JOINT CALL FOR PROPOSALS FOR INTEGRATED PROJECTS UTILISING THE SPACE ENVIRONMENT ON ISS AND CSS SUPPORTED BY ESA and CMSA

SCHEDULE OF THE CALL

• Publication	April 2017
• Letter of Intent	May 2017
• Science Workshop in Beijing with interested scientists	June 2017
• Submission Deadline	August 2017
• Completion of Peer Review	September 2017
• Selection of Proposals	November 2017

Contents

1. DESCRIPTION OF THE JOINT CALL

1.1. Introduction

The Director Generals of both the European Space Agency (ESA) as well as of the Chinese Manned Space Agency (CMSA) agreed that the cooperation between the two agencies should be intensified in the area of human spaceflight, including cooperative projects making use first of the International Space Station (ISS) platform, followed by implementation on-board the Chinese Space Station (CSS), which is planned to become operational in the early part of the next decade.
Taking into account the boundary conditions that apply to the ISS (such as constraints with regard to development of new hardware and resources), it was deemed most pragmatic to identify already-selected experiment candidates with comparable scientific objectives, that are already in preparation for implementation on both sides. It was further agreed to promote coordination and cooperation between the respective teams into integrated science teams in order to achieve maximum complementarity in joint experiments on the ISS and then the CSS, to the mutual benefit of all.
Preparations have now reached a stage where both Agencies are planning to release the Joint Call for proposals for joint experiments in Low Earth Orbit. The objective of this call is to enhance the cooperation on space science experiments that have already been selected in the European and Chinese programmes by coordinating them into integrated projects.

1.2. Call Objectives

The guiding principles of this ESA-CMSA joint call for proposals are to:

- Encourage the formation of integrated teams of scientists from pre-selected projects already supported by ESA and CMSA;
- Promote the highest quality of scientific investigations and maximise the scientific return from space experiments to the mutual benefit of all;
- Optimise the utilisation of ISS and CSS resources by sharing the use of complementary equipment and flight opportunities;
- Maximise the access to research opportunities in space within the operational capabilities and constraints of both the ISS and the CSS.

General information on this Joint Call is provided in the following, including:

- Common scientific objectives identified between ESA and CMSA/CSU
- Description of the available flight opportunities and research capabilities
- Description of the evaluation process
- Instructions for proposal preparation
- Proposal guidelines

The solicitation concerns experiments that utilise in a coordinated manner the capabilities of the International Space Station and of the Chinese Space Station thereby achieving optimal synergy.

The coordinated experiments that are aimed at include:
(1) pre- and post-mission activities involving data collection prior to and upon return from space, and/or
(2) complementary on-orbit experiments that can be implemented on the ISS and the CSS in a cooperative and coordinated manner.

The experiments must be compatible with the operational constraints and capabilities of the International Space Station and the Chinese Space Station.

2. COMMON SCIENTIFIC OBJECTIVES IDENTIFIED BETWEEN ESA AND CMSA/CSU

2.1. ESA's overarching Research Roadmaps for Science in the Space Environment

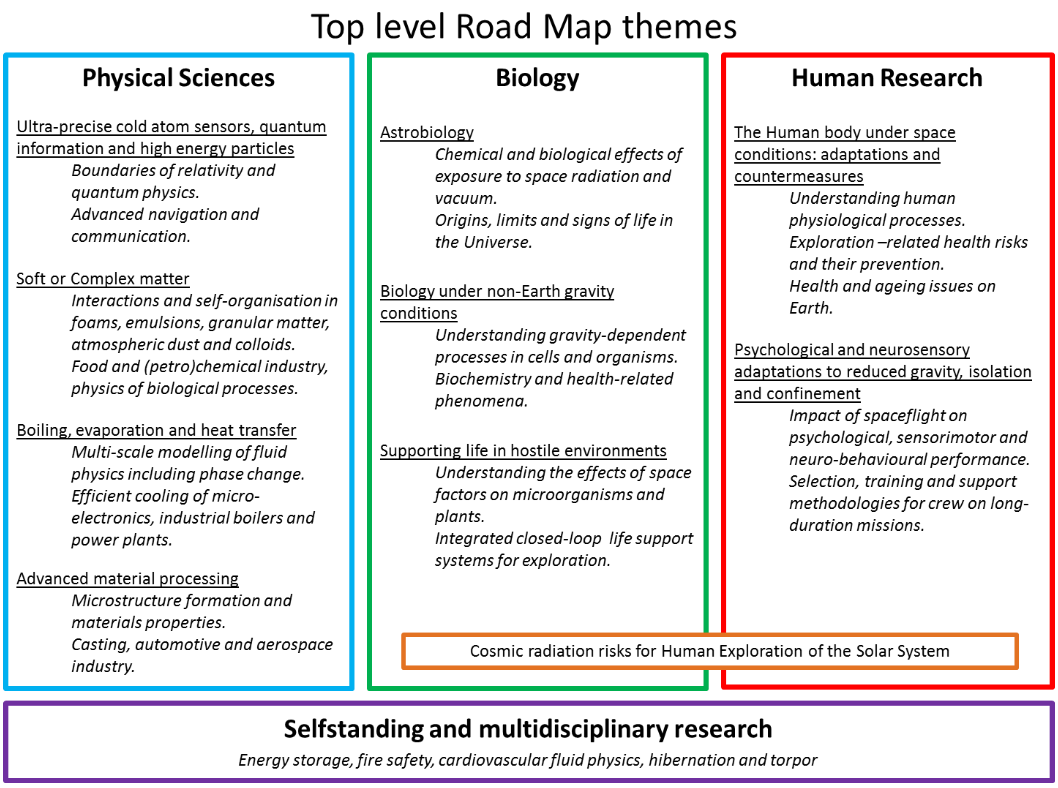
The overarching objectives of SciSpacE are to undertake world-class science that:

- delivers socio-economic benefits in terms of fundamental knowledge, contributions to global goals, education and inspiration; and
- delivers scientific contributions enabling future human exploration of the solar system.

Implementation of these objectives will be through:

- Selecting and implementing world class science in the space environment using the ISS and complementary platforms;
- Pursuing focused research on priority topics relevant for exploration;
- Promoting the development of terrestrial applications of the research carried out;
- Furthering the European scientific excellence and industrial competitiveness in these domains; and
- Effectively disseminating and exploiting the results obtained.

The above objectives incorporate fundamental, exploration relevant and applied research.
The mapping of the science Road Maps against the SciSpacE objectives is multidimensional. Whereas three of the Road Maps (related to radiation, life support and astrobiology) are almost uniquely related to exploration goals, others (such as all human research road maps) relate to both human exploration and health benefits on Earth. In addition, topics can be mostly related to fundamental knowledge (astrobiology, cold atom sensors), others can be more dedicated to Global Goals (human research, heat transfer) or describe rather enabling science (life support) necessary to develop future technologies. The figure below gives a mapping of the Road Maps on the objectives of SciSpacE.



