Post-ISS Roadmap for French Space Science (2026–2028)

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1. Executive Summary

(This report is translated from the original French language report submitted to CNES and the French scientific community. ***This updated version 1.1 replaces v1.0 to correct some minor translation errors.*** *Please signal any remaining errors to the authors.)*

The International Space Station (ISS), a crewed orbital platform that has been in operation for more than two decades, is nearing the end of its operational life. This transition represents both a risk—the loss of a unique access to long-duration microgravity with sample return—and a historic opportunity to rethink the architecture of space research by exploring new orbits, new destinations, and new modes of interdisciplinary collaboration.

The **"Post-ISS Outlook" Workshop**, held on June 24 and 25, 2026, at CNES headquarters in Paris, brought together approximately 40 scientists, engineers, and agency representatives (CNES, ESA) from the following CNES Working Groups: Life Sciences (SdV); Materials Sciences (SdM); Exobiology, Exoplanets, and Planetary Protection (E2P2). The objective was to collectively identify strategic and cross-cutting directions for French space research after the ISS, leading up to the next CNES Scientific Outlook Seminar in 2029.

Three working groups, composed of members from various disciplines and organizations, conducted three successive discussion sessions covering: (1) the identification of interdisciplinary opportunities by mission; (2) the identification of common technical elements (measurements, analyses, equipment requirements); (3) the development of an interdisciplinary roadmap.

This report synthesizes all of these discussions. It sets forth **fourteen** strategic **recommendations** covering three priority areas: **(1) Communication and Structuring (CS); (2) Low Earth Orbit and Ground Segment (OS); (3) Lunar (L)**.

Priority Recommendations	Code
CNES	
Strengthen CNES-ESA communication	CS-i
Structure interdisciplinary collaboration (cross-functional approach)	CS-ii
Facilitating access to information (lessons learned from the ISS era; "post-ISS" opportunities)	CS-iii, CS-iv
Support ground segment activities	OS-viii, OS-ii
Maintain low Earth orbit as a reference (invest in future platforms; ensure access to potential "piggyback" flights)	OS-i, OS-iii, OS-iv
Prepare for future flight systems (anticipate automation, standardize hardware, develop modular closed ecosystems)	OS-vi, OS-vii, L-ii
Ensure sample return	OS-v
Scientists/Instrument Engineers	
Identify scientific priorities for the Moon	L-i
Make the most of the transition period; take advantage of the various low-orbit platform options	OS-i, OS-ii, OS-iii
Prepare for various post-ISS opportunities (lunar, opportunity flights such as on commercial satellites or "piggyback" flights)	OS-iv
Preferably use and develop "generic" hardware, without excluding necessary specialized equipment	OS-vi, OS-vii, L-ii
Industrial Partners/Commercial Operators	
Standardize equipment; plan for automation	OS-vi, OS-vii

These recommendations have been organized into an **action plan** aimed at:

- **Maintain access to long-duration microgravity** with sample return
- **Foster interdisciplinary collaboration** between SdV, E2P2, & SdM for common themes
- **Preserve and enhance the ground segment**
- **Anticipate the automation** of in-orbit experiments
- **Prepare for** future **destinations and platforms**
- **Transition to post-ISS science** in preparation for SPS2029

This document is intended to serve as a reference framework for the scientific community, space agencies, and decision-makers involved in defining France's post-ISS space strategy. It will evolve as post-ISS interdisciplinary work progresses toward SPS 2029.

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2. Context and Challenges

The International Space Station (ISS) has proven to be an exceptional laboratory for French space science. Experiments supported by CNES have been conducted both inside the European Space Agency's (ESA) Columbus module and on its external experiment platforms. Experiments in life sciences, exobiology, astrochemistry, and materials science account for the majority of CNES's scientific activities conducted aboard the ISS during its approximately 28 years of scientific service. Research conducted aboard the ISS represents the final stage of space science, a process that begins in ground-based laboratories, proceeds through space simulation facilities, parabolic flights, stratospheric balloon campaigns, drop towers, and sounding rockets, and ultimately culminates in low Earth orbit (LEO).

With the ISS's planned end of life currently scheduled for the early 2030s, space experimentation is at a turning point in terms of access to the space environment. Access to low Earth orbit for scientific purposes will now depend on a multitude of new service providers. However, the new commercial platforms in low Earth orbit are not yet operational. Freeflyers are in development through ESA, and SpaceRider will enter service in 2028 with its maiden flight supported by ASI. These proposed platforms represent a limitation in services compared to the ISS in the following areas:

- Availability of astronauts (both as scientists and as test subjects)
- Frequency of space missions (particularly during the transition period between the planned end of the ISS and flights by other operators that allow for an equivalent level of scientific research)
- Prolonged exposure of samples to space radiation and microgravity[1]
- Return of samples

The end of the ISS era also marks a turning point toward new destinations. ESA's Explore 2040 roadmap, combined with the Voyage 2050 planetary science plan, offers new opportunities:

- Access to space radiation outside Earth's magnetosphere
- The Moon as a scientific destination and for the development of innovative habitation systems
- New commercial platforms currently being defined for space science

[1] We have chosen the term "microgravity" to describe the weightlessness produced by free fall in LEO and other phenomena that can reduce the "gravity" factor to a negligible value.

