 1 g	6 minutes
9	Continuous run time	5 days
10	In-flight balancing range	0 to ± 100 kN at 200 g
11	Maximum unbalanced force	100 kN
12	Balancing accuracy	10 kN
13	In-flight balancing time	60 seconds
14	Swing basket dimensions	1.00 m x 1.2 m (upto 0.66 m height); 0.76 m x 1.2 m (upto 1.20 m height)
15	Drive system	Thyristor controlled 450 kW DC motor
16	**Existing Electrical slip rings**	• Video – 3 nos. • Power (220 V, 20 Amp) – 5 nos. • Power (24 V, 5 Amp) – 5 nos. Transducers (10 V, 2 Amp) – 100 nos.
17	**Existing Hydraulic rotary joints**	• Hydraulic oil rotary joints 0 to 200 bars – 2 nos. Air/Water rotary joints 0 to 200 bars, flow rate 10 LPM – 4 nos.
18	**Design life**	40 years or 24,000 start-stop cycles
19	**Environmental sensors**	• Unbalance sensor with display at console and alarm • Temperature and humidity sensors with display at console and alarm • Vibration sensor Infra-red smoke detector with alarm

Table 2 Performance specifications for the requested 1D SHAKER (STASHA)	
Method	Servo-hydraulic multi-actuator system
Shaking Type	Periodic or Random, determined by input signal
Total mass of shake table assembly	Less than 1000 kg
Total mass of moving/oscillating components (excluding pay load)	Less than or equal to 150 kg
Maximum pay load (including laminar container, soil model and other accessories)	Less than or equal to 400 kg
Proof test centrifugal acceleration	100g
Maximum operational centrifugal acceleration	80g
Typical operational centrifugal acceleration	50g
Maximum shaking acceleration at cycle start	20g
Minimum shaking acceleration at cycle end	15g or as per the design
Maximum Shaking Velocity	As per the design
Maximum usable shaking displacement	± 10 mm
Useful frequency range	20 Hz – 150 Hz
Number of actuators	1 double acting actuator
Maximum force requirement	90 kN
Maximum accumulator pressure	260 – 275 bar
Maximum Shaker Height Above Current Platform (i.e. from the surface of the swing basket)	Should be as close as possible to the top surface of the swing basket of centrifuge equipment
Minimum Payload Dimensions (L x W)	800 mm x 600 mm
Maximum shake table displacement	±10 mm
Nominal Shaking Frequency Range	0 – 250 Hz
Shaking duration	Max 5 secs (at greatly reduced acceleration and velocity)
Shaker	Double acting shaker with hydrostatic bearing supported piston, fatigue rated, low maintenance, high frequency response, etc. Should meet the relevant parameters as mentioned above. Suitability of single or double actuator shaking system design to match with the existing Centrifuge swing basket for the safety and resonance compliance and should be ensured by the bidder. The design has to ensure the structural safety of centrifuge (Torsion, Shear, etc.).

(Based on the available information, the above parameters were selected. The bidder can decide appropriate parameters based on the detailed design for better compatibility with existing centrifuge facility and STASHA).