The selection of ESA projects that are aligned with these roadmaps and are addressed with this Joint Call are presented in the following.

2.2. CMSA/CSU overarching scientific objectives

The overarching objectives of utilization mission of China Manned Space Programme are to undertake space science research and utilization that:

- Acquire better understanding of the nature of life, the matter and the universe;
- Advance the development of space sciences in China and get to the frontier in some important research areas;
- Achieve significant breakthroughs in technologies of space utilization, and make contributions to satisfy the need of the social development and people's daily lives.

Implementation of these objectives will be through:

- Selecting and implementing world class space science research and technology demonstration utilizing the CSS and related (space) platforms;
- Promoting the terrestrial applications of the space research and technologies;
- Encourage international cooperation in space science and technology.

The figure below gives a map on the objectives of CMSA/CSU.

Life Science	Physical Sciences
<u>Fundamental space biology</u> • Mechanism of perception and response of living organisms on gravity change at different levels • Gravity ecology **<u>Space biotechnology and other applications</u>** • Protein Science and Engineering • Construction of cell culture and tissue • Bio-manufacturing technology **<u>Basic research of advanced space ecological life support system</u>** **<u>Frontier, crossover study and exploration</u>** • Space Biomechanics and Engineering • The magnetic biological effect • Design of biomolecules and Research of synthetic biology • Research on the extraterrestrial life and the origin of life, synthesis	**<u>Fluid physics and combustion</u>** • Microgravity fluid dynamics • Two-phase flow, phase change heat transfer and its application • Complex fluids • Microgravity combustion science • Fire prevention, detection, and suppression **<u>Space material science</u>** • Basic materials science research • Synthesis and processing of advanced materials • Service behaviour of materials in the space environment **<u>Fundamental physics in microgravity</u>** • High-Precision time-frequency system • Relativity and equivalence principle demonstration experiments

2.3. Common objectives to both ESA and CMSA/CSU

The lists of projects identified as sharing common goals and therefore with potential for integration are provided in the following.

2.3.1. Projects with common objectives in Life Sciences:

CSS Projects	ESA Projects
Molecular network of space microgravity environment regulating plant cell structure and function	Water across plant systems: effects of microgravity on organ morphological and functional traits (ILSRA-2014-020)
	Seedling Growth (ILSRA-2009-0932/1177)
Molecular network of microgravity environment regulating plant stem cell function and structure	Water across plant systems: effects of microgravity on organ morphological and functional traits (ILSRA-2014-020)
	Seedling Growth (ILSRA-2009-0932/1177)
Basic Research for the effort of space microgravity environment on bone/muscle-system	ARED Kinematics (ILSRA-2009-1080): Biomechanical Quantification of Bone and Muscle Loading to Improve the Quality of Microgravity Countermeasure Prescriptions for Resistive Exercise
	CerISS: What changes in the cervical spine and musculature in spaceflight explain increased risk of disc herniations in astronauts? (ILSRA-2014-0033)
	MUSCLE BIOPSY (ILSRA-2004-0155)
	MyotonPRO (ILSRA-2014-0015))
	EDOS-2 (ILSRA-2009-1034)
Research of advanced space aquatic ecological life support system	ArtEMISS Arthrospira gene Expression abd mathematical modelling on cultures grown in the International Space Station (AO2004-085)
Biomechanics research of space cell biology and tissue construction	Mechanocell (ILSRA-2014-112)
	Wound Healing and Sutures in Unloading Conditions (ILSRA-2014-043)
Stem cells 3D growth and tissue construction under space microgravity environment	Three-dimensional culture of bronchial mucosa in microgravity: A new model to study respiratory cell differentiation and stress during space-flight (ILSRA-2014-130)
	Premature senescence of bone mesenchymal stem cells might contribute to bone loss in Microgravity (ILSRA-2014-071)
Space radiation measurement and biological damage assessment technique (in cabin)	DOSIS-3D (ILSRA-2009-0778)

2.3.2. Projects with common objectives in Physical Sciences:

CSS Project	ESA project
Research of gravitational redshift and gravity field measurement based on high precision no-load time frequency	AO-1996 ACES AO-2004-100 SOC
Detection of the fine-structure constant dependence on space-time	AO-1996 ACES AO-2004-100 SOC
Colloid aggregation and phase transition study under microgravity	AO-2004-049 COLLOID (incl. NEUF-DIX)
Study on transformation kinetics of granular material	AO-2004-121 SPACEGRAINS; AO-2009-0943 COMPGRAN
Study of space evaporation phase transformation and heat-mass transfer process intensification experiment	AO-1999-110 EVAPORATION
Study on ebullition heat transfer and reinforcing mechanism	AO-2004-111 BOILING
Research of thermal dynamics and heat transfer of boiling bubble under microgravity	AO-2004-111 BOILING
Study on space condensation process intensification and liquid film instability	AO-2004-096 CONDENSATION
Experiment of microgravity two-phase flow pattern, pressure drop and flow condensation heat transfer	AO-2004-096 CONDENSATION
Study on compositional segregation during solidification process	AO-1999-031 MICAST, AO-1999-117 CETSOL, AO-2004-046 XRMON AO-2009-1094 DIFFSOL
Supercooling and rapid dendrite growth of alloy melt in space	EML projects, e.g.: AO-2009-0829 NEQUISOL
Study on supercooling, nucleation and solidification structure formation mechanism of alloy melt	EML projects, e.g.: AO-2009-0898 PARSEC
On line measurement of thermal conductivity of high-temperature melt under microgravity environment	EML projects, e.g.: AO-2009-1020 THERMOLAB-ISS AO-2009-1136 OXYTHERM
Thermophysical properties of space alloy melt and study on formation of amorphous materials	EML projects, e.g.: AO-2009-1020 THERMOLAB-ISS AO-2009-1136 OXYTHERM AO-2009-059 ICOPROSOL AO-2004-144 MULTIPHAS
In situ observation and mechanism study of alloy solidification under microgravity environment	AO-1999-031 MICAST, AO-1999-117 CETSOL, AO-2004-046 XRMON AO-2009-1094 DIFFSOL

3. ANNEX I: JOINT ESA-CMSA EVALUATION CRITERIA

Organisation of Joint panels under supervision of Science Advisory Bodies of CMSA/CSU and ESA

Criteria:

- Scientific Merit of integrating the projects assessed by Independent Peer Review;
- Space Relevance to be confirmed by Independent Peer Review;
- Technical Feasibility/Affordability if minor adaptations of on-going projects are proposed: In-house assessment by ESA or CMSA/CSU.
- Activity and research basis of the Research team
- Effectiveness of cooperation within the team

4. ANNEX II: DATA RIGHTS

The Agencies shall make effort to provide the Raw and Calibrated Data to the Cooperative Agency and to all members of the Integrated Science Team as soon as possible.