To successfully navigate this transition, it will be necessary to mobilize the joint efforts of scientists, engineers, and space agencies. More than ever, interdisciplinarity must be prioritized for future space experiments. Furthermore, this transition offers an opportunity to reexamine collaboration processes among agencies, scientists, and engineers, both at the national and European levels. To facilitate this transition, a series of brainstorming sessions was organized.

The "Post-ISS Outlook Workshop" was a two-day workshop held at CNES headquarters in Paris on June 24 and 25, 2026, bringing together some forty participants from various sectors. Among them were academic scientists and engineers invited by the Exobiology, Exoplanets, and Planetary Protection (E2P2) working groups, Life Sciences and Human Exploration (SdV), and Materials Sciences (SdM) working groups due to their prior experience with experiments on the ISS, as well as representatives from CADMOS, MEDES, Novespace, and space agencies (CNES, ESA). Representatives from CNRS-Biology also participated.

This in-person workshop was preceded by an online questionnaire for participants to identify the main areas of discussion. The questions focused primarily on the French community's use of the ISS, transferable areas for post-ISS science, and the identification and assessment of the resources needed for post-ISS science. The workshop itself included presentations designed to familiarize all participants with past initiatives and current post-ISS projects across all scientific disciplines, with the aim of breaking down interdisciplinary barriers. Three discussion sessions formed the core of the workshop: "Common Opportunities," "Common Techniques," and "Post-ISS Roadmap" (see **Fig. 1**). The objective of this workshop was to foster interdisciplinary connections and strategic thinking regarding scientific, technical, and administrative processes in preparation for the post-ISS transition. It resulted in the development of this initial post-ISS roadmap document, which contains recommendations aimed at facilitating the transition in preparation for CNES's SPS2029 exercise.

3. Collective Reflections

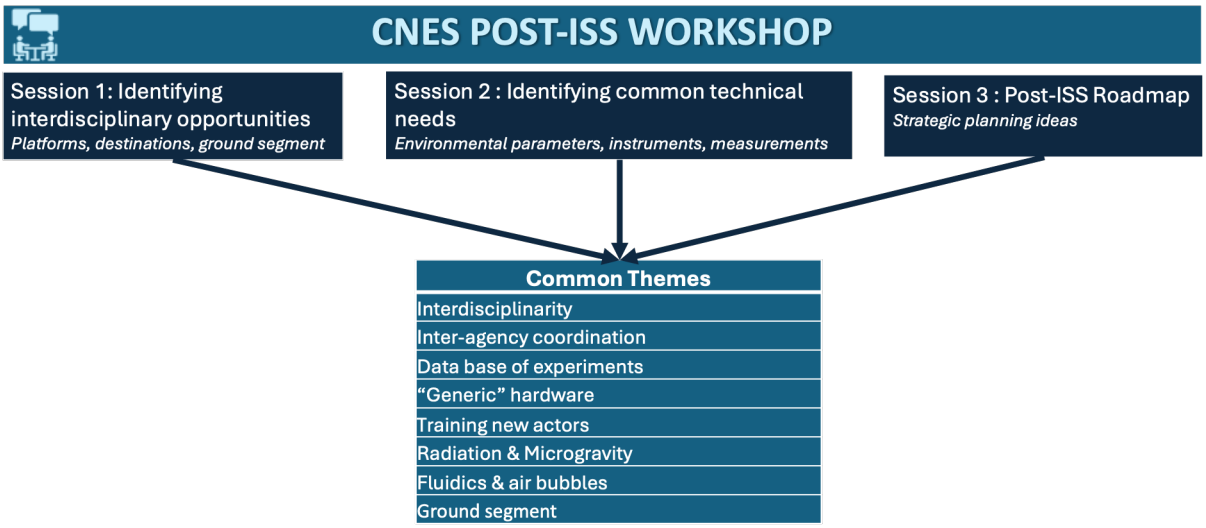


Figure 1. Points of convergence from the three discussion sessions on the post-ISS strategy in France.

3.1. The Strategic Use of Space

Space is where hypotheses developed on Earth are validated. This principle will remain unchanged from the ISS era into the post-ISS era. This allows for a more efficient use of material and financial resources to address scientific challenges. The factor most sought after in space by the French scientific community is microgravity (more than 80% of questionnaire responses), followed by radiation (64% of responses). A significant number of teams are interested in the combination of radiation and microgravity. Research on these two factors involves highly variable exposure durations to address the various specific scientific questions posed by researchers. The reduction in possible exposure durations to the space environment for the post-ISS platforms currently proposed will impose scientific constraints but may also give rise to new research topics and technological developments. Furthermore, experiments to be conducted on the Moon's surface open the door to a new reduced-gravity environment (1/6 g) and a wider variety of radiation environments for research.

