Short-Arm Human Centrifuge

SAHC

Preliminary Requirements Document (PRD)

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1 Introduction

In the frame of the Aurora programme for planetary exploration, the European Space Agency is preparing for future long-duration manned missions. During these missions the crews will be exposed for extended periods of time to microgravity. As past and current experience shows, currently employed microgravity countermeasures are not sufficient to avoid adaptations even in low Earth orbit during Space Station, Shuttle or other missions.

Intermittent exposure to artificial gravity via a short arm centrifuge is seen as a promising concept for a future, improved countermeasure. In order to validate this and develop operational application schemes, it is planned to perform ground simulations for microgravity changes, namely bed rest studies, during which a short arm centrifuge would be employed alone or in combination with other methods, as countermeasure.

2 Scope of Document

This document describes the preliminary requirements on the design of the SAHC. “Tbd’s” in the requirements shall be completed by the contractor during Work Package 1 of the activity.

3 Applicable and Reference documents


4 Systems Description

4.0 System Objectives:

The objective of this activity is to build a Short-Arm human centrifuge in order to provide a ground facility capable to study methods for artificial gravity based countermeasures on long term (interplanetary) missions. The results achieved on ground based scientific experiments with this facility will form a valuable input for the design of a space based countermeasure facility.

4.1 System composition

The SAHC consists of the subsystems:

1) centrifuge structure
2) centrifuge rotor
3) centrifuge drive
4) control electronics
5) subject holding (nacelle)
6) control station
7) science operator bench
8) scientific instrumentation
4.1.1 Centrifuge Structure
The centrifuge structure includes:
- The static part with the connection to the floor and the central bearing and structural assembly

4.1.2 Centrifuge Rotor
The centrifuge rotor is the core of the system and includes
- The rotor structure
- Interfaces for the test subject holding device (nacelle)
- Mechanical and electrical interfaces for exercise equipment
- Mechanical and electrical interfaces scientific instrumentation
- Housekeeping and safety equipment

4.1.3 Centrifuge Drive
This subsystem contains all components for the acceleration, rotation and deceleration and position locking of the centrifuge as:
- Motor
- Gears and/or drive belts
- Encoder for speed/position measuring
- Brakes

4.1.4 Control Electronics
The control electronics is composed of all components required to achieve the specified functions and will consist of:
- The speed/motor controller
- The balancing control system
- The nacelle position and orientation control
- The safety control and interlock system

4.1.5 Subject Holding Device (Nacelle)
This subsystem is the interface to the human subject and is mounted on the rotor. It consists of:
- Body support including foot rests
- Body, head and limb restraints

4.1.6 Control Station
The control station is detached from the centrifuge and comprises the following function:
- Technical operator interface for command and monitoring
- Scientific operator interface for command and monitoring
- Safety caution and warning
- Recording of data.
- Routing of data
4.1.7 Science Operator Workstation
This workstation is the interface for the science operator. The Workstation acquires all the scientific and housekeeping data required for the scientific evaluation of the experiments. This data are received via the control station.

4.1.8 Scientific Instrumentation
The scientific instrumentation is composed of all equipments required to acquire the test related scientific data. It will consist of a basic set and instruments added according the scientific aims of the specific test. This set of instruments does not form part of the SAHC system, but interfaces to operate the instruments are provided from SAHC side.

4.2 Accommodation
The final SAHC location is presently tbd. A first location will be defined during the study. Exceeding the baseline accommodation, the SAHC is transportable to be accommodated in locations with interface compatible with the SAHC and similar to the baseline accommodation.
5 Preliminary Requirements/System

5.1 System Requirements

5.1.1 Scientific requirements

5.1.1.1 Noise and vibrations
5.1.1.1.1 The noise during operation of the SAHC at the level of test subject shall not exceed 70 db in the frequency range 100 to 20 000 Hz and comply with national and European regulations (lower value is applicable).

5.1.1.1.2 The vibrations generated by the centrifuge on Nacelle level shall not exceed limits tolerable for experiment aims.