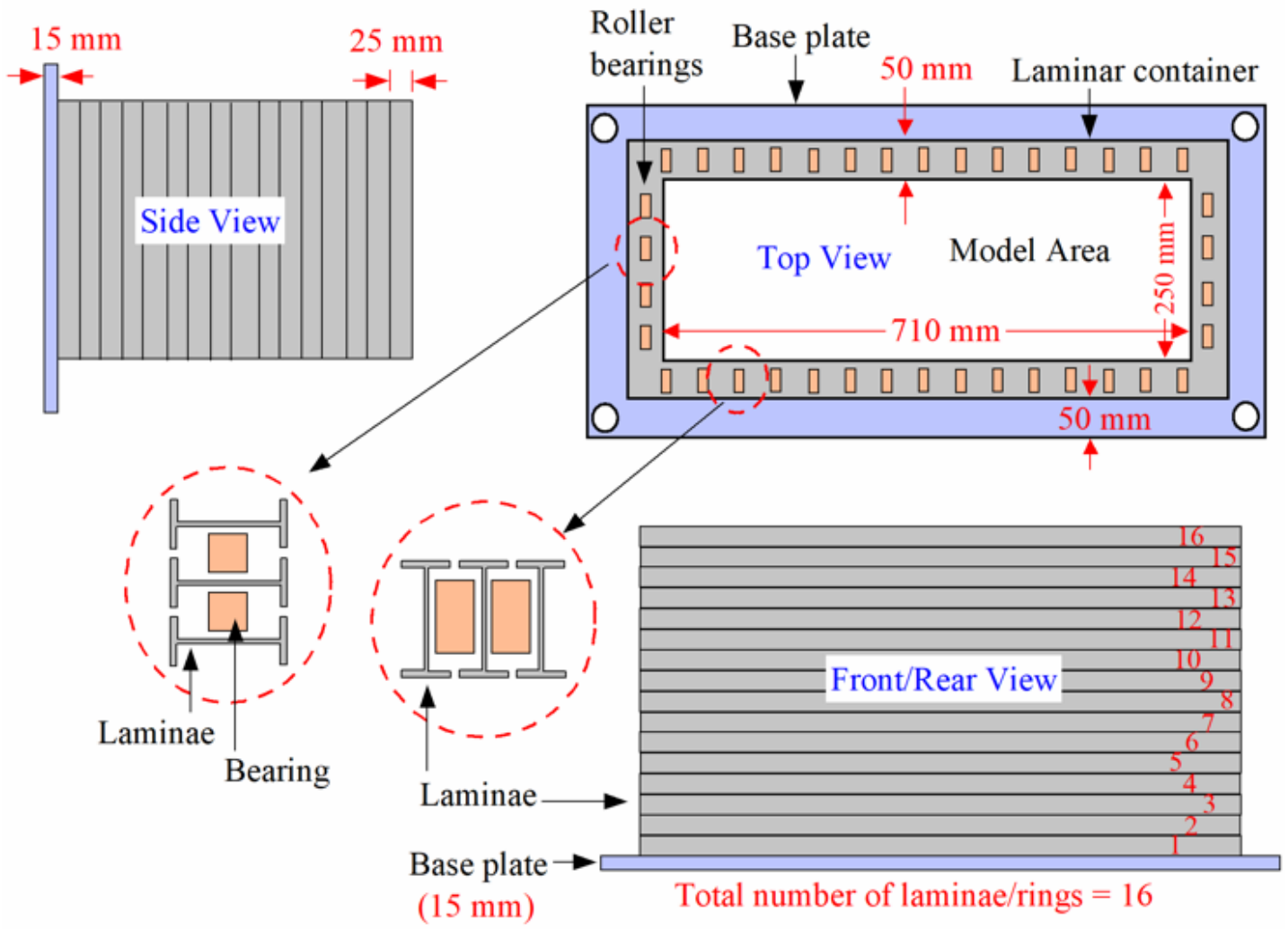

Figure 3 Schematic details of rectangular laminar container

Annexure – 2

Existing details of Electric and Hydraulic sliprings at Centrifuge lab

Existing Slipring Requirements						
Sr. No	**Channel/ Port**	**Application Description**	**Pressure Bar**	**Flow Rate L/min**	**Temp min**	**Temp max**
Rotary Union - Air, Oil, Water						
1	8	6 Ports for passing Air or Oil or Water, 2 ports for slipring cooling	20	20		
Connection type : Stator (Housing) : 1/4"						
Connection Type: Rotor (shaft) connection: 1/4"						
Electrical Slipring						
Power : For AC Motor						
Sr. No	**Channel/ Port**	**Application Description**	**Type AC/ DC**	**Voltage V**	**Current A**	**Hz**
2	4	Power voltage Phase R+G+B	AC	600	20	60
	1	PE Earth				
Power : For Other devices						
3	6	Power voltage: Phase + Neutral+ Earth (Two Sets)	AC	600	20	60
Signals						
4	16	Signal (Load Cell, Limit Switches, Proximity Switches)	DC	24	5	

Center Camera Power						
5	2	Power for camera (+) & (-) (1 Sets)	DC	24	10	
Spare slip rings						
6	64	Signal or Power	AC & DC	220	20	60 for AC
Camera Signal (including center cameras + Model veiwing cameras)						
	Channel/ Port	**Application Description**	**Type AC/ DC**	**Voltage V**	**Current A**	**S/N ratio**
7	1	Camera Signal with Shield Signal - PAL /NTSC 1280x960 , 60f/s NTSC & 50f/s PAL 1.OPV-P 75 V (BNC) (existing cam has BNC Co-axial connector)	DC	24	5	≥48 db
Ethernet - CAT 4 (Rotary)						
Sr. No	**Channel/ Port**	**Application Description**	**CAT**			
8	2	Ethernet	CAT4			