It is important to note that radiation exposure studies will benefit significantly from this expansion beyond low Earth orbit. Access to the Moon, the Lagrange points, and potential "piggyback" missions as part of future planetary missions all offer opportunities to study the effects of radiation outside Earth's magnetosphere on materials, molecules, and microorganisms. This finding is consistent with the responses from workshop participants, according to whom >75% of the projects will be small-scale devices (< 24 units) compatible with piggyback missions and/or capable of being shared.

3.2 Ground-Based Facilities and Simulation

The exploration of these destinations must continue to be complemented by the use of ground-based and simulation segments.

Parabolic flights (Novespace), stratospheric balloons (CNES Balloon Service), sounding rockets, and microgravity towers (operated by our European partners at ESA) will be important tools during the transitional period between the end of the ISS's operational life and the advent of commercial platforms. Nevertheless, making optimal use of these resources will require an awareness campaign targeting potential users, combined with feedback from current users, in order to rapidly expand the pool of qualified users and facilitate collaboration or the shared use of experimental equipment. These platforms provide continuous access to variable gravity conditions and even certain types of radiation (UV) for the development of new experimental devices (R&T), for resolving technical issues prior to orbital flights, and for obtaining preliminary data in microgravity. Standardizing experimental equipment across the various platforms, to the extent possible, will allow for direct comparison of results while reducing costs and shortening experiment development times.

Ground-Based Facilities are essential for simulating gravity, radiation, and environmental conditions (e.g., regolith, temperature, atmosphere, etc.). One specific issue that emerged from the workshop concerned random positioning machines (RPMs), which are widely used terrestrial microgravity simulators. Indeed, several issues were identified, such as the heterogeneity of the technical characteristics of devices currently on the market, which leads

to a lack of standardization and reduces the comparability of the results obtained. Defining specifications for the various types of experiments conducted with RPMs will help improve existing devices and expand their applications. Furthermore, coordinating RPMs in France will help harmonize facilities (which ones for which experiments) and verify their compatibility with other systems (plant cultivation, cells, microorganisms, organoids, control of physical parameters, etc.). Beyond microgravity simulators, conventional terrestrial experiments remain relevant for studying the effects of radiation, material aging, or diffusion phenomena—all of which are preparatory topics for spaceflight.

The effects of solar and cosmic radiation on materials are important for future lunar habitats. Radiation is a subject of study in astrochemistry, exobiology, and planetary protection, as well as for astronaut health. Radiation can also be an indirect source of artifacts and contamination. Indeed, this radiation can degrade materials and produce or release toxic molecules that contaminate microbiology or cell culture experiments. Since culture media, growth substrates, and solutions containing samples are sensitive to radiation, they can be altered without this being detected. These artifacts can lead to erroneous interpretations of scientific results. Therefore, access to solar simulators is crucial for advancing space research in France. Sharing solar simulators across France will complement the existing infrastructure and enable systematic preparatory testing.

The ground segment also remains essential for the preparation, calibration, and validation of space experiments. Access to a broader range of laboratories equipped with the necessary equipment, along with the sharing or networking of these facilities, will increase efficiency and reduce costs for:

- Preparing samples
- Integrating samples for flight
- Testing/validating flight devices
- Conducting Ground Reference Experiments essential for analyzing results
- Retrieving samples for post-flight analysis
- Store and share samples

3.3 Post-ISS Platforms and Destinations

The end of the ISS will change the terms of access and the parameters of space science. For the French community, access to astronauts—both as experimenters and as subjects of study—the ability to return samples after a spaceflight, and the need to automate spaceflight equipment in the absence of astronaut-experimenters were highlighted as major challenges. These are summarized in **Table 1**. The return of samples has been highlighted as mandatory for approximately 40% of all scientific activities in low Earth orbit.

Table 1. Comparison of Low Earth Orbit (LEO) Platforms.
(table generated with the help of the Lumo AI, reviewed and verified, prior to translation to English)

Platform	Microgravity	Radiation	Sample Return	Time required to retrieve samples	Crew duration	Required autonomy	Operational status
ISS	Long-term (months/years)	Dominant unit	Yes, regular	Weeks	Yes, available	Low	Active until the end of operations
SpaceRider	Short duration (weeks)	Varies depending on orbit	Yes, automatic	Weeks	No	High	First flight scheduled for 2028 (already booked by ASI)
Moon (surface)	Reduced gravity (1/6 g)	Multiple types, aggressive	Difficult, expensive	Months/ years (if ever)	Future, Artemis/ Argonaut	High	Under development
Lagrange point	Long-term	Interplanetary	Very difficult	N/A	No	Complete	Conceptual
CubeSat / Piggyback	Variable	Variable	No	N/A	No	Complete	Available
Stratospheric balloon	Days	UV (limited)	Yes, regular	Immediate to weeks	No	High	Active (CNES)
Parabolic flight	Short (~20s), variable (simulations of lunar/Martian gravity)	N/A	Immediate	Immediate	Yes	Low	Active (Novespace)
Sounding rocket	Minutes	UV (limited)	Yes	Immediate to weeks	No	High	Coming soon (Opus Aerospace, other European operators)
Drop tower	Seconds	N/A	Immediate	Immediate	Yes	Low	Active (ZARM)