5.1.1.2 Test subject accommodation:

5.1.1.2.1 The SAHC shall allow the accommodation of 2 test subjects.

5.1.1.2.2 The SAHC shall allow the operation with 1 or 2 test subjects simultaneously.

5.1.1.2.3 Test subjects shall be accommodated in supine position.

5.1.1.2.4 The test subject accommodation shall also support a position with legs flexed as in sitting position.

5.1.1.2.5 The subject shall be oriented with the acceleration vector pointing from head to feet, with the face pointing in upwards.

5.1.1.2.6 It shall be possible to adjust the angle against the x-direction from −10 degrees to 80 degrees (negative angles correspond to head down tilt in centrifuge rotating plane).

5.1.1.2.7 The test subject shall be able to perform (tbd) exercises during the operation of the centrifuge.

5.1.1.2.8 The transfer of the test subject to the test position shall be feasible from a standing or supine position.

5.1.1.2.9 The system design shall allow easy transfer of a test subject in supine position from a typical bed used in bedrest studies.

5.1.1.3 Accelerations:

5.1.1.3.1 The rotor shall be able to turn clockwise and counter clockwise on command of the operator.

5.1.1.3.2 The maximal rotational speed shall allow a maximal acceleration at the outer diameter of 50 m/sec².

5.1.1.3.3 The maximal acceleration at foot level in lying position shall not exceed 40 m/sec².

5.1.1.3.4 The speed of the rotor shall be settable in steps such as to achieve acceleration values at the outer diameter between 1 m/sec² and 50 m/sec² in steps of 1 m/sec².

5.1.1.3.5 The set speed shall be controlled to an accuracy equivalent to an acceleration value of +/- 0.5 m/sec² at the outer diameter for each setpoint.

5.1.1.3.6 The acceleration time from static position to nominal speed shall be settable between 30 and 120 sec in steps of 10 sec. The same applies for the deceleration from nominal speed to static position.

5.1.1.3.7 The system shall be compatible with (tangential) accelerations experienced during an emergency stop.
5.1.2 Functional and Operational Requirements

5.1.2.1 Lifetime and maintenance:
5.1.2.1.1 The SAHC system lifetime shall be 10 years.
5.1.2.1.2 The system shall be maintained on an idle time and operational time base.
5.1.2.1.3 Maintenance intervals based on idle time shall be above 6 months.
5.1.2.1.4 The system shall at least be able to perform a campaign of 10 runs of 1 hour duration per day during 60 days without maintenance (600 hours/60days).

5.1.3 Mechanical Requirements

5.1.3.1 Dimensions
5.1.3.1.1 Diameter: The radius of the Centrifuge system shall not exceed 2.70 m
5.1.3.1.2 The footprint of the SAHC including safety provisions shall not exceed 6 m by 6 m for the centrifuge and 1 m by 2 m for the control station.
5.1.3.1.3 The height of the centrifuge system in operating status shall not exceed 2.40 m
5.1.3.1.4 The size of any element of the system in transport configuration shall not exceed a total envelope of 3m x 2m x 1m

5.1.3.2 Mass
5.1.3.2.1 The mass of the system (excluding the control station) shall not exceed a floorload of 1000 kg/m² for the mounting area
5.1.3.2.2 The mass of any element of the system in transport configuration shall not exceed 200 kg
5.1.3.2.3 The centrifuge shall be able to perform within the specifications with a load of up to 110 kg per test subject and up to 30 kg of additional test equipment for each subject in single or 2 subject configuration.