The data set contents and the common format suitable for analysis should be pre-agreed and detailed in the joined proposal. Both Agencies will make best efforts to make the complete set of raw data available to the Integrated Science Team within 6 months from receiving all raw data and samples on the ground.

The Agencies shall grant the Integrated Science Team an exclusive right of prior access to the raw data and samples. The duration of the exclusive right (Period of Prior Access) shall be one (1) year from the provision by the Agencies of the data and samples to all members of the Integrated Science Team in a form suitable for analysis. The exclusive right of prior access belongs to members of the Integrated Science Team only.

The exclusive right of prior access shall be granted to the Integrated Science Team under the condition that the Integrated Science Team shall:

- undertake to furnish the Agencies with an analysis of the results obtained and shall take all reasonable steps to publish such results or, alternatively, shall authorise the Agencies to do so (such publication shall include a suitable acknowledgement of the services afforded by the Agencies, and the cooperation framework); and

- acknowledge the support of both Agencies in any publication using data from experiments implemented under this agreement.

- present to the Agencies the publications generated by the team prior to their submission to a journal to enable comments within a maximum of two weeks

- provide both Agencies with an electronic copy of any such publication at the date of appearance. The Agencies shall have the right to reproduce and disseminate results that have already been published.

- These data rights shall be recalled along with the announced contributions of the different team members to the realisation of the experiments and the analysis of data as well as the agreed approach to publications in the corresponding Experiment Scientific Requirements Document of ESA and Experiment Scientific Demands of CMSA, that are both to be signed by all members of the Integrated Science Team.

- Changes to the duration of the Period of Prior Access can be applied for; they shall require agreement of both Agencies taking into account, inter alia:
  - the extent and nature of the involvement of the Integrated Science Team and of the Cooperating Agencies in the development of the Experiments; and
  - the complexity of processing the raw data to get to usable, publishable results.

5. ANNEX III: HOW TO SUBMIT

5.1. Letters of Intent

To facilitate proposal processing, investigators identified for their potential to integrate are requested to inform ESA and CMSA/CSU of their plan to submit an integrated proposal in response to this Joint Call.
Therefore, investigators are required to submit the letter of intent (LOI) in the form of a one-page abstract with a tentative list of team members.
The LOI shall state that adequate information were already exchanged between the parties and that based on this information, both parties concur on holding more detailed discussions towards a possible integration of the two projects. The letter shall be signed by the coordinator of each party.

The LOI is required to be submitted in both English and Chinese language with identical contents.

LOI shall be submitted before 15. May 2017 (GMT+01:00)

E-mail submission (PDF format, max. 1 MB) in parallel to

ESA: Call-ESA-CMSA@esa.int

CSU: CMSA-ESA-CFP@csu.ac.cn

It is NOT required to submit printed versions of the LOI by regular mail.

5.2. Proposals

Proposals are required to be composed in both English and Chinese language with identical contents, and signed by all team members. Both versions of the proposal shall include the same scanned page with the signature of all team members.

Final Proposal by 18 August 2017 (GMT+01:00)

E-mail submission (PDF format, max. 8 Mb) in parallel to

ESA: Call-ESA-CMSA@esa.int

CSU: CMSA-ESA-CFP@csu.ac.cn

Printed versions of the Chinese version should be sent in parallel to CSU in 4 copies
Address CSU: Dengzhuangnan Rd 9#, Haidian Dist, Beijing, 100094, China

ESA does not require any printed versions.

6. ANNEX IV: ENDORSEMENT OF PEER REVIEW RESULTS AND FORMAL SELECTION

The final selection must follow the applicable processes of approval of both sides.

On the ESA side, all proposals that successfully passed the criteria are presented to the Life and Physical Sciences Working Groups for endorsement and subsequently to the Exploration and Utilisation Board (EUB) prior to approval by the Programme Board (PB-HME). Science project thus approved enter the SciSpacE Research Pool and will be incorporated into the Research Pool Database that will be published on an annual basis as a working document.

On the CMSA/CSU side, all proposals that successfully passed the criteria are presented to the Discipline Expert Groups for related areas, so as for the endorsement and subsequently to the Space Utilization Board prior to approval by CMSA. Cooperative projects thus approved enter the International Cooperative Research Pool.

Proposers shall be informed immediately as to the formal outcome of the Review process by a joint letter from ESA and CMSA, giving the consensus opinion, the overall marking and any relevant comments of the Peer Board as well as the outcome of the preliminary Technical Feasibility Assessment in case minor adaptations of running projects would be beneficial. The results of the Review are final and shall not be open to appeal.

7. ANNEX V: PROJECT IMPLEMENTATION

After formal agreement on an integrated project, the following steps will be initiated:

For the part of each jointly agreed project that would be implement on ISS, the Project Scientist will initiate the detailed assessment of any minor adaptations of the Experiment Scientific Requirements (ESR) document that may be called for by the integration of the projects. This exercise will involve the integrated science team, the project manager of the instrument concerned and the operations manager. If deemed feasible, affordable and if approved within ESA, the ESR will formally be updated after signature by the integrated science team and ESA and the adaptations implemented.

For the part of each jointly agreed project that would be implement on CSS, the Project Scientist will submit the detailed Experiment Scientific Demands (ESD) document that may be called for the integration of the engineering requirement. The exercise will involve the integrated science team, the hardware developer of the related hardware and the project manager. If deemed feasible, affordable and if approved within CMSA and signed by the science team, the ESD will formally be updated and the adaptations implemented

All selected projects will still be subject of a tri-annual review coordinated by the **Joint ESA-CMSA Working Group on Space Experiment and Utilisation**.