However, few future space platforms have been designed for sample return. This will require the development of automated spaceflight hardware capable of performing *in situ* analyses and transmitting data to Earth. There are currently few types of such hardware available. Many of those that do exist are the intellectual property of commercial partners and were developed under ESA contracts for specific projects; as such, they are not designed for generic application to other projects, and access to them is restricted for the scientific community. It should also be noted that while Europe has been a leader in Earth-orbit exposure campaigns for decades, opportunities for ESA exposure experiments have greatly diminished. With the notable exception of the CNES IR-COASTER experiment in 2025, no new exposure devices have been deployed in orbit since 2016. The development of "generic" devices for various applications will be necessary. This presents an excellent opportunity for collaboration with the planetary exploration community, which has developed a suite of imaging and spectroscopic instruments designed for automated *in-situ* analysis in space, thereby providing a starting point for the development of applications in low Earth orbit and on the Moon.

Low Earth orbit remains the most accessible and best-equipped destination. The ISS is the archetype, but post-ISS commercial platforms (private stations in LEO) and SpaceRider offer alternatives. Operations in low Earth orbit, depending on the platform used, offer the possibility of sample return, identified as a key factor for space research in France. Environmental control (temperature, atmosphere, H_2O levels, etc.) and longer periods of exposure to microgravity will be elements to maintain in the post-ISS era. Crew time will no

longer be the same after the end of the ISS[2] , but uncrewed flights will help reduce both access costs and the health and safety constraints imposed on experimental equipment. To meet scientific needs, low Earth orbit must remain the foundation of post-ISS space research, supplemented by automated platforms such as SpaceRider.

Expansion beyond low Earth orbit is essential for exposure to radiation beyond the UV spectrum (gamma rays, charged particles, cosmic rays). The Lagrange points, as well as the Moon's surface and orbit, will be destinations to be exploited for ionizing and particle radiation. Lagrange points offer a radiation environment representative of interplanetary space, but without the possibility of easily returning samples, requiring complete self-sufficiency. The Moon represents an intermediate point between Earth and the deep interplanetary environment. Future lunar habitats provide an environment for testing materials in conjunction with chemical or biological systems for both basic research (e.g., exobiology and astrochemistry) and applied research (e.g., the MELiSSA project for plant production and the development of closed ecosystems, accelerated material aging, and radiation protection). On the other hand, access will be complex and is currently being defined, and sample return will be costly and limited. Lunar bases may be well-suited for one-way experimental setups that take advantage of the environment (*in situ* sample analysis, preliminary data analysis, storage space for generated waste, etc.).

The use of artificial satellites, such as telecommunications satellites, in polar orbit (at an altitude of approximately 1,200 km) can also serve as a relevant complementary platform. Unlike the ISS, these orbits allow for the reproduction of a synergy between solar ultraviolet radiation, the solar wind, and the flux of galactic cosmic rays at the poles (not to mention exposure to the Van Allen belts, which amplifies the effects of radiation). Furthermore, this altitude ensures a chemically neutral environment, free of residual atomic oxygen and the pollution inherent in crewed stations. It would then be possible to expose samples directly to the space environment, without protection from portholes that filter out part of the solar radiation. A major limitation here is that the samples cannot be returned to Earth, which requires the development of onboard diagnostic tools.

A multi-platform strategy is recommended, favoring different orbits to diversify the radiation environments, while preserving the ability to return samples as much as possible.

3.4 Instruments of Common Interest

Although the E2P2, SdV, and SdM working groups' programs all focus on distinct areas, they share common points of interest both thematically and in terms of the techniques used for sample analysis (see **Fig. 2**). Given future needs for increased autonomy of space equipment and *in situ* analysis when sample return is not practically feasible, it is important to identify these areas of common interest. Life sciences, exobiology, astrochemistry, and materials science remain too compartmentalized within French and European space research. These

[2] This refers to the time the crew has to conduct experiments either as test subjects (physiology) or as experimenters. This time is also an important financial variable, given that astronauts may have to contend with budget constraints and flight durations that vary widely depending on the mission.

communities sometimes use the same platforms (the ISS, parabolic flights) but do not engage in sufficient dialogue regarding their respective research questions.

