



**Report on the evaluation of the
European Space Resources
Innovation Centre (ESRIC) at the
Luxembourg Institute of Science
and Technology (LIST)**

**Based on a peer review as commissioned by the Ministry of
Higher Education and Research of Luxembourg**

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1. Introduction

The Ministry of Higher Education and Research (MESR) of Luxembourg mandated *Interface Policy studies Research Consulting*, Switzerland, to organise and lead a research evaluation of the Centres de Recherche Publics (CRP).

The Grand Duchy of Luxembourg operates three non-university public research and technology institutions. They are the Luxembourg Institute of Science and Technology (LIST), the Luxembourg Institute of Health (LIH) and the Luxembourg Institute of Socio-Economic Research (LISER). The three CRPs include departments linked to different scientific disciplines. The evaluation focused on the research performance of the CRPs' departments.

The research evaluation was conducted in 2022. This report presents the evaluation of the European Space Resources Innovation Centre (ESRIC) of LIST.

The observations and recommendations presented in this report are based on a peer review by the following three experts working in the department's research fields:

- Prof. Dr. Angel Abbud-Madrid, Director, Center for Space Resources and Space Resources Graduate Program, Colorado School of Mines, USA
- Prof. Dr. Michelle Lavagna, Professor of Flight Mechanics, Department of Aerospace Science & Technology, Politecnico di Milano, Italy
- Prof. Dr. Tilman Spohn, Executive Director, International Space Science Institute (ISSI), Switzerland & Former Director, Institute of Planetary Research, German Aerospace Center, Germany

The peer review consisted of a self-assessment report written by ESRIC and a hearing at the department that took place in September 2022. The evaluation of ESRIC was carried out in an abbreviated procedure as the department was still in the process of being established during the evaluation period and therefore did not yet demonstrate any research or innovation activities. The assessment period runs from 2020 to 2021. The hearing, which was organised and moderated by Interface, comprised a presentation by the department as well as individual interviews with three of the department's stakeholders. The report was finalised by Stefan Rieder and Chiara Büchler of Interface.

The overall results of all departmental evaluations are summarised in an institute report for each CRP¹ and a synthesis report². The institute report includes an assessment of the CRPs as a whole. It also summarises the findings from additional governance interviews with representatives of the management teams at the CRPs as well as a comparison between the CRPs and a foreign benchmark institute.

¹ Rieder, Stefan; Grosjean, Nicolas; Büchler Chiara (2023): Report on the evaluation of the Luxembourg Institute of Science and Technology (LIST), Interface Policy studies Research Consulting, Lucerne and Lausanne.

² Rieder, Stefan; Balthasar, Andreas; Haefeli, Ueli; Grosjean, Nicolas; Büchler, Chiara; Essig, Stefan; Thorshaug, Kristin (2023): Synthesis report on the evaluation of the Centres de Recherche Publics (CRP) in Luxembourg, Interface Policy studies Research Consulting, Lucerne and Lausanne.

The report is structured into two parts: The first part discusses in detail the observations gathered by the expert team during the evaluation process. This part will focus on the strengths of this young department and the challenges facing it. The evaluation focuses on assessing ESRIC's strategy, financial and human resources, infrastructure and organisation. It is too early to assess the department's performance.

The second part presents the expert team's overall assessment and recommendations for further developing existing strengths and overcoming observed weaknesses.

2. Observations

First, we will briefly introduce ESRIC and then we will describe the department's current strengths and challenges.

2.1 Department overview

ESRIC is the result of a process that started in 2016 when the Luxembourg Government launched the SpaceResources.lu initiative with the aim of promoting the peaceful exploration and sustainable *in-situ* utilisation of space resources for the benefit of humankind. The European Space Agency (ESA) joined the Initiative of the Luxembourgish Government as a strategic partner in 2020. In November 2020, after the signing of a Framework Agreement between the Luxembourg Ministry of the Economy (MECO) and LIST, the department was officially launched.

ESRIC exists as a department as well as an Innovation Centre of LIST and aims to become “an internationally recognised centre of expertise for scientific, technical, business and economic aspects related to the use of space resources for human and robotic exploration, as well as for a future in-space economy”³. Thus, a close strategic partnership with the main stakeholders, ESA and the Luxembourg Space Agency (LSA), is crucial for further developing ESRIC in terms of infrastructure, funding, and building up competencies.

The department started its research and innovation activities in late 2020. The activities are structured around four pillars:

- Firstly, research and development of space resources includes industry-relevant activities in the research areas of ISRU Value Chain as well as Prospecting and Mining. Furthermore, the department wants to build competencies in a) processing and supplying space resources and b) constructing and manufacturing components and infrastructure using space resources. Thus, ESRIC is developing partnerships with international companies like Airbus and Air Liquide.
- Secondly, with the support of ESA, ESRIC is promoting economic activities through a start-up incubator program.
- Thirdly, ESRIC is emphasising knowledge management by launching its knowledge-sharing platform for the space resources community in 2022.
- Lastly, the department focuses on community involvement by organising events such as the Space Resources Week and Innovation Challenges.