8. ANNEX VI: POINTS OF CONTACT

8.1. Points of Contact at ESA

Questions to ESA regarding this Joint Call for Proposals may be submitted via the dedicated e-mail address: Call-ESA-CMSA@esa.int or directly to:

For Human Physiology
Dr. Jennifer Ngo-Anh
HRE-UL
Tel. +31 (71) 565 8609
E-mail: Jennifer.Ngo-Anh@esa.int

For Biology, Astrobiology and Radiation Research:
Dr. Jason Hatton
HRE-UB
Tel. +31 (71) 565 4059
E-mail: Jason.Hatton@esa.int

For Physical Sciences
Dr. Astrid Orr
HRE-UP
Tel. +31 (71) 565 3942
E-mail: Astrid.Orr@esa.int

8.2. Points of Contact at CMSA/CSU

Questions to CMSA regarding this Joint Call for Proposals may be directed to:

For Space life science
Dr. Qian Cao
CSU-ICO
Tel. +86(10) 82178267
Email: caoqian@csu.ac.cn

For Physical sciences
Dr. Yang Yang
CSU-ICO
Tel. +86(10) 82178280
Email: yy@csu.ac.cn

9. ANNEX VII: GUIDELINES TO THE PRODUCTION OF A PROPOSAL

Proposals shall include the following elements:

1. Abstract
2. List of team members and institution + their signature
3. Summaries of the pre-selected original projects that are proposed to be integrated
   (Summary of project supported by CMSA/CSU and summary of the project supported by ESA)
4. Implementation plan
   (How is the cooperation proposed to be implemented with the joint realisation of one single integrated project making use of both ISS and CSS? Distribution/sharing of tasks, schedule)
5. Mutual benefit of the cooperation and sharing of the outcome
   (How will synergies be mutually beneficial? How is the outcome going to be shared between team members? Details of the flight data sets and of the common format suitable for analysis in which these data will be shared by the integrated team
6. Cooperation basis
   (Is it already started or completely new? Provide more detail if it is already started)
7. Support needed
   (What does the cooperation require in terms of support from CMSA and ESA?)
8. Recent Relevant Publications by the team members

10. ANNEX VIII: POTENTIAL CONTRIBUTIONS OF ESA AND CMSA IN LIFE SCIENCES

10.1. ESA potential contribution in Human Research

ESA’s contribution to project in Human Research essentially consists in standard biological sample kits to collect relevant samples and the time spent by the crew itself to follow procedures to collect these samples and store them under appropriate conditions until they can be returned to Earth.

10.2. ESA potential contribution in Biology and rodent research

The most efficient ESA facility to implement biology experiments is the KUBIK facility. It consists of a small controlled temperature volume, which can function both as an incubator or cooler. Additionally, self-contained automatic experiments can be performed using power provided by the facility. Experiments interface with KUBIK by a variety of removable inserts. A centrifuge insert permits simultaneous 1g control or intermediate g-level samples to be run in parallel with microgravity samples.
Experiments interface with the centrifuge insert via a set of small standardized containers, therefore experiments need to be designed to fit inside these containers. Alternatively, larger dedicated experiment hardware can be installed via a KUBIK Interface Plate. Enhancements of KUBIK to enable communication and some control from the ground are also under discussion.

10.3. ESA potential contribution in Exobiology

A new external exposure facility is planned for development which would permit biological and chemical samples to be exposed to the external space environment for up to 18 months, then returned to ground for analysis. In addition simple in-situ measurements such as spectroscopy will be possible. This will follow on from the passive EXPOSE-E and EXPOSE-R facilities which have been successfully used for international Exobiology and Astrochemistry experiments onboard ISS.

10.4. CMSA potential contribution in Life Science

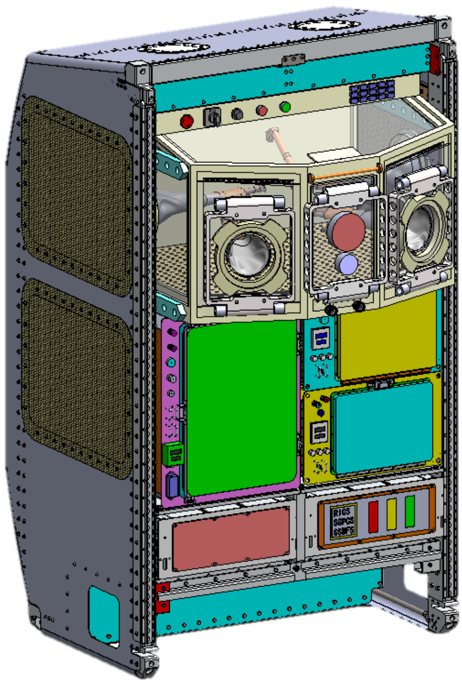
Sketch of the Ecology Science Experiment Rack (ESER)

The Ecology Science Experiment Rack provides strong technical support and conditions for space life science experiments and studies.
This rack is composed of Biological safety online detection module, small ecological life experimental system, general biological experimental culture system, gas composition detection module, small mammal culture system, small centrifuge experiment module and specialty experiment module.
It can be used for various kinds of samples such as plant, seeds, plant tissue, hydro-organism, mouse, drosophila, nematode and other small animal. It is characterized with a small 1g centrifuge and various kinds of detection instruments.
This rack focuses on individual organisms and organizations research to target the effects of microgravity research and basic research for space controlled ecological life support system. It is also to explore the perception and adaptation mechanism of life bodies and organizations on the gravity, radiation and synergies of the both. This rack can be used for exploring the effects of the space environment on biological ontogeny, growth, development, reproduction, aging and biological rhythms as well as to investigate the biological complex systems function regulatory network, and applied to bio-manufacturing technology experiments
This research hardware will provide its corresponding utilisation capacity to support the cooperative project(s) on board of CSS.

Sketch of the Biotechnology Experiment Rack (BER)

The Biotechnology Experiment Rack is be used for space life science and biotechnology research.
This rack is characterized with various microscope detection instruments such as life support and environment control system, biotechnology experimental system, protein crystallization analysis, in situ detection module, Specialty experiment module and Dynamic analysis module.
It can be used on samples such as plant/animal bio-molecular, protein, cells and tissues.
The Biotechnology Experiment Rack focuses on research concerned about biological cells and tissues, microorganisms, animals as well as stem cell differentiation and development in space, three-dimensional tissue culture and tissue engineering, cell culture, bio-mechanics, radiation biology research and applications. It can also support researches about new biomaterials, drug and medical. Besides, the Biotechnology Experiment Rack can be used to explore the effect of microgravity environment and space radiation and its molecular mechanism on cell structure, function and

properties as well as the space environment effects on animal ontogeny, growth, development, reproduction, aging and biological rhythms.
This research hardware will provide its corresponding utilisation capacity to support the cooperative project(s) on board of CSS.



Sketch of the Science Glove-box and Refrigerator Rack (SGRR)

The Science Glove-box and Refrigerator Rack is a multipurpose service facility to support space science and aerospace medical experiments.
This rack is composed of platform accessories, basic platform, platform control system, environment control system and three freezers.
The Gloves-box can provide unique conditions for space life science experiment, namely enclosed environment, fine robotic mechanism, and also micro-observation. The refrigerators can provide temperature in 4 ℃, -20 ℃, and -80 ℃ which is important for sample storage and reaction in space life science research.
The Science Glove-box and Refrigerator Rack is designed to support samples or small scientific experiments with astronauts' participation, and to support the loading or transfer of experimental samples. Besides, this rack possesses freezers in three different temperature ranges to meet different requirements of various samples in biology and medicine.
This research hardware will provide its corresponding utilisation capacity to support the cooperative project(s) on board of CSS.