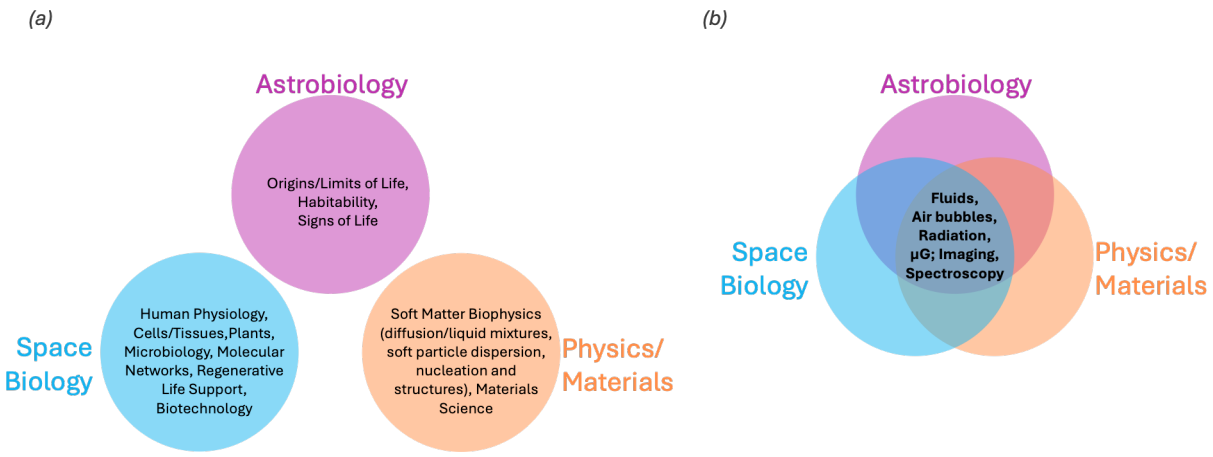


Figure 2. (a) Specific and (b) common interests and techniques of the E2P2, SdV, and SdM working groups

Several factors account for this compartmentalization:

- Different vocabularies and conceptual frameworks
- Measuring instruments with different resolutions and fields of view (µm vs. nm)
- Distinct scientific cultures
- Lack of structured forums for exchange

The areas of common interest to the three working groups are as follows:

- Thematic areas: µG, radiation, fluids, air bubbles
- Techniques: imaging, spectroscopy/spectrometry

A survey of workshop participants revealed that more than three-quarters of the projects rely on microgravity, while microfluidics is being considered in more than 50% of future projects. The issue of atmospheric and gas parameters surrounding the sample is important for at least 50% of the projects, and temperature is also an essential parameter for half of the projects. It is important to note that “late access” (access to samples just before launch) is critical for biology, where the preparation of living samples cannot be done too far in advance[3] . Reducing late access prior to a mission must be taken into account in the design of future platforms: for example, the issue of maintaining the setpoint temperature stability of biological samples during late access and while waiting at the launch pad is a central concern that must be anticipated during the planning and design phases of the systems.

Fully automated experiments will require data transmission. The survey conducted among the community revealed that most experiments could be conducted at low transmission rates.

[3] This excludes, to a certain extent, seeds and certain microorganisms that can remain dormant for longer periods under specific conditions but will require stimulation—such as the addition of water—to be reactivated.

Real-time telemetry is a necessity, particularly for biology, where experiments may require adjustments during flight, and is justified by:

- ground-based decision-making or choosing a course of action based on the result of the first action or measurement,
- the decision to continue or halt the experiment,
- faster data processing,
- very large data volumes (unloading data from storage),
- the need to take action on ground controls.

On the ISS, real-time telemetry exists but remains costly. For future platforms (SpaceRider, other satellites, the Moon), this need must be anticipated as early as the specification phase.

Table 2. Technologies at the interface between different scientific disciplines.
(table generated with the help of the Lumo AI based on the minutes of the workshop's discussion sessions, with proofreading and verification prior to translation to English)

Instrument / Method	SdV/E2P2	SdM	State
Fluorescence microscopy	Essential (cells, tissues)	Limited	Under development
FTIR / Raman	Flexible	Reusable	FTIR available
GC-MS (Mass Spectrometry)	Metabolomics	Analytical chemistry	Available, fairly large
High-frequency cameras	Behavioral imaging	Heat transfer	Available
Microfluidics	Cell culture, microbiology	Fluids, Interfaces	Under development

The identification of common instrumental needs among E2P2, SdV, and SdM revealed a complex landscape in which some instruments are already shared, others are discipline-specific, and some require joint development (see **Table 2**). Imaging systems will need to be calibrated based on spatiotemporal parameters (nm to mm, intervals ranging from seconds to months), the desired signal (UV/Vis, fluorescence, phase contrast, etc.), the nature of the sample (solid or in solution), and the scientific question. The development of "generic" devices promotes the use of the same equipment across disciplines, forming the basis for these shared measurements and analytical methods. They enable greater knowledge sharing and likely reduce production costs, contributing to greater flexibility in their use.

To take the sharing of flight instruments even further, an incremental, modular approach can be applied. This strategy is already being used by the ESA for the BioBoxes that came out of the work of the former Lunar Gateway Facility Design Team METIS. The goal is to define a basic set of common instruments (microscopy, spectrometry, imaging), allowing for the addition of specialized modules depending on the discipline. The interfaces between modules are standardized, as is compatibility between platforms (LEO, lunar). For example, a modular closed ecosystem can be created to study an ecosystem's ability to develop in microgravity or reduced gravity, and then be broken down into subsystems for targeted studies (molecules, cells, organisms, materials, fluids). This type of system will be a useful tool for applied research (regenerative systems for lunar habitats, water-limited ecosystems) as well as for fundamental questions (e.g., studying the formation of an ecosystem based on lunar regolith as a starting point).