2.2 Strengths of the department

2.2.1 Strategy

The experts acknowledge that the department has a clear overall strategy that has been developed together with ESRIC's main stakeholders. The strategy is complete from a formal point of view: a vision, mission, and objectives are in place. Furthermore, the four strategic pillars that ESRIC has defined are evaluated as coherent and sufficient.

Overall, the experts assess the concept of ESRIC as a research and technology department within LIST as very positive. Firstly, because of the opportunity to promote the international positioning and visibility of the department under the aegis of LIST and secondly, because ESRIC is filling a niche with its focus on the rapidly developing space

³ Source: ESRIC (2022): Self-assessment report, p. 61.

economy. In addition, ESRIC has the opportunity to work closely with the other departments of LIST and profit from their expertise.

2.2.2 Organisation, Human and financial resources, infrastructure

The expert group emphasises that the department's highly motivated team stands out very positively. The Head of the department provides a beneficial connection to the research area of terrestrial resources, which ESRIC should explore in the future.

The solid administrative support ESRIC receives from LIST and the strong support of the other stakeholders (LSA and ESA) is rated as crucial for the young, developing department. The base funding provided through the MECO and LIST as well as the FNR PEARL funding secured by the Head of the department has led to an excellent short-term financial situation. With the clear signs of commitment from the main stakeholders, the medium and long-term funding potential of ESRIC is also assessed as good. The additional research equipment that ESA has provided to date is impressive and provides a basis for the further development of the department.

2.2.3 External research and industry collaboration

The experts assess the location of ESRIC in a favourable research and technology environment as an opportunity. The proximity of the University of Luxembourg (UL) is an advantage for ESRIC, especially as regards collaboration in research projects with low TRL-levels in the future. The experts encourage the department to seek exchange and eventually collaboration opportunities with the UL where possible.

ESRIC's strategic partnership with ESA seems to be strong and has long-term potential. The close collaboration with ESA and the collaborations with industry so far, are an evident asset for ESRIC. These collaborations increase the visibility of the department and the attractiveness of ESRIC as a research and technology organisation. The clear commitment from ESA to closely collaborate with ESRIC, especially regarding the stationing of research equipment in the Luxembourgish facilities, is seen as a promising step towards achieving the goal of becoming a focal point for space resources utilisation in Europe.

With the developing space and terrestrial markets, there is an industry containing small and medium enterprises with high interest in space resources. Thus, there is great potential for cooperation with partners both nationally and internationally. The experts strongly encourage ESRIC to concentrate on partnership development within industry in order to provide impact-driven research and applications. So far, the main stakeholders seem clearly satisfied with ESRIC's performance during the evaluation period.

Overall, ESRIC has strong political backing at the national and European level. The commitment of the involved actors is an evident strength of the department. This strong support system secures the short and medium-term attractiveness of ESRIC for the industry both within and outside of Luxembourg.

2.3 Challenges for the department

2.3.1 Strategic challenges

The expert group notes that the four strategic pillars mentioned in section 3.2 require further definition for their implementation, which was not advanced at the time of the assessment. The most urgent tasks to advance the implementation are to a) set up a budget plan and b) develop a plan for staff recruitment and implement it as soon as possible.

Luxembourg was one of the first countries worldwide engaging in space resources utilisation with a law on the utilisation of space resources⁴ and is well known for promoting space resources activities through outreach activities such as conferences. However, the country is not yet well known as an actor in the academic field. ESRIC has not yet produced research results nor developed ISRU technologies. The experts identify ESRIC's currently low visibility in the space resources research community as a challenge. According to the experts, Luxembourg needs to grow its visibility and recognition in the field of research and technology development in space resources utilisation during the next evaluation period.

According to the experts, the European research landscape is open for new approaches (such as the close collaboration between ESA and ESRIC and ESRIC's goal to becoming a focal point for space resources utilisation in Europe) but remains sceptical as long as the approach has not yet been proven to be useful. With ESRIC being a young and developing department, this will be a challenge in the coming years. Overall, ESRIC's governance structure includes the main stakeholders. However, ESRIC is a department of LIST and needs to work towards LIST's overall strategic objectives.