11. ANNEX IX: POTENTIAL CONTRIBUTIONS OF ESA AND CMSA IN PHYSICAL SCIENCES

11.1. ESA potential contribution in Fundamental Physics

ACES is a payload including two atomic clocks: PHARAO ("Projet d'Horloge Atomique par Refroidissement d'Atomes en Orbit"), a primary frequency standard based on laser cooled caesium atoms, and SHM ("Space Hydrogen Maser"), an active hydrogen maser for space applications. The two clocks are used to generate an on-board time scale combining the short-term frequency stability of SHM and the long-term stability and accuracy of the caesium clock. PHARAO and SHM are compared on-board ACES in the Frequency Comparison and Distribution Package (FCDP), which also distributes the ACES clock signal to a time & frequency transfer system in the microwave domain (MWL). A laser link for time transfer and ranging experiments (ELT, acronym of "European Laser Timing") and a GNSS receiver for orbit determination of the on-board clocks are also included in the ACES payload.
One of the main objectives of the ACES mission consists in maintaining an extremely stable and accurate timescale on-board the ISS, used for space-to-ground as well as ground-to-ground comparisons of frequency standards. Based on these comparisons, ACES will perform general relativity tests of high scientific relevance and develop applications in different areas of research.

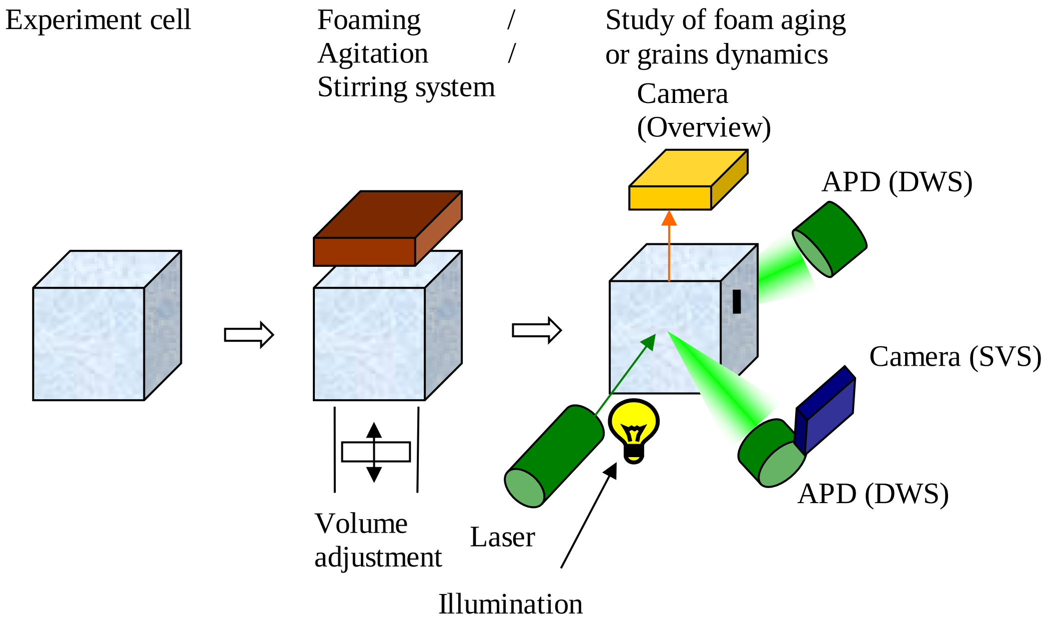
Scientists can contribute additional clocks to the current ground network of ACES so as to increase the basis for comparison with the space clocks. Upon recommendation by the ACES Investigators Working Group based on the performance and location of the proposed ground clocks, enabling comparisons utilising the laser link (or the microwave link depending on the availability of a transportable terminal and resources) can be considered.

11.2. ESA potential contribution in Fluid Physics

11.2.1. Experimental set-up for soft matter dynamics research

The instrument enables studies on foam, emulsion and granular matter samples in weightlessness.
To produce foams or emulsions, a stirring mechanism is used by moving a piston back and forth in liquid and gas mixtures. For granular matter, an agitation system is accommodated in the experimental volume available next to the cell itself. A set of optical diagnostic instruments is accommodated around the cell to provide quantitative information on the evolution of the sample with time.

The soft matter dynamics instrument is sketched here below.



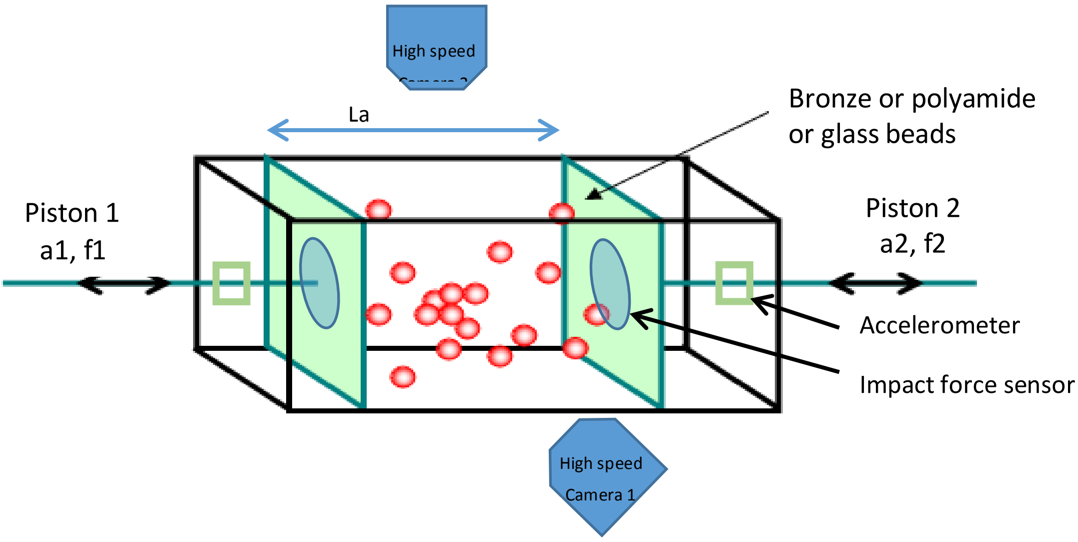
Sketch of the Soft Matter Dynamics instrument

A uniform laser illuminates the samples over an area of at least 10x10 bubbles/drops/particles. The scattered light is then detected by two APD detectors (one for backscattering and one for transmission) to perform DWS and by a camera in backscattering that allows for SVS measurements.
The DWS in backscattering characterizes the nature and average rate of bubble rearrangement or the particle dynamics. The SVS technique is a multi-speckle time-resolved version of DWS. It is used in backscattering to characterise the duration of rearrangement events, and the speed of bubble/droplet/grain motion during an event.
The DWS in transmission will test whether or not bulk behaviour is identical to the near-surface behaviour probed by DWS-backscattering and by SVS, and will give complementary information on the transport mean-free path l*.
Finally, an overview camera will be used just before and after the DWS/SVS diagnostics to inspect the uniformity of foam or emulsion production; to determine the average bubble/droplet size and the width of bubble/droplet size distribution.