5.1.4 Electrical requirements

5.1.4.1 Voltage:
5.1.4.1.1 The SAHC shall be compatible with 220 to 240 V AC domestic power supply.

5.1.4.2 Power
5.1.4.2.1 The SAHC shall not exceed a total power consumption of tbd W.
5.1.4.2.2 The maximal current per used outlet shall be 16 Amperes including centrifuge acceleration and deceleration.
5.1.4.2.3 The SAHC shall have interface connectors compatible with ESA member states domestic sockets for power supply with ground pin.
5.1.4.2.4 The operation of the SAHC without proper grounding shall be impossible
5.1.4.2.5 All power supply lines shall be protected by earth leak switches (see also 6.2.6.2.1
5.1.4.2.6 For the operation of scientific instruments electrical power shall be available on the rotor

5.1.4.3 Data and housekeeping
5.1.4.3.1 The operator shall be connected via a bi-directional audio link with the subject.
5.1.4.3.2 The operator shall be able to observe the face of the test subjects via a video connection.
5.1.4.3.3 The operator shall be able to observe the complete set-up with the help of surveillance cameras.
5.1.4.3.4 The SAHC shall have an Ethernet link enabling the connection to a remote monitoring station.
5.1.4.3.5 The SAHC system shall have the capability to link to the Internet for remote monitoring of housekeeping and scientific data

5.1.4.4 Electromagnetic Compatibility
5.1.4.4.1 The electromagnetic noise generated by the system shall comply with national and European standards and stay under all operational conditions below the occupational exposure limits for electromagnetic fields.

5.1.5 Thermal Requirements
5.1.5.1 Environment:
5.1.5.1.1 The SAHC shall operate with nominal performance at environmental temperatures between 15°C and 30°C
5.1.5.1.2 The SAHC shall allow storage at temperatures from –20°C to +40°C without degradation of performance.

5.1.5.2 Surfaces:
5.1.5.2.1 The touch temperatures of accessible surfaces shall not exceed 50°C

5.1.6 Interface Requirements
5.1.6.1 Mounting:
5.1.6.1.1 The SAHC shall be compatible with mounting via bolts to a concrete floor.
5.1.6.1.2 The mass of the SAHC shall not exceed usual floor loads (see also 5.1.3.2.1 above)

5.1.6.2 Vibration:
5.1.6.2.1 The vibrations induced by the SAHC shall not exceed usual vibration loads defined for buildings.

5.1.6.3 Electrical see also 5.1.4 above
5.1.6.3.1 Electrical connections between the centrifuge and the control station shall be secured in an appropriate cable channel, such as to avoid any damage to cabling not obstructing access to the centrifuge (walking, beds etc)

5.1.6.4 Noise
5.1.6.4.1 The noise generated by the SAHC in operating mode shall not exceed levels defined by national legislation for working areas. (see also 5.1.1.1 above)

5.1.6.5 EMC
5.1.6.5.1 See 5.1.4.4.1
5.1.7 Safety Requirements

5.1.7.1 Operation:
5.1.7.1.1 It shall be impossible to start the centrifuge rotation without the presence of a human operator.
5.1.7.1.2 Acoustic link between operator and test subject see 5.1.4.3.1
5.1.7.1.3 The centrifuge shall perform an emergency stop in case there is no operator present for tbd seconds.
5.1.7.1.4 The rotating parts of the SAHC shall be protected by a barrier preventing access and contact with rotating parts during operation.
5.1.7.1.5 Any breaking of the barrier during operation (rotating) shall trigger an immediate emergency stop.
5.1.7.1.6 The Centrifuge shall be mechanically locked in static position.
5.1.7.1.7 The rotor shall not be able to start rotation as long as obstacles or people are within the barrier.
5.1.7.1.8 The test subject secured in operating position shall not be able to reach any static part of the centrifuge.
5.1.7.1.9 The centrifuge shall only be able to be started by the operator, when the test subject is fully secured in his test position.

5.1.7.2 Fire caution and warning
5.1.7.2.1 All critical components of the system shall have a temperature monitoring system.
5.1.7.2.2 In case of any an overtemperature monitored by any of temperature sensors the centrifuge shall be commanded into emergency stop
5.1.7.2.3 The test subject shall be immediately informed (method tbd) of the fire risk.
5.1.7.2.4 The control electronics shall have a connection to a smoke sensor placed above the centrifuge. In case this smoke sensor gives an alarm procedure is as in 5.1.7.2.2 and 5.1.7.2.3.