3.5 Issues Requiring Interdisciplinary Approaches

The workshop identified several cross-cutting issues where collaboration between life sciences/chemistry (SdV, E2P2) and materials science/physics (SdM) is not only possible but necessary:

i) Air bubbles generated more abundantly in microgravity: they affect experiments in fluid mechanics and heat transfer, as well as those involving biological systems and autonomous spectrometric measurements, which are hindered by the presence of these bubbles. This problem has a significant impact on post-ISS science, in which more than 50% of experiments will use fluidic systems with automated measurements. Air bubbles in orbit have already been documented, but this problem remains unresolved. Potential solutions depend in part on volume: technical solutions will likely differ for capillary microfluidic chips, millifluidic cuvettes, bioreactor vessels, or other systems with liter volumes. Solutions derived from disciplines within SdM will directly benefit teams within SdV and E2P2. In addition to air bubble generation, there are questions regarding gas diffusion in biological fluidic systems. These questions require close collaboration between fluid physicists and biologists.

Course of action: Organize a workshop focused on the issue of air bubbles in µG, in which discussions can be initiated with CNRS research groups (GDRs) such as those focused on microfluidics.

ii) Inert Materials: The use of inert materials is a point of convergence between SdM, which focuses on surface properties and chemical inertness, and SdV/E2P2, which seeks biologically neutral substrates to avoid artifacts or contamination caused by the release of molecules from sample supports or containers.

Course of action: Develop common inert materials through a joint CNES-scientists-engineers R&T project.

iii) Materials for protection against solar radiation: potential materials for lunar habitats can be tested after exposure to radiation while also serving as protection for control samples in biological experiments. This initiative will create a genuine experimental interface between the two communities

Approach: Interdisciplinary development of a collaborative experiment, for example for the Argonaut facility.

To structure this interdisciplinary approach and implement these actions, **ongoing exchanges between the E2P2, SdV, and SdM working groups** will be beneficial through regular meetings.

3.6 Sample Return

The issue of sample return has been identified as a critical point of interdisciplinary convergence. Without the capacity for sample return, a significant portion of scientific output is lost:

- Detailed analyses (electron microscopy, mass spectrometry, -omics) require ground-based equipment
- On-board analysis in orbit is possible but costly and limited in resolution

- Certain types of analysis are simply not feasible in space

It is therefore necessary to maintain the capability to return samples as a fundamental requirement for future post-ISS platforms. However, current sample return solutions (microtubes, miniature containers) are incompatible with large-volume samples. For example, experiments involving whole plants, fluid dynamics, and the development of space-based bioreactors require volumes ranging from deciliters to liters. Material exposure experiments also often require large samples. It is therefore necessary to develop solutions for sending these “large” samples into space and studying them there.

3.7 Industrial Partners and Commercial Operators

CNES plays an important role as both a coordinator and an intermediary between scientists and commercial partners. For the post-ISS era, this role includes facilitating the formation of experiment consortia that share costs. Negotiating protective contractual frameworks for scientists is also critical. Current and future commercial partnerships must be established within a clear framework to ensure effective and fruitful interaction with the scientific community. A set of 3 to 4 types of generic equipment should be developed, adapted to the most common conditions and the measurement requirements of the French space science community. Development must involve equal participation by scientists and engineers to ensure that scientific needs are met. This will reduce development costs and timelines, thereby increasing the potential rate of in-flight experiments. It will also ensure standardization, facilitating data comparison. Given the variety of future space platforms, it is strongly recommended that all connectors be standardized to allow for the transfer of equipment from one platform to another.

In addition to R&T, the financial and legal framework (intellectual property) governing the development of new equipment should be clarified. Contracts with industrial partners should involve scientists to ensure that all equipment produced meets scientific requirements. Contracts relating to intellectual property should specify the roles of the scientists who test and use the equipment, the industrial partners who design and manufacture it, and the commercial entities that provide access to space and/or equipment for scientific purposes. To this end, we recommend:

- establish a **clear framework** for commercial partnerships (guarantees, performance standards),
- promote the role of CNES as **an intermediary** and coordinator,
- prioritize a **network of** accredited **European partners**,
- develop **mechanisms for** cost-sharing (consortia).

In this context, it is also important to highlight the strength of the network of French space laboratories, which are capable of leading the development of new space instruments necessary for the objectives outlined in this document.

3.8 Funding for Space Experiments

Future space experiments will need to be more cost-effective. The budgets of space agencies and university researchers are currently facing significant cuts. By pooling and centralizing

resources, CNES can help reduce the financial barriers to accessing space. For workshop participants, this includes, in particular:

- funding for technical staff to prepare and conduct the experiment,
- funding for consumables and platform services.

These objectives could be achieved through:

- pooling human resources for flight preparation and support,
- expanding ground infrastructure

4. Recommendations

Workshop participants identified twelve recommendations for the post-ISS transition (see **Table 3**). These recommendations aim to promote interdisciplinarity by breaking down the silos between the SdV, SdM, and E2P2 working groups through cross-cutting initiatives related to shared interests. They also aim to encourage the entry of new players in France by facilitating access to information through digital means (e.g., a centralized website) and a dedicated contact person(s). Communication and the pooling of resources are emphasized to reduce costs and optimize work processes, under the coordination of CNES.