11.2.2. Experimental set-up for granular matter research

The instrument consists of a cell filled with particles where two opposite container walls act as vibrating pistons that are driven by electromagnetic coils.
Different cells can be used, split into different compartments or not, and will be interchangeable on the instrument.
Control parameters are the number of particles N, the cell length L, and the amplitude, a, and the frequency, f, of vibrations. Impact force sensors will be implemented to resolve collisions of particles on cell walls and deduce the experimental distributions of particle velocity and the time of flight between two successive collisions with a wall. Accelerometers fixed to the shaft of each vibrating piston enable to infer mean injected power and the temporal fluctuation of injected power. Two cameras enable to visualize the system, and perform quantitative measurements from particle tracking in dilute regime and correlations between particle displacements.
The pistons can be controlled for their exact position and also for the force they apply on the granular sample.

The different cells considered include: 3-D or quasi 2-D cells equipped with bead feeders, with dilute or dense fillings; cells with beads immersed in a liquid; cells where sound waves can be generated on one side and detected on the other; cells for rheology studies.

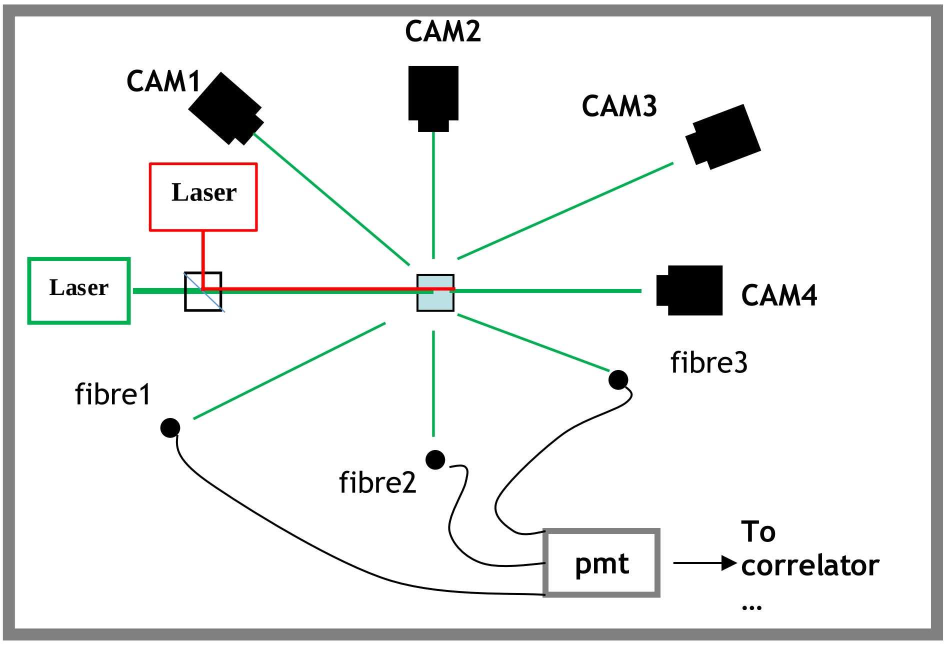


Schematic representation of the VIP-GRAN experiment

11.2.3. Experimental set-up for colloidal physics research

The colloidal solid instrument is sketched below. The instrument will host an exchangeable experimental cell to reduce the up/down load mass in view of a long term utilisation plan. The instrument will probe one cell at a time.
The instrument will allow multiple light scattering diagnostic tools with a 532 nm laser source:

- **DLS** at three angles: (near) backscattering (fibre1), 90 °(fibre2) and a low angle in the range 35 º-70 °(fibre3). The same sensors can provide SLS and C (D)DLS data.
- **SALS** in homodyne configuration. The sensor is a camera (CAM4);
- **TRC** at three angles. The sensor are cameras (CAM1, CAM2, CAM3). The TRC angles shall be the same ones for DLS measurements (symmetrically around the optical axis).



Sketch of the instrument processing unit of Colloidal Solids

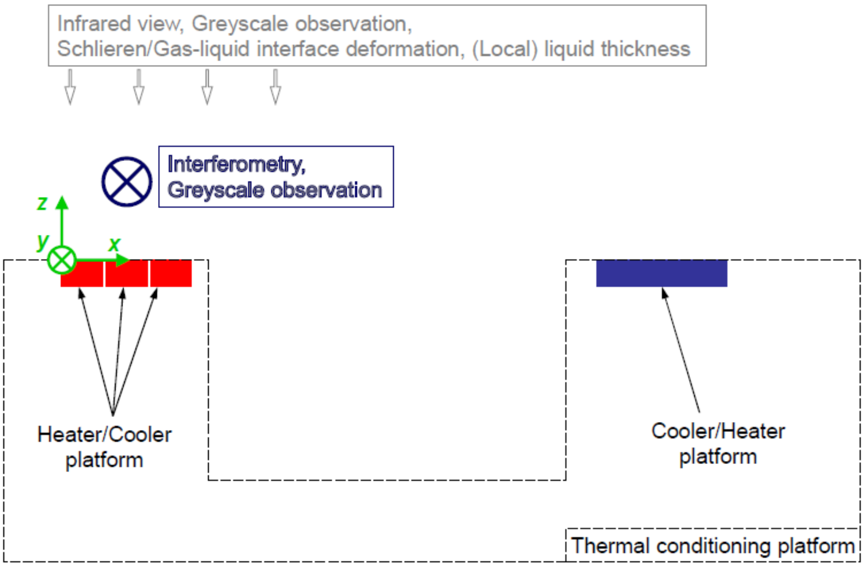
Thermal perturbation can be obtained by optical means, by heating the scattering volume with a 2nd laser beam collinear with the main one, operating at a wavelength where the solvent displays moderate optical absorption. For aqueous samples, which constitute the large majority of the systems to be investigated, a suitable wavelength in the near IR is ~ 980 nm, where water displays a mild absorption peak.