5.1.8 Maintenance Requirements

5.1.8.1 Maintenance intervals:
5.1.8.1.1 The system shall monitor the operational time and issue a maintenance request based on a function taking into account
   - Non-operational time
   - Operational time
   - Value of g/rpm applied during operation
   - Acceleration and deceleration profiles
6 Preliminary Requirements/Subsystems

6.1 Centrifuge Structure Requirements

6.1.1 Scientific requirements (N/A)

6.1.2 Functional and Operational Requirements

6.1.2.1 Restraints and foot rest
6.1.2.1.1 The test subject restraint system of the nacelle shall not interface with acceleration-loading via legs/feet against the footrest.

6.1.3 Mechanical Requirements

6.1.3.1 Dimensions
6.1.3.1.1 Diameter: footprint size see functional requirements

6.1.3.2 Mass
6.1.3.2.1 See system mass 5.1.3.2

6.1.4 Interface Requirements
See system requirements

6.1.5 Safety Requirements
See system requirements
6.2 Centrifuge Rotor Requirements

6.2.1 Scientific requirements

6.2.1.1 Test subject accommodation
6.2.1.1.1 The rotor shall support operation with 1 or 2 test subjects Mixed operation (1 lying-1 sitting or different tilting angels for each subject are not required) See also system requirements 5.1.1

6.2.2 Functional and Operational Requirements

6.2.2.1 Loading of test subject see 5.1.1.2

6.2.3 Mechanical Requirements

6.2.3.1 Dimensions.
6.2.3.1.1 Diameter: footprint size see functional requirements

6.2.3.2 Speed
6.2.3.2.1 The rotor shall be compatible with all operational speeds. See 5.1.1.3

6.2.3.3 Acceleration
6.2.3.3.1 The rotor shall be compatible with all nominal and emergency acceleration values. (see 5.1.1.3)

6.2.3.4 Balancing
6.2.3.4.1 A static and dynamic balancing shall be applied to the rotor before delivery. Levels are tbd
6.2.3.4.2 The rotor shall be statically balanced before each run (loaded with restrained test subject). Level to be defined by the contractor in line with scientific/vibration/building requirements and constraints.
6.2.3.4.3 The test subject shall be restraint to avoid any unbalancing during operation of the rotor

6.2.4 Electrical requirements

6.2.4.1 Voltage

6.2.4.2 Power

6.2.4.3 Data

6.2.5 Thermal Requirements

6.2.5.1 Cooling

6.2.5.2 Surface temperatures

6.2.6 Interface Requirements
6.2.6.1 Nacelle
6.2.6.1.1 The rotor shall provide support points for 2 nacelles. See also 5.1.1.2
6.2.6.1.2 The rotor shall support the nacelle in all required angular positions either by providing the tilting system as part of the rotor or by providing suitable anchoring points for nacelles with built in tilting systems. See also 5.1.1.2
6.2.6.1.3 The nacelle position shall be adjustable on the rotor in radial direction with 0.25 m before operation.

6.2.6.2 Instrumentation:
6.2.6.2.1 The rotor shall provide the electrical and mechanical interfaces for the camera observing the face of the test subject. See also 5.1.4.3.2

6.2.6.3 Scientific equipment
6.2.6.3.1 The rotor shall provide power outlets with 220 to 240 V AC / 5A suitable to operate scientific instruments during the rotation. See also 5.1.4.2.6
6.2.6.3.2 The rotor shall provide suitable interfaces for mounting exercise devices in case they do not form part of the nacelle design.
6.2.6.3.3 The rotor shall provide means to transfer scientific and housekeeping data to the control station.
6.2.6.3.4 The rotor shall be able to support mounting of scientific equipment of 30 kg each for both nacelle locations.

6.2.7 Safety Requirements
6.2.7.1 Balancing: see also 6.2.3.4
6.2.7.1.1 The rotor shall not be able to be started to full speed in a situation where the unbalance exceeds the defined limits.
6.2.7.1.2 The rotor shall be commanded into emergency stop, in case unbalance during rotation exceeds the defined limits.