Annexure-3

Existing details of NI based Data Acquisition system (with and without Wireless)

18 [Eighteen No.] Channels for IEPE Accelerometer

- 102.4 kS/s per channel simultaneous AI; 41 kHz bandwidth; ±30 V input, 24-bit resolution, 99 dB dynamic range
- Software-selectable AC/DC coupling; AC coupled (0.1 Hz); Software-selectable IEPE signal conditioning (0 or 4 mA); IEPE open/short detection
- Smart TEDS sensor compatibility; Type of ADC: Delta-Sigma (with analog pre-filtering)
- Sampling mode: Simultaneous
- Type of TEDS supported: IEEE 1451.4 TEDS Class I; TEDS capacitive drive: 3000 pF
- Internal master time base (fM): Frequency is 13.1072 MHz and Accuracy is ±100 ppm
- Data rate range (fs) using internal master timebase Minimum: 0.985 kS/s; Maximum: 102.4 kS/s
- AC cutoff frequency (-3 dB: 0.1 Hz and -0.1 dB: 0.87 Hz max)
- DC voltage input range Minimum: ±30.87 V and Maximum: ±32.13 V
- AC voltage full-scale range Minimum: ±30.87 Vpk and Maximum: ±32.13 Vpk
- IEPE excitation current (software-selectable on/off) Minimum: 4 mA; excitation noise: 100 nArms; compliance voltage: 22 V min
- Power consumption from chassis Active mode: 1 W max; Sleep mode: 25 µW max
- Thermal dissipation (at 70 °C) Active mode: 1 W max; Sleep mode: 25 µW max
- Operating vibration Random (IEC 60068-2-64): 5 grms, 10 Hz to 500 Hz and Sinusoidal (IEC 60068-2-6): 5 g, 10 Hz to 500 Hz
- Operating shock (IEC 60068-2-27): 30 g, 11 ms half sine, 50 g, 3 ms half sine, 18 shocks at 6 orientations
- Operating temperature (IEC 60068-2-1, IEC 60068-2-2): -40 °C to 70 °C
- Operating humidity (IEC 60068-2-56): 10% to 90% RH, non-condensing

20 [Twenty No.] Channels for Pressure Sensors

- 50 kS/s per channel sample rate; ±500 mV measurement range
- ADC resolution: 24 bits; Built-in anti-alias filters; 250 V rms channel-to-channel, CAT II isolation
- Screw-terminal connectivity; Type of ADC: Delta-Sigma(with analog pre filtering)
- Sampling mode: Simultaneous
- Internal master time base (fM): Frequency 12.8 MHz; Accuracy: ±100 ppm max
- Data rate range (fs) using internal master time base Minimum: 1.613 kS/s and Maximum: 50 kS/s
- Data rate range (fs) using external master time base Minimum: 390.625 S/s and Maximum: 51.36 kS/s
- Input voltage range Nominal: ±0.5 V; Minimum: ±0.496 V

- Input coupling DC; Input impedance >1 GΩ; Input noise 3.9 μV rms
- Power consumption from chassis Active mode: 730 mW max; Sleep mode: 50 μW max
- Thermal dissipation Active mode: 1.48 W max; Sleep mode: 0.5 W max
- Operating vibration Random (IEC 60068-2-64, 5 grms, 10 Hz to 500 Hz); Sinusoidal (IEC 60068-2-6, 5 g, 10 Hz to 500 Hz)
- Operating shock (IEC 60068-2-27): 30 g, 11 ms half sine, 50 g, 3 ms half sine, 18 shocks at 6 orientations
- Operating temperature (IEC 60068-2-1, IEC 60068-2-2): -40 °C to 70 °C
- Storage temperature (IEC 60068-2-1, IEC 60068-2-2): -40 °C to 85 °C
- Operating humidity (IEC 60068-2-78): 10% RH to 90% RH, non-condensing