This will enable unravelling new features of many of the systems and physical processes to be studied (such as the structure and dynamics of depletion gels, the nucleation and growth of protein crystals, or the elastic properties of colloidal crystals).

11.2.4. Experimental set-up for two-phase heat transfer research

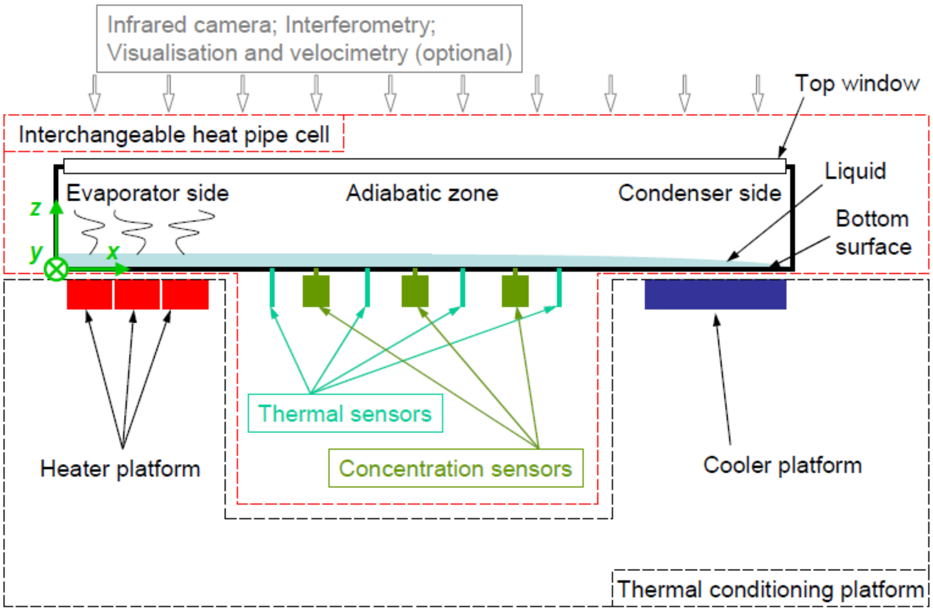
Beyond the Multiscale Boiling experiment currently undergoing Critical Design Review, he two-phase heat transfer programme will mainly rely on the Thermal Platform instrument that aims to provide the generic heat transfer and diagnostic capabilities common to most space experiment projects. Each type of experiment will then realised in a dedicated experiment insert to be installed in orbit and activated on Thermal Platform.

The concept of Thermal Platform currently under study is depicted in the sketch below.



Different types of inserts compatible with Thermal Platform are currently subject of development. The overall concept will enable on the one side to vary parameters within a given insert in orbit and on the other side if they cannot be varied in orbit, to vary parameters or features of a recurring insert from one flight to the next.

One example of such an insert, the Heat Pipe insert, is sketched below.



Inserts are in development or in definition phase to address the main topics in the field of two-phase heat transfer such as:

- Drop evaporation
- Boiling and Flow Boiling
- Condensation on films or in tubes
- Enhanced evaporators
- Etc.

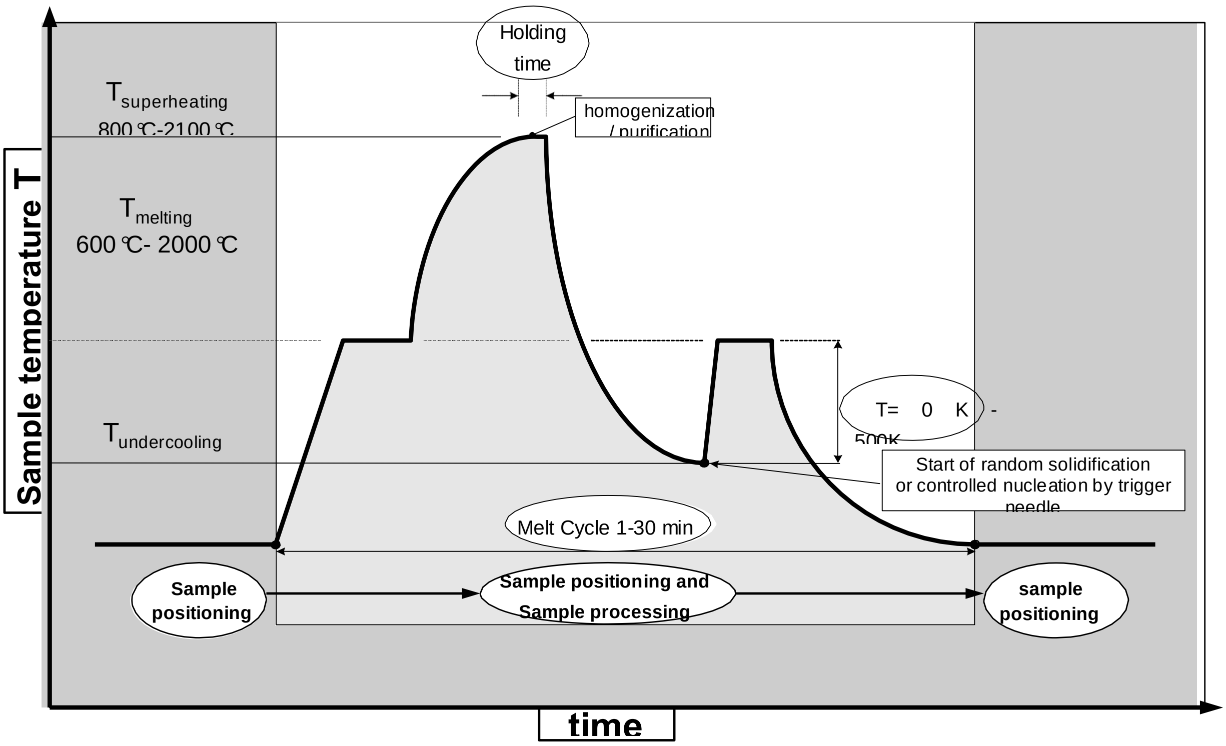
11.3. ESA potential contribution in Materials Sciences

The ISS capabilities available to ESA for research in Materials Sciences are:

- the Materials Sciences Laboratory (MSL) and its two Bridgman-type furnace inserts (Low Gradient Furnace LGF, and Solidification and Quenching Furnace SQF) for near-to-equilibrium solidification studies. Dedicated cartridges containing the sample to be processed are developed for each experiment. The possibility of implementing a new insert providing for in-situ x-ray diagnostic is in discussion.