6.2.7.2 Emergency Stop:
6.2.7.2.1 In case of an emergency the centrifuge shall be decelerated from nominal speed to static position within less then 1 rotation.
6.2.7.2.2 The deceleration time for an emergency stop shall be in line with applicable safety regulations.
6.2.7.2.3 Loss of power shall induce an immediate emergency stop.

6.2.7.3 Electrical safety
6.2.7.3.1 The rotor grounding and electrical safety concept shall allow the safe operation of electrical equipment mounted on the rotor with no risk for the test subject or the operator under all operating conditions.

6.3 Centrifuge Drive Requirements
6.3.1 Scientific requirements
6.3.2 Functional and Operational Requirements
6.3.3 Mechanical Requirements
6.3.3.1 Dimensions
6.3.3.1.1 tbd

6.3.3.2 Mass
6.3.3.2.1 tbd

6.3.3.3 Speed
6.3.3.3.1 The centrifuge drive shall provide rotation/acceleration and deceleration (braking) to the rotor as specified under 5.1.1.3

6.3.3.4 Acceleration
See 6.3.3.3.1

6.3.3.5 Deceleration
See 6.3.3.3.1

6.3.3.6 Balancing
6.3.3.6.1 The rotating parts of the drive connected to the rotor shall be taken into account in the rotor-balancing concept. See also 6.2.3.4.1

6.3.4 Electrical requirements

6.3.4.1 Voltage
6.3.4.1.1 The drive shall be operated via its control electronics from 220 to 240 V AC.

6.3.4.2 Power
6.3.4.2.1 The power consumption of the drive including control electronics in all operating conditions shall not exceed 16 A at 220 to 240 V AC.

6.3.4.3 Data
6.3.4.3.1 The drive system including its control electronics shall transfer all data to the control station: this includes as a minimum:

- Rotational speed
- Rotational direction
- Power consumption
- Operational mode (static, rotating, acceleration, deceleration, emergency braking)
- Temperature at safety critical places
6.3.5 Thermal Requirements

6.3.5.1 Cooling
6.3.5.1.1 The drive system shall be air-cooled. See also 5.1.5.1.1

6.3.5.2 Surface temperatures
6.3.5.2.1 See 5.1.5.2.1

6.3.6 Interface Requirements

6.3.7 Safety Requirements

6.4 Control Electronics Requirements

6.4.1 Scientific requirements

6.4.2 Functional and Operational Requirements

6.4.2.1 Functions
6.4.2.1.1 The control electronics comprises all control functions as
   • Speed and drive control
   • Balancing control
   • Nacelle position and orientation control
   • Safety control and interlock system

6.4.3 Mechanical Requirements

6.4.3.1 Dimensions
6.4.3.1.1 The dimensions of the control system are tbd

6.4.3.2 Mass
6.4.3.2.1 The mass of the control system is tbd

6.4.4 Electrical requirements

6.4.4.1 Voltage
6.4.4.1.1 The Control Electronics shall be operated from 220 to 240 V/AC mains power.

6.4.4.2 Power
6.4.4.2.1 The system shall not require more than 16 Amps under all operating conditions.

6.4.4.3 Data
6.4.4.3.1 The control electronics shall send status data to and receive and execute commands from the control station
6.4.5 Thermal Requirements

6.4.5.1 Cooling
6.4.5.1.1 The control electronics shall be air-cooled. See also 5.1.5.1.1

6.4.5.2 Surface temperatures
6.4.5.2.1 See 5.1.5.2.1

6.4.6 Interface Requirements

6.4.7 Safety Requirements

6.4.7.1 Inherent safety
6.4.7.1.1 Under no operational conditions the control electronics shall be able to command the system into a safety critical status.
6.4.7.1.2 The control electronics shall be designed to allow switching to controlled emergency stop from an emergency stop switch without any software involved.
6.4.7.1.3 Emergency Stop switches with the above-described function (6.4.7.1.2) shall be available for the operator, the scientist, each test subject and around the barrier.
6.4.7.1.4 The centrifuge speed shall be controlled via a redundant or 2 independent control circuits.
6.5 **Subject Holder (Nacelle) Requirements**

6.5.1 **Scientific requirements**

6.5.1.1 **Head restraint**
6.5.1.1.1 The nacelle shall provide means to restrain the head of the test subject from sideward movements to avoid influence of Coriolis forces.