2.3.2 Organisation, human and financial resources, infrastructure

Where human resources are concerned, the department is in a growth process. At the end of 2021, ESRIC had five staff members: two research and technology staff members, two staff members in the domain of research support, and one administrative staff member. The experts note that engineering competencies in the department especially were scarce during the evaluation period. The expert group sees a clear need for capacity building in the field of engineers and technicians in the next evaluation period. However, talent attraction is a challenge for ESRIC. ESRIC's unique position as the first (and, by the time of the evaluation, only) research centre in Europe exclusively focused on space resources gives the department an advantage in attracting talented researchers eager to get involved in this new field. Therefore, the department should implement a dedicated recruitment plan for attracting outstanding senior researchers who will, in turn, attract young researchers and PhD students.

The financial resources of the department during the evaluation period are evaluated as good. Nevertheless, sustainable long-term funding for the next evaluation period is neither clearly outlined nor secured. Moreover, the financial situation of ESRIC, and the laboratory equipment available, depend heavily on the commitment of its stakeholders at the European and national levels. According to the experts, ESRIC should work towards a long-term funding structure that not only concentrates on acquiring competitive funding, for example, from the Fonds National de la Recherche (FNR) or Horizon2020/Horizon Europe and other ERC grants, but also builds on collaborative funding from private and public partnerships.

ESRIC has established research facilities such as a laboratory and a demonstrator provided by ESA. The fact that ESA is an important partner for ESRIC because of the in-kind contributions of equipment is assessed as positive. However, the experts could not identify a clear strategy in the selection of this laboratory infrastructure. With ESA being the driving force for the infrastructure and equipment in the department's research facilities, the experts formed the impression that the alignment between the infrastructure and the strategic goals of the research units needs further reflection. In addition, ESRIC will receive its own building by 2030. Nevertheless, the building situation of LIST should be

⁴ ESRIC (2022): Self-Assessment Report, p. 59.

borne in mind by the department's management. Currently, two other LIST departments, the department of Materials Research and Technology (MRT) and the department of Environmental Research and Innovation (ERIN), are experiencing difficulties in further developing their building infrastructure because of delays and other challenges in the building process.

2.3.3 External research and industry collaboration

The development of ESRIC in the last evaluation period was closely accompanied and supported by ESA. It is understood by the experts that the involvement of ESA is an asset for ESRIC. However, the expert group sees the need for further proactive development of new areas of research and innovation according to ESRIC's strategy.

On this note, the experts also encourage ESRIC to further reflect on a possible business case in the future. ESRIC needs to identify and specify which markets are relevant and include these markets in the overall strategy for the department. According to the experts, the department's management should take stock of the current research and market situation in the envisaged core areas. Based on this inventory, the experts encourage ESRIC to initiate a discussion on future business cases for the department.

With Luxembourg being a small research and innovation ecosystem, the experts state that ESRIC should build a strong connection with the UL. This development can be achieved through affiliations of staff members to the UL and through access to the UL's doctoral schools as well as through joint training of PhD students and Postdoctoral researchers.

ESRIC should keep an eye on already existing capabilities in the space resources field in Europe. The experts are of the opinion that the department should strive to be a focal point for clustering smaller research capabilities. Therefore, ESRIC needs to position itself accordingly. The first step towards this positioning is identifying a way to gain a comprehensive overview of the European research and innovation landscape in the field of space resources utilisation and exploitation.

3. Overall assessment and recommendations

3.1 Overall assessment

In 2016, the Luxembourgish Government launched a programme for space resources utilisation. To strengthen the Space Resources Initiative, a separate department was created within LIST in 2020: The European Space Resources Innovation Centre. Following the inception of ESRIC, LIST's MRT department executed and managed a joint research program regrouping resources from MRT and ESRIC in order to kickstart ESRIC's research effort. ESRIC is dedicated entirely to the space resources sector.

ESRIC's overall strategy is clearly defined. The department's highly motivated management team stands out very positively. In addition, even though the department has only recently been formed, funding appears to have been secured for the medium to long term. This secure perspective is provided through strategically and financially engaged stakeholders at both national and European levels. MECO, LSA, ESA, and LIST are committed to ESRIC and provide vital funding, infrastructure, and governance. Overall, ESRIC has the potential to be a strong asset in Luxembourg's research and innovation landscape.

However, different strategic and organisational challenges must be addressed during the next evaluation period. ESRIC's strategy needs to be implemented, especially as regards the long-term research focus. Thus, translating the long-term industrial vision into a research strategy should be prioritised. In addition, the organisational structure of ESRIC is evolving. The department therefore needs a human resources strategy that includes, in particular, the recruitment of engineers and technical staff.

With its focus on space resources utilisation, the department targets a niche market. To grow and position itself internationally, striving for the coordination of competencies and initiatives within Europe is seen as a promising possibility for the department. The most serious threat on this path is that other larger research institutions may take up the topic. ESRIC should use its advantage to establish itself quickly as a central focal point for European space resources utilisation.