- The Electro-magnetic Levitation (EML) facility for containerless processing of electrically conducting samples up to 2000 degC with stimuli and diagnostics enabling studies on solidification from undercooled melt as well as measurements of various thermophysical properties as a function of temperature. A typical measurement cycle on a sample in the melt is featured below.

- The Transparent Alloys instrument that permits to observe optically the dynamics of formation of microstructures in transparent model materials contained in cells that can be exchanged in orbit.



Characteristic Temperature-time profile of a sample processed in EML

11.4. CMSA potential contribution in Fundamental Physics

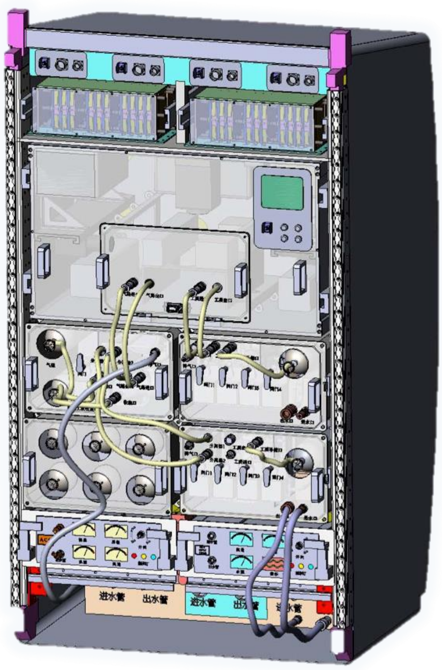
Sketch of the High precision time-frequency rack (HTFR)

High precision time-frequency rack will be used as a novel experimental platform to supporting the precision measurement experiments in the fields of fundamental physics and geodesy.
High precision time-frequency rack will be composed with various atomic clocks, time and frequency transfer link, frequency comparison and control system, and GNSS terminal.
High precision time-frequency rack is focusing on generation of high precision time and frequency signal, test of variance of fundamental physics constants, measurement of gravity induced red-shift.
This research hardware and the capabilities it provides can support cooperative project(s) on board of CSS.

11.5. CMSA potential contribution in Fluid Physics and Combustion

Sketch of the Fluids Physics Experiment Rack (FPER)

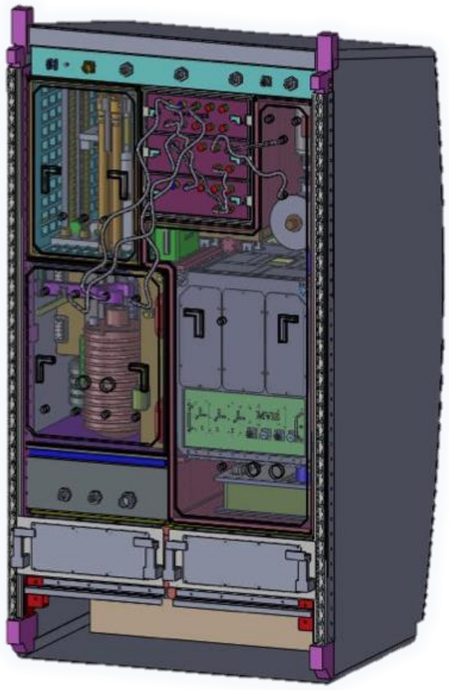
The Fluids Physics Experiment Rack is a research facility designed to support experiments on basic laws of microgravity fluid physics.
This rack is composed of a storage unit of complex fluid sample, a complex fluid module and an diagnostic bench for the fluid, a storage unit for the fluid chamber, a central processing unit and also the power distribution unit for the experiment. The diagnotics instruments include PIV and LDA, laser induced fluorescence, digital holography, temperature sensitive liquid crystals and infra-red imager, microscopy and spectrometry.
The Fluids Physics Experiment Rack is suitable for a variety of experiments on transparent liquid system. focusing on the exploration on both the macro and the micro convection of the fluid in space, microgravity fluid dynamics, microgravity complex fluids research, crystal growth from solution, fluid transport processes research and also the basic laws of microgravity fluid physics.
This research hardware and the capabilities it provides can support cooperative project(s) on board of CSS.



Sketch of the Two-phase System Experiment Rack (TSER)

The Two-phase System Experiment Rack accommodates the key scientific issues and engineering technology research of two-phase systems in microgravity.
This rack is constituted with a core control unit, an observation area, a gas circuit, a spare area and expansion unit, an experiment zone, a small flow fluid circuit and a large flow fluid circuit. The diagnosis instruments of this rack includes PIV and LDA, CCD camera and CCD Microscope, laser interference measurement and an infra-red imager.
The Two-phase System Experiment Rack can support research on evaporation and condensation phase transition in space, phase change heat transfer, loop system for two-phase flow, advanced life support system, battery gas in space. And the circulation and control of liquid, in-orbit control and thermal management as well as mass transfer can be completed in this rack.
This research hardware will provide its corresponding utilisation capacity to support the cooperative project(s) on board of CSS.

11.6. **CMSA potential contribution in Materials Sciences**



Sketch of the Material Furnace Experiment Rack (MFER)

The furnaces of the Material Furnace Experiment Rack can achieve 1600°C in gradient mode and can also provide conditions enabling zone melting experiments.

This rack is composed of a sample management module, an intelligent control module, a multifunction materials furnace and a real-time observation module. It has different furnaces, the middle temperature furnace can reach maximum temperature of about 1000°C. The middle temperature furnace is equipped with X-ray and optical monitor. For the high temperature furnace, the maximum temperature can reach more than 1500°C. The high temperature furnace is equipped with a magnetic field.

The Material Furnace Experiment Rack is used for conducting research in space material growth mechanism and kinetics, functional materials including metallic alloys, semiconductor optoelectronic materials, nanometre and meso-porous materials, metastable materials and special glass, inorganic functional materials and specialised new functional materials.

This research hardware and the capabilities it provides can support cooperative project(s) on board of CSS.

Sketch of the Container-less Material Experiment Rack (CMER)

The Container-less Material Experiment Rack employs electrostatic levitation technology to realise the container-less process.
This rack consists of a main control box, a power distribution box, a material box, a sample transport mechanism, a laser, a high voltage amplifier, an air and atmosphere environment control system, a sample processing module, a vacuum and exhaust gas control system. The Maximum temperature of the Electrostatic levitation furnace can be up to 3000℃ with high temperature stabilisation of ±10℃.It is equipped with laser heater and high speed CCD camera.
The Container-less Material Experiment Rack enables container-less processing of materials and research concerned about space material growth kinetics and mechanism, and also widely used for functional materials research.
This research hardware and the capabilities it provides can support cooperative project(s) on board of CSS.