8 [Eight No.] Channels for Laser LVDT, LVDT, Linear Potentiometer

- 100 kS/s per channel sample rate, ±10 V measurement range, 16-bit resolution
- Input voltage ranges Measurement Voltage: Minimum is ±10.4 V and Maximum is ±10.6 V
- Conversion time: 10 μs min; Sample rate: 100 kS/s max
- Stability: Gain drift (5 ppm/°C) and Offset drift (29 μV/°C)
- CMRR (fin = 60 Hz): 70 dB; -3 dB bandwidth: >100 kHz
- Input Impedance: >1 GΩ; Input Noise: 0.85 LSB rms
- Power consumption from chassis (full-scale input, 100 kS/s): Active Mode (1 W max) and Sleep mode (4 mW max
- Thermal dissipation (at 70 °C): Active Mode (1.250 W max) and Sleep Mode (510 mW max)
- Operating vibration: Random (IEC 60068-2-64) - 5g rms, 10 Hz to 500 Hz; Sinusoidal (IEC 60068-2-6) - 5 g, 10 Hz to 500 Hz
- Operating Shock (IEC 60068-2-27) - 30 g, 11 ms half sine, 50 g, 3 ms half sine, 18 shocks at 6 orientations
- Operating temperature (IEC 60068-2-1, IEC 60068-2-2) -40 °C to 70 °C

8 [Eight No.] Solid State Relays for Solenoid Valve Control

- Relay type Normally open solid-state relay (SSR)
- 60 VDC, 30 Vrms switching voltage; Switching current of 1.2 A/channel for up to 4 channels;
- 750 mA/channel for all channels; 250 Vrms CAT II continuous channel-to-earth ground, and 60 VDC channel-to-channel isolation
- Switching rate (90% duty cycle)1 1 operation per second
- Relay open time 0.5 ms typ; Relay close time 9.0 ms typ
- On resistance 200 mΩ max

8 [Eight No.] analog output channels

- 25 kS/s per channel simultaneous analog output; ±10 V output range, 16-bit resolution
- Output range: Nominal is ±10 V, Minimum is ±10.35 V, Typical is ±10.5 V, and Maximum is ±10.65 V
- Output impedance: 2.0 Ω; Slew rate: 4 V/µs; Monotonicity: 16 bits
- Thermal dissipation (at 70 °C) and Power consumption from chassis : Active mode (1 W max), Sleep mode (25 µW max)
- Operating vibration: Random (IEC 60068-2-64, 5 g rms, 10 to 500 Hz), Sinusoidal (IEC 60068-2-6, 5 g, 10 to 500 Hz)
- Operating shock (IEC 60068-2-27): 30 g, 11 ms half sine,50 g, 3 ms half sine, 18 shocks at 6 orientations
- Operating temperature (IEC 60068-2-1, IEC 60068-2-2): –40 to 70 °C

Controller

- Processor: CPU Intel Atom E3940, 4 cores, 1.6 GHz (base), 1.8 GHz (burst), On-die L2 cache 2 MB
- Network/Ethernet Port: Number of ports 2; Network interface 10Base-T, 100Base-TX, and 1000Base-T Ethernet; Compatibility IEEE 802.3; Communication rates 10 Mb/s, 100 Mb/s, 1000 Mb/s auto-negotiated
- Network Timing and Synchronization: Protocol IEEE 802.1AS-2011; IEEE 1588-2008 (default end-to-end profile); Supported ether-net ports Port 0, port 1; Network synchronization accuracy <1 µs
- RS-232 Serial Port: Maximum baud rate 115,200 b/s; Data bits 5, 6, 7, 8; Stop bits 1, 2; Parity Odd, even, mark, space; Flow control RTS/CTS, XON/XOFF, DTR/DSR; RI wake maximum low level 0.8 V; RI wake minimum high level 2.4 V; RI overvoltage tolerance ±24 V
- RS-485 Serial Port: Maximum baud rate 230,400 b/s; Data bits 5, 6, 7, 8; Stop bits 1, 2; Parity Odd, even, mark, space; Flow control XON/XOF; Wire mode 4-wire, 2-wire, 2-wire auto
- USB Ports: 2.0 and 3.1
- Memory: Nonvolatile memory (SSD) 4 GB; Nonvolatile memory (SSD) type Planar SLC NAND; Volatile memory (DRAM): Density 4 GB, Type DDR3L, Maximum theoretical data rate 12.8 GB/s
- Voltage input range: 9 V to 30 V with Maximum power consumption 60 W

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