Table 3. Recommendations for the post-ISS transition. The recommendations are grouped by theme, not in hierarchical order. (Table generated with the help of the Lumo AI based on the minutes of the workshop discussion sessions, with proofreading and verification prior to translation to English.)

		Recommendation	Justification	Scientists	CNES	ESA	CADMOS	CNES R&T	Instrumentalists	Industry
Communication & Structuring	CS-i	**Strengthen ESA-CNES coordination:** More dialogue between CNES, ESA, and scientists	Currently a Lack of clarity regarding ongoing and future actions in the post-ISS transition	o	o	o				
	CS-ii	**Structure interdisciplinary collaboration:** Establish ongoing exchanges between CNES working groups E2P2, SdV, and SdM; provide mission instrumentation for in-orbit experiments; identify and address common challenges; CNES annual workshop for follow up actions	Existing 'silo' effect between working groups, common challenges identified	o	o					
	CS-iii	**Document lessons learned:** Create a database of flight systems (successes, failures, technical solutions) accessible to the French community (similar to ESA's HREDA)	Collective learning, avoid repeating mistakes				o			
	CS-iv	**Create a website for scientific users:** Clear information on opportunities, calls for proposals, accessible procedures, and at least basic links between CNES and ESA websites	Fragmented information, discouraging new actors		o	o				
LEO & Ground Segments	OS-i	**Maintain low Earth orbit as the standard:** Continue access to experimentation in LEO despite radiation limitations; remains essential for long microgravity phases involving sample return	Continuity of access, sample return, controlled conditions		o	o				
	OS-ii	**Make the most of the transitional period:** Maximize/optimize use of all available resources (parabolic flights, drop towers, sounding rockets, ground-based simulators, LEO platforms)	Preparation for future experiments, technical tests, preliminary data	o	o	o	o	o	o	o
	OS-iii	**Invest in LEO platforms:** Expand opportunities across various Earth orbits; reserve slots on SpaceRider for the French scientific community	Post-ISS transition, sample return, autonomy		o					
	OS-iv	**Leverage commercial satellites in orbit (e.g., polar or geostationary orbit):** Direct exposure to the space environment, invest in the development of in situ analytical instruments	Access to full solar radiation (within the magnetosphere), increase launch opportunities, reduced costs		o					o
	OS-v	**Preserve some sample return:** Required for continued LEO & BLEO experimention; develop solutions for large volumes (plants, liquids) needed for key Exploration experimentation	Irreversible scientific loss; Current incompatibility with large volumes		o	o				
	OS-vi	**Standardize hardware:** Invest in development of a few key 'generic' hardwares for interdisciplinary use while maintaining specialized hardware as needed; Use the same hardware across platforms (parabolic flights, free flyers, ...) based on scientific needs	Reduce costs, decrease preparation time before launch; Reproducibility, comparability of results	o	o	o	o	o	o	o
	OS-vii	**Anticipate automation:** Invest in instrument development for crewless experiments based on shared scientific needs (in situ, automatic analytical hardware); interdisciplinary teams to address key development issue (e.g. air bubbles in fluidic systems in microgravity)	Transition to future platforms	o	o	o	o	o	o	
	OS-viii	**Support ground segment activities:** Standardize RPMs, facilitate access to solar simulators and laboratories to conduct ground-based reference experiments linked to in-flight experiments, utilize ground-based facilities, and coordinate via CADMOS	Current facility heterogeneity, under-utilization	o	o		o		o	
Lunar	L-i	**Prioritization of lunar experiments:** Identify scientific priorities for the French community (preparation for crewed missions, science related to lunar conditions—radiation outside the magnetosphere, lunar dust, 1/6 gravity, etc.) as well as the strategic systems to be developed	Changes to the lunar program after CNES SPS 2024; Maximize scientific return from future lunar opportunities	o	o					
	L-ii	**Develop the concept of a modular closed ecosystem:** A complex system that can be broken down by discipline and is standardized	Methodological framework for interdisciplinarity	o	o	o	o	o	o	

5. Action Plan

The Post-ISS Outlook Workshop took place midway between the 2024 SPS report and the next SPS in 2029 to address changes to post-ISS space projects following the 2025 Ministerial Conference. The recommendations resulting from this interdisciplinary and cross-cutting workshop will enable all stakeholders to move toward a collective strategy. Actions to be launched before the 2029 SPS are proposed in **Fig. 3**, beginning with communication initiatives to improve exchanges between agencies and scientists, as well as coordination efforts regarding the development of experimental systems of common interest that will follow, targeting critical issues requiring interdisciplinary approaches.