3.2 Recommendations

Based on the observations stated above and in the previous chapters, the expert team formulates the following recommendations (any aspects which concern LIST as well as ESRIC are also reported in the institute report for LIST):

I Recommendation 1: Develop a focus on research and technology by further recruitment

ESRIC is currently developing and specifying its research agenda. The choice of the new director with a thematic background in mineral processing and beneficiation is the first step in this direction. The experts recommend continuing to pursue the concretisation of the research agenda by choosing a subset of core research topics (see also recommendation three) and recruiting staff with appropriate corresponding competencies.

Emphasis should be placed on the involvement of industry personnel. This could help ESRIC further develop its technological competence and innovation capacities, especially in the engineering domain.

I Recommendation 2: Use the evolving space economy as a niche

Due to its inclusion in LIST and its location in Luxembourg, ESRIC is in an excellent position to become an important centre for space resources utilisation in Europe. The available financial resources, secured for the short-term, can enable this development further. Moreover, a growing space economy is emerging in Luxembourg and Europe, including many companies that should become essential partners for ESRIC in the future.

Thus, the experts recommend taking advantage of this environment and the emerging industry as a niche and positioning ESRIC as a consulting voice for the industry, providing a bridge between the space industry and research. Furthering the start-up incubator program would be a good start in the next evaluation period.

The experts further recommend keeping a close eye on developments in Europe, preparing for possible competition situations, and thinking about focusing on specific topics in which ESRIC can take a leading role in the long term.

I Recommendation 3: Develop a business and research plan

Currently, ESRIC has no clear, focused business and research plan. The in-space markets ESRIC wants to target were not yet in existence during the evaluation period. Therefore, to be the incubator and main centre for *in-situ* utilisation and exploitation of space resources, the experts recommend developing a business and research plan to reach the existing space and terrestrial market in the short to medium-term perspective.

The following elements should form the basis of the business and research plan:

- A clearly-defined yearly budget and financial plan for the next evaluation period.
- A consolidated research roadmap based on core research topics (see recommendation one). The work on the core topics should follow a clear workflow based on building blocks for competence growth. The financial plan and budget must consequently be combined with a clear overview of the next steps in the research and technology development (e.g., beneficiation, processing, storing, analysing). The acquisition of competencies should then be traceable through the key performance indicators (KPIs).
- Specific targets for research and innovation outputs aligned with LIST's KPIs, such as publications, number of PhD students, collaborations with industry, spin-offs, patents, and licenses.
- A stakeholder and competitor inventory of the space economy inside, and especially outside, Luxembourg.

I Recommendation 4: Consider expansion beyond lunar research

The research field of "space resources" is developing extremely rapidly. The experts assess the focus of ESRIC on lunar resources during the evaluation period as very positive. In order to become the main space resources utilisation centre in Europe, an early focus on lunar resources is an excellent starting point. However, to become a leader in the field of space resources, the department's strategy should also include the exploration of other important extra-terrestrial resources as well.

Given the growing level of competition that is to be expected in the coming years, the experts recommend conducting studies on additional space resources, which could be considered important for the European research and technology landscape. Examples are space debris utilisation, space-based solar power, space manufacturing, and Mars and asteroid resources.

I Recommendation 5: Develop and promote an intensive collaboration with UL

The proximity to the UL should be used as a strong asset for ESRIC. The experts therefore recommend developing and promoting an intensive collaboration with the UL in terms of:

- Joint teaching activities between the UL and ESRIC
- Joint training activities for PhD students and Masters students
- Affiliations to the UL for ESRIC staff to identify and use synergies
- Offering PostDoc positions to attract early career researchers

This will enable ESRIC to attract, support, and keep talent. The collaboration is seen as essential for the development of strong in-house expertise in the future.

Appendix: Agenda of hearing

Monday, 12 September 2022		
1 15:45 – 16:45 Welcome address by the Ministry of Higher Education and Research (MESR)		MESR
16:45 – 17:00 <i>Break</i>		ESRIC Evaluation team
2 17:00 – 18:00 Presentation by the European Space Resources and Innovation Centre (ESRIC)		ESRIC Evaluation team
Time	#	Function/institution of participants
17:00 – 18:00	1	Head of the Department
	2	Head of the Department ad. int.
	3	Strategic Advisor
18:00 – 20:00	Discussion of self-assessment report and preparation of interviews	
Evaluation team		
Tuesday, 13 September 2022		
3 8:30 – 10:10 Individual interviews with stakeholders		ESRIC Evaluation team
Time	#	Function/institution of participants
8:30 – 9:00	1	European Space Agency (ESA)
9:05 – 9:35	2	Ministry of the Economy, Luxembourg
9:40 – 10:10	3	Air Liquide
10:00 – 10:30 <i>Break</i>		
4 10:15 - 14:30 Report writing, discussion of results & Lunch (Panel)		Evaluation team
5 14:30 – 15:00 Presentation of results (Department)		MESR ESRIC Evaluation team