6.5.2 **Functional and Operational Requirements**

6.5.2.1 **Modularity**
6.5.2.1.1 The nacelle shall support supine and sitting position of the test subject either in a design adjustable for both positions or via exchangeable units.
6.5.2.1.2 The nacelle shall support all orientations of the test subject (see 5.1.1.2), if this function is not implemented as part of the rotor
6.5.2.1.3 The nacelle shall allow easy transfer of the test subject to the nacelle. (see also 5.1.1.2.8 and 5.1.1.2.9
6.5.2.1.4 The nacelle shall be equipped with an exchangeable cover sheet not interfering with restraining requirements.

6.5.2.2 **Restraints and foots Rest**
6.5.2.2.1 Body restraints and foot rests shall form an integral part of the nacelle system
6.5.2.2.2 The successful application of the restraint system to the test subject shall be monitored by the safety system.
6.5.2.2.3 The nacelle shall provide mounting interfaces for the exercise systems, in case this is not an integral part of the rotor.
6.5.2.2.4 The nacelle and its body restraint system shall allow exercise of the test subject during operation.
6.5.2.2.5 The test subject restraint system of the nacelle in supine position shall not interface with acceleration-loading via legs/feet against the footrest.
6.5.3 Mechanical Requirements

6.5.3.1 Dimensions
6.5.3.1.1 The nacelle size shall be compatible with the size of a subject according to NASA STD 3000 (see http://msis.jsc.nasa.gov/).

6.5.3.2 Mass
6.5.3.2.1 The mass of the nacelle shall be in a range to be easily handled (without test subject) by 2 people.

6.5.4 Electrical requirements

6.5.4.1 Voltage
6.5.4.2 Power
6.5.4.3 Data

6.5.5 Thermal Requirements

6.5.5.1 Cooling
6.5.5.1.1 The material of the nacelle in contact with the body of the test subject shall be permeable for water vapour and have thermal properties comparable to the beds for bedrest.

6.5.5.2 Surface temperatures

6.5.6 Interface Requirements

6.5.6.1 Test subject instrumentation
6.5.6.1.1 The nacelle shall provide the necessary interfaces to route data from sensors on the test subject to the rotor interface for data.

6.5.7 Safety Requirements

6.5.7.1 Nacelle shape and restraint
6.5.7.1.1 The nacelle and its restraint system shall keep the test subject safely attached to the nacelle under all operational conditions (including emergency stop)

6.5.7.2 Emergency Stop Command
6.5.7.2.1 The test subject shall have easy access to an emergency stop button. See also 6.4.7.1.3

6.5.7.3 Emergency Release
6.5.7.3.1 In case of an emergency stop, the restraint system shall be either automatically released after stopping or the test subject shall be able to release the restraints with a simple one hand operation within applicable safety regulations and time limits defined. See also 5.1.7.2.
6.6 Control Station Requirements

6.6.1 Scientific requirements

6.6.2 Functional and Operational Requirements

6.6.2.1 Parameter recording and display
6.6.2.1.1 The control station shall receive all data from centrifuge system.
6.6.2.1.2 The control station shall record all data received with related time information.
6.6.2.1.3 The control station shall be able to display, print and transfer all data.
6.6.2.1.4 The control station shall be able to display tbd subsets of data in easy readable form.
6.6.2.1.5 The control station shall be able to display graphically the evolution of selected data over time up to real time.

6.6.2.2 Parameter commanding
6.6.2.2.1 The control station shall support the definition and storage of operational scenarios.
6.6.2.2.2 The control station shall perform a consistency and safety check on operational scenarios.
6.6.2.2.3 The control station shall issue commands to the control electronics according to a predefined scenario.