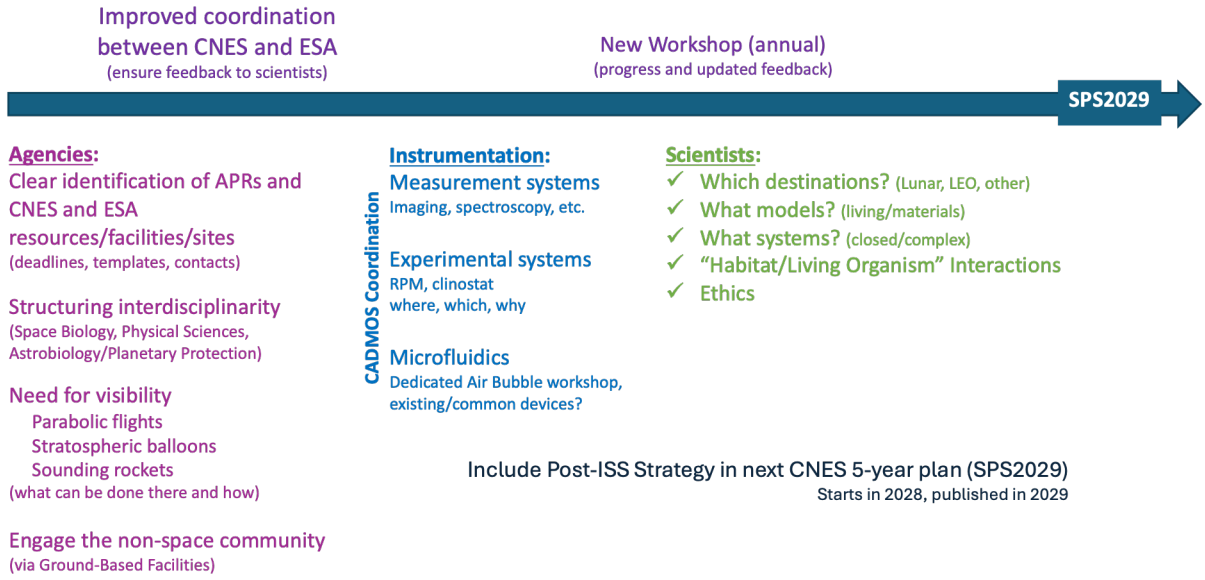


Figure 3. Action Plan Leading Up to the SPS2029 Exercise.

This workshop represents only the first step. An annual workshop is strongly recommended to broaden participation and ensure the continuity of interdisciplinary exchanges. These exchanges will serve to launch preparations for the strategic planning exercise in 2029. Now that this brainstorming activity has been validated at the national level, plans are underway to extend it to the European level through ESA.

6. Appendices

Appendix A – Resources, Strategic Documents, and Selected Publications from relevant ESA Topical Teams

ESA & CNES Strategic Plans:

ESA Human and Robotic Exploration Data Archive (HREDA): https://www.cosmos.esa.int/web/hreda

ESA's Planetary Science Archive (PSA): https://psa.esa.int/psa/#/pages/home

ESA Roadmap White Papers 2021: https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Research/The_SciSpacE_White_Papers

CNES SPS 2024: https://cnes.fr/scientifiques/seminaires-prospective

Selected publications from ESA Topical Teams:

Materials Science:

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Life Sciences:

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Exobiology, Exoplanets, and Planetary Protection:

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Appendix B - Acronyms and Definitions

Acronym	Meaning/Description
CADMOS	Center for Support of Microgravity Activities and Space Operations (CNES)
CERES	Committee for the Evaluation of Space Research and Exploration (CNES)
CubeSat	*Standardized mini-satellite*
DIVO	Orbiting Plant Irradiation Device (CNES)
FTIR	Fourier Transform Infrared Spectroscopy
GC-MS	Gas Chromatography–Mass Spectrometry
GDR	Research Group (CNRS) (*Thematic Coordination Unit of the National Center for Scientific Research*)
GeneLab	*NASA-ESA -omics Database*
GT E2P2	Working Group (CNES) – Exobiology, Exoplanets, and Planetary Protection
GT SdM	Working Group (CNES) - Materials Science in Microgravity (*Soft Matter and Complex Fluids, States and Phase Transitions, Instabilities, Transport, and Waves*)

Acronym	Meaning/Description
GT SdV	Working Group (CNES) - Life Sciences and Human Space Exploration (*Biology, Ecology, Physiology, Space Medicine*)
HREDA	Human Robotic Exploration Data Archive (https://www.cosmos.esa.int/web/hreda)
ISS	International Space Station
Late access	(Late access—*the ability to incorporate samples just before launch*)
LEO	Low Earth Orbit
MEDES	Institute of Space Medicine and Physiology
MELiSSA	Micro-Ecological Life Support System Alternative (ESA)
Piggyback	*Carrying an experiment as secondary payload*
RAMAN	Raman Spectroscopy
RPM	Random Positioning Machine (*Earth-based microgravity simulator*)
R&T	Research and Technology
SEM/TEM	Scanning/Transmission Electron Microscopy
SpaceRider	https://www.esa.int/Enabling_Support/Space_Transportation/Space_Rider
SPS	Scientific Outlook Seminar (CNES) (*strategic planning every 5 years; next: 2029*)

Appendix C – Participants

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