6.6.2.3 Status and Warning
6.6.2.3.1 The control station shall give complete information on the status of the system.
6.6.2.3.2 The control station shall issue a warning in case one or more parameters are out of specification/definition in scenario.
6.6.2.3.3 The control system shall issue a visual and audible warning in case parameters are reaching a safety critical limit.

6.6.2.4 Information transfer
6.6.2.4.1 The control station shall transfer all medically relevant data to the Science workstation; this includes a selected set of centrifuge technical parameters and all data originating from scientific instruments and the images of the video cameras pointing to the face of the test subject.
6.6.2.4.2 The control station shall have the ability to route scientific and housekeeping data via Ethernet and Internet to remote workstations for scientific operators. (see also 5.1.4.3.4 and 5.1.4.3.4)

6.6.3 Mechanical Requirements

6.6.3.1 Dimensions
6.6.3.1.1 tbd

6.6.3.2 Mass
6.6.3.2.1 Tbd kg

6.6.4 Electrical requirements
6.6.4.1 Voltage
6.6.4.1.1 The control station shall work from a 220 to 240 V/AC power outlet

6.6.4.2 Power
6.6.4.2.1 The power shall not exceed 16 A at the defined Voltage

6.6.5 Thermal Requirements

6.6.5.1 Cooling
6.6.5.1.1 The control station shall be air cooled

6.6.5.2 Surface temperatures
6.6.5.2.1 See 5.1.5.1

6.6.6 Interface Requirements

6.6.7 Safety Requirements
6.7 Science Operator Bench (SOB) Requirements

6.7.1 Scientific requirements

6.7.1.1 Scenarios
6.7.1.1.1 The SOB shall provide templates to support the establishment of experiment scenarios.
6.7.1.1.2 Completed scenarios shall be automatically checked for safety and consistency. (see also 6.6.2.2)

6.7.2 Functional and Operational Requirements

6.7.2.1 Experiment Data
6.7.2.1.1 The SOB shall receive experiment relevant housekeeping data and scientific data from the Control Station
6.7.2.1.2 The SOB shall be able to record, retrieve and display this data.
6.7.2.1.3 The display of data shall include actual numerical values and graphical representation of data against time in freely selectable time windows.
6.7.2.1.4 The SOB shall store all data in a format compatible with typical data processing and statistical software in the medical field and/or with Microsoft Excel.

6.7.3 Mechanical Requirements

6.7.3.1 Dimensions
6.7.3.1.1 tbd

6.7.3.2 Mass
6.7.3.2.1 tbd kg

6.7.4 Electrical requirements

6.7.4.1 Voltage
6.7.4.1.1 The SOB shall run from 220 to 240 V/AC mains

6.7.4.2 Power
6.7.4.2.1 The SOB shall be compatible with 16 A max on above Voltage

6.7.4.3 Data
6.7.5 Thermal Requirements

6.7.5.1 Cooling
6.7.5.1.1 The SOB shall work with air cooling under the defined environmental conditions (5.1.5.1.1)

6.7.5.2 Surface temperatures
6.7.5.2.1 The temperature of accessible surfaces shall not exceed 50 °C.

6.7.6 Interface Requirements

6.7.7 Safety Requirements

6.8 Scientific Instrumentation Interface Requirements

6.8.1 Scientific requirements

6.8.2 Functional and Operational Requirements

6.8.3 Mechanical Requirements

6.8.3.1 Dimensions
6.8.3.1.1 Compatible with mounting on the rotor

6.8.3.2 Mass
6.8.3.2.1 Compatible with mounting on the rotor

6.8.3.3 Acceleration
6.8.3.3.1 All scientific instruments mounted on the rotor shall be compatible with the specified maximal accelerations.

6.8.4 Electrical requirements

6.8.4.1 Voltage
TBD

6.8.4.2 Power
tbd

6.8.4.3 Data
tbd
6.8.5 Thermal Requirements

6.8.5.1 Cooling
6.8.5.1.1 tbd

6.8.5.2 Surface temperatures

6.8.6 Interface Requirements

6.8.7 Safety Requirements